

[Digest Version]

Future Vision of the Optoelectronics Industry

**Toward Further Growth
by Evolutionary Technologies and Progressive Developments
in an Advancing Borderless Society**

Optoelectronic Industry and Technology Development Association

Note: This Digest Version is for your reference only. When and if quoting this document, the original version should be used. (The original version is available only in Japanese right now.)

Table of Contents

Summary -----	4
Chapter 1 Perspectives for the future society -----	6
Introduction -----	6
1.1 Social trend -----	7
1.1.1 Analysis of social change in the future society-----	7
1.1.2 Typical example of social trends -----	8
1.2 Future perspectives of the subject of user/player -----	10
1.2.1 Perspectives for civic activities-----	10
1.2.2 Perspectives for corporate activities -----	11
1.2.3 Perspectives for the administrative activities of governments -----	12
1.3 Scenario for the future society and technology-----	14
1.3.1 Trends of the future technology -----	14
1.3.2 Example of services -----	14
1.4 Future society and optoelectronics industry-----	16
Chapter 2 Perspectives on optoelectronics products and markets -----	17
Introduction-----	17
2.1 Structure of chapter 2-----	17
2.2 Estimation method of future market sizes of the optoelectronics industry -----	17
2.2.1 Outline of the estimation method-----	17
2.2.2 Estimation method for each application field -----	18
2.2.3 Method for estimating regional markets -----	18
2.3 Future perspectives of optoelectronics products and technologies -----	19
2.3.1 Info-communications-----	19
2.3.2 Optical Memory-----	20
2.3.3 Display/Lighting -----	21
2.3.4 Input & output -----	23
2.3.5 Processing -----	24
2.3.6 Optical (Solar) energy-----	25
2.3.7 Environment/sensing -----	27
2.3.8 Medical care/welfare -----	28
2.4 Future perspective of the optoelectronic industry-----	29
2.4.1 Market estimates in each area-----	29
2.4.2 Estimates for each region -----	30
2.4.3 Overview of the whole market-----	31
2.4.4 Summary of the market estimates -----	34

Chapter 3 Topics in optoelectronic technologies	35
Introduction	35
3.1 Info-communications area	35
3.1.1 Future network and services	35
3.1.2 Photonic network	36
3.1.3 From DWDM to super-high-speed OTDM and to control of optical phases	37
3.1.4 Optical signal processing	37
3.1.5 Super high-speed optical device	38
3.1.6 Light and quantum encryption communication	39
3.1.7 The fusion of robot and optoelectronic technologies	40
3.2 Display/lighting and optical memory area	41
3.2.1 Digital TV broadcasting and optical technology	41
3.2.2 Displays with enhanced reality	42
3.2.3 Personal 3D display	43
3.2.4 Organic EL technology	43
3.2.5 Solid state lighting	44
3.2.6 Molecule memory	45
3.3 Environment, Energy, and Life Science Areas	46
3.3.1 New developments in optical fiber sensing technology	46
3.3.2 Application of optical catalyst to environment	47
3.3.3 Future perspectives of solar energy power generation	48
3.3.4 Optical catalyst and energy	49
3.3.5 Laser nuclear fusion technology and its ripple effects	50
3.3.6 Laser technology in space development	51
3.3.7 Agriculture and optoelectronic technology	52
3.3.8 Future of nano bio-photonics: pseudo brain produced by light	53
3.3.9. Remote medical care and optoelectronic technology	54
3.3.10 Low-invasiveness optical treatment	55
3.3.11 New optical diagnosis opened up by optical coherent tomography(OCT)	56
3.4 Nano-photonics key technology area	57
3.4.1 Perspectives of the nano-photonics devices	57
3.4.2 Photonic crystal	58
3.4.3 Nano-photonics	59
3.4.4 Optical micro-electro mechanical system (MEMS)	60
3.4.5 Femtosecond laser processing	61
3.4.6 Light pulse electrical field manipulation technology	62
3.4.7 Organic and non-organic nano composite optical materia	63

Summary

This report is comprised of four chapters, and the focusing issues of each chapter are as follows: In Chapter 1 shows economic and social trends as the preconditions of developing the future vision of the optoelectronics industry. Chapter 1 is titled “Perspective for the Future Society.” With this background, chapter 2 shows the forecast of optoelectronics products and market sizes of worldwide and the breakdown to each region and each field as well, are forecasted in the time range of years 2010 and 2015. Chapter 2 is titled “Perspectives for the Optoelectronics Products and Markets.” Then in chapter 3, “Prospective Topics in Optoelectronics Technologies” are taken up, which are expected to be flourishing in use beyond the mid 2010’s. In this chapter, therefore, the potentiality of the optoelectronics industry with upcoming new technologies is shown. Finally, chapter 4, with the title of “Toward Further Growth of Optoelectronics Industry,” shows “estimates of domestic production volume of the optoelectronics industry in fiscal years 2010 and 2015”, “mid- and long-term growth factors and prospects in the optoelectronics industry”, and “proposing strategy for promoting optoelectronics industry”.

In Chapter 1, in order to estimate the market size of the optoelectronics industry in 2010 and 2015, the trend of the future society is envisioned which is to be contrasted with the current conditions. In this manner, the effects of the differences between the present and the future are considered. The changes and trends that affect the citizens and corporations worldwide, the following three factors are extracted: “advancing borderless society,” “environment-friendly society,” and “Aging society with fewer children (demographic aging society).” The relations between these changes and trends and the optoelectronics industry are elucidated.

In an advancing borderless society, information is exchanged all over the world, which will require the following functions to be prevalent: telecommunication functions which promote free trade among countries of the world (especially in financing and security); functions that speed up services provided in adaptation with the surrounding environment; and security functions for avoiding conflicts and rifts caused by clashes among different values.

In environment-friendly society, in addition to such changes as “containment of emissions of CO₂,” “reduction of waste materials,” and “improvement of consciousness and awareness of environment,” it has been indicated that the service functions in the manufacturing industry can actually become commodities.

In demographic aging society, changes will occur not only among the elderly, but also with all generations. Improvements are sought after, therefore, in info-communications equipment, social infrastructure, medical care and social key infrastructures that support the daily lives of all of different age groups.

The specific behaviors and phenomena in the future society, furthermore, have been categorized for three subjects of activities; “citizens,” “corporations,” and “governments.” It has been indicated that, with the “telecommunications” area as the core, the future society is strongly related to optoelectronic industry.

In Chapter 2, matching has been attempted between needs and technological seeds that can be deduced from the scenario for the future in Chapter 1. Estimates for the market volume of the optoelectronics industry in 2010 and 2015 are indicated, based on the trends for the optoelectronics products in various fields. The respective fields of optoelectronics industries are the following eight; info-communications, optical memory, display/lighting, input & output, processing, optical (solar) energy, environment/sensing, and medical care and welfare. As for market size estimates, forecasts are made for four major regions of Japan, North America, Europe, and others and these

are also made for different fields.

As a result, the world-wide market size of the optoelectronic industry is estimated to be about 29 trillion yen in 2002, 60 trillion yen in 2010 and 107 trillion yen in 2015. Average annual growth rate from 2002 to 2010 is 9.5%, from 2002 to 2015 is 10.5%, which indicated that the growth rate will be higher after 2010. The growth rates thus estimated will have the following distinctions.

Distinctions between products using existing technologies and new products

The products using new technologies will comprise about 22% of the whole in 2010, which will rise to 37% in 2015. The growth rates for these products, at the same time, will be about 25% from 2010 through 2015 and they will be the driving engines of the market as a whole.

Distinctions among regional markets

Among the market size of the optoelectronic products in the subject four regions, the order among the largest North America to Europe, others, and to the smallest Japan would not change for the time being. The “Others” will show rapid enlargement in the following years, although they will not catch up with the market size of the Europe until 2015.

Distinctions from application fields

The market size is large in the four areas of display/lighting, info-communications, input & output, and optical memory, and the four areas comprise about 3/4 of the whole. The growth rate is higher among the areas of medical care/welfare, optical energy, followed by telecommunications.

The market trends in the optoelectronics industry, in the mean time, can be analyzed as follows: that is, one of the factors that bring about the market size expansion of optoelectronics industry is the sheer increase in the amount of information in the societies. It can be seen that the increase is due to changes in the quality and the increases in the number of opportunities for using the equipment and devices that handle information. Along with the increases in the amount of information handled, furthermore, the telecommunications networks are expanded along with the demand for storage devices. This will further lead to the expansion in the markets for info-communications and optical memory.

In Chapter 3, while keeping an eye toward 2015 and onward as far as the time frame goes, optoelectronics technologies with bright perspectives in the future are taken up for perspectives, including those with high social values regardless of large and small market sizes. As far as the contents are concerned, however, applications of optoelectronics technologies (uses and effectiveness) are described with emphases. At the same time, approximate timing of making the technologies practical are indicated as much as possible. In the meanwhile, the factors that promote or hinder in making the technologies practical and the measures considered necessary for the technologies in doing so are touched upon as much as possible.

From these standpoints, in total, 31 themes are taken up. In terms of different fields, 7 themes in info-communications, 6 themes in display/lighting and optical memory, 11 themes in environment, energy, and life science areas, and 7 themes in nano photonics and key technology areas are described.

In Chapter 4, the perspectives of the optoelectronics industry in the domestic production volume are indicated, followed by growth factors of the mid-term optoelectronics industry and themes related to further development. Then, lastly, proposing strategy for promoting optoelectronics industry is summarized for further growth of the

optoelectronics industry.

In the perspectives of domestic production volume, which are estimate values that are inclusive of the estimate for increases in the shifts to overseas production, are indicated. In Fiscal 2002, the actual production volume was 6.2 trillion yen. In Fiscal 2010, this is estimated to be doubled and will reach 12.7 trillion yen. In Fiscal 2015, the figure will further expand to 3.7 times as much and will amount to 23.0 trillion yen.

Then, various discussions are provided on the following two themes: “expectations on the optoelectronics industry, roles of optoelectronic industry, creation of markets, etc.” and “strategies for research and development, strategies for intellectual property, measures for industrial promotion, tasks towards development of the optoelectronics industry in the points of view for globalization, etc.” Indications are made for continued development of the optoelectronic industry into the future.

As for measures and proposals for the development of the optoelectronic industry, which are the last items in this report, based on the contents of chapters 1 through chapters 3 of this report, points relating to proposal-like items in the discussions are sorted out. The following seven items summarizes the majors points in the proposal which are considered necessary for the further development of optoelectronic industry.

- Coping with an advancing borderless society
- Creating market / stimulating demands
- Facilitating research and development
- Strengthening intellectual property/standardization strategy
- Reinforcing education and cultivating experts
- Developing and supporting start-up or small businesses
- Utilizing regulation policy and promoting deregulation

In conclusion, in order for the optoelectronics industry to be the driving force for the economic growth in Japan, in the society of qualitative and rapid changing such as advancing borderless society, environment-friendly society, demographic aging society, it is the key that how to realize the potential of the optoelectronics industry, and at the same time it is also important to accomplish positive spiral of two factors that are “market creation” and “innovations in the optoelectronics technology.” Therefore it is expected to realize the proposing strategy of seven items above mentioned steadily.

Chapter 1 Perspectives for the Future Society

Introduction

The flow of analysis:

In Chapter 1, in order to estimate the market sizes of the optoelectronic industry in 2010 and 2015, the state of the future society will be envisioned which is to be contrasted with the current conditions. In this manner, the effects of the differences between the present and the future will be considered.

Grasp on domestic and overseas issues:

In chapter 2, estimates are provided for market sizes of optoelectronic equipment and devices and related services. Estimates will have as the subjects the whole globe and subdivisions of the estimates are four major

regions: Japan, North America, Europe, and Others. In chapter 1, at the same time, citing the state-of-the-art examples in different countries, various social images relating to optoelectronic industry will be described.

Effects of optoelectronic industry to the related industries:

Customer needs are satisfied by various functions and products and combination of mechanisms. Services satisfying various means of the customers are increasing.

Positioning on the examples of services introduced in chapter 1:

Importance is placed on iconoclastic innovations that overcome the existing framework of status quo. Efforts and made, however, to extract scenes that compose the mainstream of the society to certain extents.

1.1 Social Trend

1.1.1 Analysis of social change in the future society

(1) Outlines of the future society

On the global level, the population continue to increase, but in some countries, population begin to decrease. The ratio of the aged population, however, will increase. The gross domestic product (GDP) will steadily increase both in the advanced countries and in developing countries. On the world-wide level, there will be 20 percent increase in GDP in 2010 compared to the 2000 level. In the same token, the increase figure will be 37 percent in 2015. The daily life of the people will be saturated with consumer goods, which leads to trends of increasingly placing importance on the kinds of services available. We will continue to see the advent of the networking society, which makes it possible for everybody to receive the benefits without any trouble. The economies will globalize and products are produced in the country where it is most suitable. Then, the products are sold all of the world. Many free trade zones will come to exist and trade among the nations will become very active. At the same time, forms of the progress of industries will change. The possibilities are a high for electronic, electric machinery industry, and the telecommunications industry to be prosperous without necessarily having heavy industries within a country. This is because, as the horizontal division of labor on the production progresses, it is possible to procure materials necessary overseas and maintain industries only with high profitability. The progress, therefore, is such that each country will specialize into industries advantageous for them.

(2) Analysis of social changes

Social trends, which will affect citizens and business all over the world, have been observed,. Three trends have been extracted as representative social changes and trends in the future society: (1) demographic aging society (aging society with fewer children); (2) environment-friendly society; and (3) advancing borderless society.

- **Demographic aging society:**

In the advanced countries, birthrate will be shrinking, while at the same time, aging population will increase into the future. Although the current circumstances differ from country to country, in general as the economies develop, birthrates tend to shrink, while at the same time, life expectancy of the people tend to increase. Due to these two factors, it has been observed worldwide that, along with economic development, there will be increases in the ratio of the elderly. The shrinking birthrate and increasing aging population would not only affect the elderly and children. The young and middle-aged generations supporting them in the society are greatly affected as well. In essence, all generations are affected. Thus, worldwide shrinking birthrate and increasing aging population,

especially among the advanced countries, can be positioned out as one of the salient and representatives trend.

- **Environment-friendly society:**

As a worldwide trend, more and more importance is placed upon measures dealing with the environmental problems. Due to that globalization of the economies, imbalances among countries have surfaced concerning environmental pollution caused by moving of waste materials across the boaters and disparities between that producing countries and consumer countries. Due to these circumstances in recent years, environmental regulations and measures are becoming more and more international in nature, which means countries cannot but act to harmonize with the environment in terms of daily life and industrial activities. Thus, heightened awareness toward environments and more stringent environmental regulations have become social trends that no one in the world can ignore. “Environmentally harmonizing society,” therefore, is positioned as one of the representative social changes and trends.

- **Advancing borderless society:**

Various barriers that constrain people and corporations will be removed one after the other in the future. In concrete terms, these barriers are roughly categorized into those that relate to regions and those that relate to people.

Barriers relating to distance removed: Borderless elements relating to regions

Barriers relating to age, sex, and nationality removed: Borderless elements relating to people

In the increasingly borderless society, there will be exchanges of people, materials, and information beyond the borders. Without being constrained by the boulders and distance, there will be activities of people and corporations. These two borderless elements will affect people all over the world. “Increasingly borderless society, therefore, can be positioned as one of the representative social trends.

“The ubiquitous network society” is the key social change and it is positioned as a foundation for “shrinking birthrate and the aged society,” “environmentally harmonizing society,” and “increasingly borderlands society.”

- **The ubiquitous network society:**

Data communication is increasingly becoming faster and larger in quantity. The broadband services are becoming cheaper and cheaper. Due to digitization and networking of the household electric appliances, all kinds of products around us will begin to exchange large quantities of data via networks. By and around 2010, therefore, Info-communication is said to reach the size of about 1000 times the current level due to images and three-dimensional images, and pictures transmitted. The lives of people and corporate activities will be connected to the ubiquitous network in one way or the other. The ubiquitous network society is a future society that will exist by absorbing the three fundamental social changes indicated above. When examining concrete service examples, therefore, the “ubiquitous” elements should be combined with the three basic trends. Thus, the following will be the three major axes of analysis; “ubiquitous” x “shrinking birthrate and the aged society,” “ubiquitous” x “environmentally harmonizing society” and “ubiquitous” x “increasingly borderless society.”

1.1.2 Typical example of social trends

From the concept level of “ubiquitous” x “shrinking birthrate and the aged society,” it is necessary for us to break down into concrete activities and phenomenal changes. By doing this, it is possible to indicate the actual social scenes and their relationships to optoelectronic equipment and devices.

(1) Demographic aging society

In the “demographic aging society,” the changes will occur not only on the part of the elderly but also on all the generations. There will be increased number of the aged and their activities will increase. The middle-aged in the society will decrease and they would tend to look for replacements in the labor market.

(a) Increased activities among the aged

In the future aged society, the aged will “expand their activity ranges” and “the number of aged with disposable incomes will increase.”

(b) Increase in the adult influences over the children

Child contacts with adults will increase. There will be “increases in the amount of investments per child” and “children tend to mature early in their thoughts.”

(c) Decrease of ratios of the middle-aged in the labor market

In the concept of the “shrinking birthrate and the aged society,” one tends to overlook the fact that the middle-aged group will also shrink. When economic growth is aimed at a time when the labor market population is decreasing, changes occurring in the labor market will be “the further pursuit of higher added values” and “changes in the labor force.”

(2) Environment-friendly society

Many fields are contained in the problems relating to the environment. There are the following three major categories:

(a) Carbon dioxide (CO₂) containment

The governments will ask the citizens and corporations to reduce carbon dioxide emissions. There will be heightened consciousness and awareness in the society as a whole to reduce the load on the environment. There are activities for reducing energy consumption in various corners of the society.

(b) Reduction on waste materials

There are less and less land available for land filling and increases in contamination by hazardous materials caused by waste materials in Europe and other places. Governments will, then, put in place regulations in order to cope with various problems. These in turn will become the incentives for reducing waste materials, which will lead to various other actions.

(c) Heightened consciousness toward better environment

In the advanced countries, certain achievements will be made to correct public hazard problems. There will be, on the other hand, heightened consciousness and awareness or orientations for better health, which will lead to behaviors demanding cleaner environments, rather than the demands for simple health and safety.

(3) Advancing borderless society

In the advancing borderless society, people will be paying less attention to individual attributes and a regional differences. More importance will be placed on the values held by the information. Instead of various barriers recognized by the people in the past, the borderless society will arrive. The characteristics of the borderless society will be explained below:

(a) Distance as a barrier will disappear

People, materials, and information will be exchanged freely, beyond countries and regions. As a consequence, there will be the following changes:

Rise and increase of small organizations

The communities will be formed by the people who share values and beliefs.

Changes in the ways of the nations

The meaning of national borders will weaken and new and different images of a nation will emerge.

Conflict and harmony

Due to arrival of global economy, development in the transportation and increase in the amount of information in the society, cultures and values that existed contained in certain places will be exchanged on the enhanced level.

(b) Disappearing barriers of age, sex, and nationality; Borderless phenomena concerning people

Work system shaped for individual-oriented

The conventional forms of “labor,” which employed workers until the retirement age will come to an end. Companies will be hiring people when they are necessary. Likewise, individuals will be working when necessary, or so long as working is necessary.

Increase of services customized for individuals

In the future society, people will not act according to the conventional attributes of age and sex. Individuals will behave according to their personal values and beliefs.

1.2 Future perspectives for the subject of user/player

“Subject of user/player” has differences in their pattern of behavior and this has major consequences on the future trends in the optoelectronic equipments and devices. “Subject of user/actor” can be categorized into “individuals,” “corporations,” and “governments” and future perspectives for these will be sorted out below.

1.2.1 Perspectives for civic activities

People belonging to a population will present different characteristics according to such factor as age. The absolute number as the “quantitative aspect” and ratios of composition as the “qualitative aspect” will be considered. Furthermore, in order to achieve compatibility with the market trend survey in Chapter 2, the perspectives for these elements will be described for each of the four regions: Japan, North America, Europe, and Others.

(1) Specific changes

Population will decrease in Japan and in Europe and increase in North America and others.

In all regions, however, the aged will show the highest rate of growth.

In relation to the above, there are the following trends:

- Worldwide types are different for Japan and Europe, North America, and Others. Due to the influences of immigrants, North America has the combined characteristics of mature societies of Japan and Europe and expanding societies of Others.
- Worldwide trends are such that, however, the growth rate is the smallest for the youth group and it is the highest among the aged group.

(2) Overall aspects

Based on the three social trends and perspectives on the civic activities, the aspects of the future civic

activities can be summarized as follows:

Demographic aging society:

In the future society, with the children and aged as core groups, environments will be pursued so as to facilitate realization of activities sought after by each age group. It would be desirable that the optoelectronic equipment would be supportive of the needs of each age group.

Environment-friendly society:

In the future society, the citizens will increase their activities in pursuit of more efficient use of energies and protection from pollution. In essence, they must protect their own lives.

Increasingly borderless society:

In the future society, the citizens will be transmitting their own thoughts to outside through coming into contacts with people with varied values and orientations. On the other hand, however, activities to limit the contacts from outside will be on the increase.

1.2.2 Perspectives for corporate activities

Trends among “corporations” that will be using the optoelectronics equipment will be grasped here in terms of quantity and quality. The values of Gross Domestic Product (GDP) are considered as representative of quantitative aspects. On the other hand, in terms of qualitative aspects, the industrial trends in recent years will be considered. Thus, from both aspects of quantity and quality, the future perspectives of corporate activities as subjects of service users will be described.

(1) Specific changes

GDP will increase in all regions.

Manufacturing industries will take on the aspects of service industry.

There will be rises in spin-off businesses.

Flexible organizations and manpower will be in demand in the future.

In order to cope with the markets in the ubiquitous network society, the manufacturing concerns must put in place the “vertical organization” of production, in the increased speed than before. This is to say that establishing the horizontal division of labor, which utilizes the global production system, is no longer sufficient to cope with the market needs. The corporations must also have capabilities for developing technologies for speedily coping with the market needs. As a system for supporting the capabilities for developing technologies, with the advanced countries as the core, it can be considered that there will emerge two movements in the near future.

● **Formation of technology development consortium**

In the product development in the ubiquitous network society, it is considered that the risks are very high when one company alone engages in product development. In order to hedge for risks in the technological development and as a method for realizing quick marketability, formation of technology development consortiums will progress in the future. This means that, although the corporations will continue to develop in-house core technology, they will share general purpose technologies. In this manner, they share the risks of research and development investments. By establishing a system where each company can freely use the development results, the corporations will be able to cope flexibly with increasingly varied needs.

● **Strengthening of technological development coordination capabilities**

It is conceivable that the formation of technology development consortiums will enrich the resources for technology development. Even if this is the case, however, if there is no way to “apply” the technology, creation of a new technology would not lead to market formation. In other words, corporations would need ways to find the usable technology for the existing needs. This is to say that corporations would need coordinators who would know how to “apply” the technology in a product.

(2) Overall aspects

Based on the three social trends and perspectives on the corporate activities, the characteristics of the future corporate activities can be summarized in the following manner.

Demographic aging society:

Corporations will promote employing truly capable employees in order to maximize the values to be added to the products. This means that, regardless of the ages of potential employees, corporations will employ those who actually possess the skills needed.

Environment-friendly society

Corporations will seek efficiency in production activities through making considerations for the environment. At the corporations, therefore, energies will be conserved, waste materials will be reduced, and materials are recycled or reused. If reusing of products are pursued, this may lead to overflow of products. Therefore, corporations would not just limit themselves to marketing product but they would also market the “fun” in using the products. This means that they would be marketing the contents as the added value to the product.

Advancing borderless society:

With the advent of the increasingly borderless society, among the corporations, capabilities for coping flexibly with the user needs will be in demand as far as the products and corporate organizations are concerned.

1.2.3 Perspectives for the administrative activities of governments

After the 1980’s, administrative innovations of governments have been carried out and some of the roles played by the national government up to the point have been shifted to the private sector corporations. This means that the governments would have private corporations do the conventional work and they would be more and more dedicated to the work of maintaining and improving environment, which would strengthen the competitiveness of the private sector corporations as is shown below.

(1) Specific changes

Emphasis on intellectual property (IP) strategy:

There are increased number of countries that place importance on intellectual property strategy and the Japanese Government has announced that it will attempt to restructure Japan in view of making it a country strong in intellectual property. This means that the government has made apparent its orientations for placing more importance on inventions and creation and it is now recognizing that, not only “material goods” but also the “information” such as design, brand, and contents (i.e. music, movies, etc.) are properties. The Japanese Government, therefore, is now willing to have creation of these as the foundation of industries. The advanced countries will be building up their positions as the bases for research and development through such

intellectual property strategies.

Advent of free trade:

Industries with strong international competitiveness are increasingly expanding to other parts of the world. On the other hand, industries that are weaker in international competitiveness are now asked to convert the existing stocks and manpower into other industries. Promotion of free trade and selection and concentration of industries are promoted worldwide as national policies. Japan will sign free trade agreements with East Asian countries. The interdependency with these countries and high on the one hand but some of them have high trade barriers at the same time. EU is promoting integration and development within-EU by involving East European countries. On the other hand, EU is also promoting free trade with North Africa and South American regions.

Homeland Security

In the future society, a well-balanced policy that minimizes the risk of attacks on homeland is sought after. These include restriction on illegal aliens coming in for preventing acts of terrorism, stoppage of flow of illegal funds and products, and prevention of calamities. In recent years, people are experiencing increased anxieties about future risks of disasters and epidemics, including earthquakes and the like. In this regard, disaster prevention technology development would be very important in the future. There have been world-wide efforts on maintenance of energy security that relate to depleting energy resources and securing supply routes for energy resources.

(2)Overall aspects

Based on the three social trends and perspectives on the administrative activities of the governments, the characteristics of the future administrative activities can be summarized as follows:

Demographic aging society:

There are needs for the administrative activities of the governments to adapt to the civic and corporate activities. The citizens, especially, would want highly convenient infrastructures that facilitate satisfaction of their own needs rather than such realization as improvement in the economic productivity. Corporations would tend to be engaged in activities adapted to the needs of the citizens who are end users and they would also opt for infrastructure suited to that end.

Environment-friendly society:

In the administrative activities of the governments, what are truly wanted are activities that would remove the anxieties of the people ahead of time about the environments in the future, not just simply securing the health of the citizens and corporations.

Advancing borderless society:

The administrative activities of the governments should be directed toward the communities that share the same values. There will be increased activities to harmonize the values among the communities and to evade the classes of values.

1.3 Scenario for the future society and technology

1.3.1 Trends of the future technology

In the future shrinking birthrate and the aged society, as the activities increase in the different age groups, conveniences for these groups are pursued. These include development systems with high flexibility for coping with the worldwide increases in the aged groups, employment of manpower, and homeland security.

In the environmentally harmonizing society, not only the efficient use of resources and energies but activities for removing anxieties for future environment and production of commodities that realize functionality exemplified by the contents services would be pursued.

In the increasingly borderless society, it can be considered that the following functions would be pursued: functions in the info-communication that promote free trade; functions for quickly accommodating services adapting to the surrounding environment; and security functions for evading the clashes of values.

According to the Technology Forecast Survey and the Comprehensive Science and Technology Conference of the Ministry of Education, Culture, Sports, Science and Technology, the following are listed as prospective technologies in the future.

- Information-related field:

Telecommunication technology, electronics technology, software technology

- Life science-related fields:

Life science technology, hygiene and health technology, agriculture, forestry, fishery and food technology

- Environment and energy-related field:

Environment technology, resource and energy technology, ocean, earth, and space technology

- Manufacturing related the field:

Manufacturing technology, distribution and management technology

- Social infrastructure-related field:

Urban, construction, and civil engineering technology, transportation, distribution and service technology

- Nanotechnology and material-related field:

Nano processing technology, material technology

1.3.2 Example of services

The way to represent example of services

With social change as the core, and at the same time, referring to subjects of activities and technological change, example of services will be indicated.

(1) Example of services in the demographic aging society

(a) Comprehensive security service

Users: Parents in their 20s through 50's

Target: Infants and children from the newborn to about 10 years olds

Associated future technology: social infrastructure-related field (security), information-related field, life science-related field, etc.

In the future society, the security will deteriorate and the ratio of police arrests will decrease and people must use self-defense for their own security. When this happens, network technology can be used to provide security around-the-clock for people and properties. There will be increased number of services for indicating appropriate to countermeasures and executing them when the crisis situation arises. The following optoelectronic-related equipment will play major roles.

Digital Video Camera (DVC), mobile display, high-definition display, optical communications equipment

(b) Services supporting the aged to move around

Users: Aged in their 60s and older

Target: Aged in their 60s and older

Associated future technology: social infrastructure-related field (urban design, transportation) information-related field, life scientists-related field, etc.

In the future society, the aged will begin to go out by themselves actively. For their movements, however, it would be dangerous for them to drive cars on their own. Their eyesight and hearing may deteriorate, endangering going out by themselves. In spite of the difficulty in their movements, needs as strong among the elderly to go out on their own, rather than having their sons and daughters providing rides every day. In response to these needs, in the future, there will be equipments, supporting the elderly drivers at the wheel. There will also be equipment supporting the elderly on foot. The following optoelectronics-related equipment will play major roles.

Eye-safe laser , DVC , displays, etc.

(2) Example of services in the environment-friendly society

(a) Information service utilizing traceability

Users: Retailers, consumers

Target: All products

Associated future technology: environment and energy-related field (urban design, transportation), information-related field, life science-related field (food), etc.

Concerning fresh foods and electric appliances, it would be required in the future to disclose contents of agricultural chemicals and other chemical substances which are harmful for the humans. Services that comprehensively manage such information will emerge and consumers are able to easily access the information for making selections when purchasing commodities. In the methods of managing information, two-dimensional bar codes and RFID are used in parallel. The following optoelectronic-related equipment will play major roles.

Two-dimensional bar code reader, optical communication equipment, etc.

(b) Environment sensing service

Users: From the youth to the aged

Target: From the youth to the aged

Associated future technology: Environment, energy-related field, information-related field, etc.

In the future, people will be paying for clean environment. The needs will surface, for example, in which people will pay for services for evading polluted environment. Such services will provide environmental data for various locations. The data will be obtained by many kinds of assessing equipment. The data will be transmitted to mobile terminals of the service users. The service will propose from time to time the methods for

evading pollutions. The following optoelectronic-related equipment will play major roles.

Various measurement equipment, telecommunication network, mobile display

(3) Examples of service in the advancing borderless society

(a) Daily life health support services

Users : From the youth to the aged

Target : From the youth to the aged

Associated future technology : life science-related field, information-related field

There is no end to diversifying individual needs. People will be pursuing services that are as close to one's needs as possible. Concierge-type services that can provide for such individual needs using various equipment will come to flourish. The following optoelectronic-related equipment will play major roles.

DVC, human interface, optical communication equipment, mobile display, high-definition display, Remote medical services

(b) Service is supporting spin off small-scale companies

Users: Owners of spin off small-scale companies

Target: From the youth to the aged

Associated future technology: manufacturing-related field, information-related field, etc.

In the future society, needs will diversify and numerous small markets will emerge. They only have a short lifespan, coming and going. This means that the markets will be dominated by small-scale flexible companies, which soon disappear after taking profits. It will be the age of small companies. Even major corporations will make small units independent with the purpose of making profits. Organizational flexibility will be pursued. For these companies, it will be desirable only to have functions needed for the intended purposes. Companies specializing in certain back-office functions, such as personnel, general affairs, legal, finance, and part of the marketing, will provide for groups of small-scale companies. Companies that provides such services will flourish. Those companies that provide services and the companies that receive services are connected with each other by networks on the basis of complete information security system. By communicating through high-definition image communications system, they will be able to conduct efficient business, as if they are next to each other within the same office. The following optoelectronic-related equipment will play major roles.

Optical communications equipment, mobile display, high-definition display, optical memory

1.4 Future society and optoelectronics industry

Based on the axes of the “demographic aging society,” “environment-friendly society,” and “advancing borderless society, the future society will be described and concrete example of activities and phenomena will be sorted out according to the behaviors of the three subjects in the future society. The three subjects are “citizens,” “corporations,” and “governments” and their behaviors are described in terms of “concrete changes in behaviors and phenomena” and “characteristics.” At the same time, as per behaviors of each subject, related general technologies are described as “technologies that will become necessary (in general).” The technological categories will follow the kinds of technologies that will come to prevail indicated in Section 1.3. The relations between the future society and the optoelectronic industry will be indicated by listing the major optoelectronic equipment that correspond to “technologies that will become necessary (in general)” in the “associated future technology.”

Chapter 2 Perspectives on optoelectronics products and markets

Introduction

In Chapter 2, based on the social picture described in Chapter 1, future demands (markets) for the optoelectronic industry through 2015 will be estimated. At the same time, in this chapter, products to be produced for practical uses by 2015 and images of technologies to realize them will be described.

2.1 Structure of chapter 2

By matching the needs that can be deduced from the future scenario in Chapter 1 and technological seeds, estimates for markets for the optoelectronic industry for 2010 and 2015 will be indicated. Also indicated will be the development conditions of major optoelectronic-related products, which will be used as bases for calculating estimates in various fields. This is to say that, based on the images that can be deduced from Chapter 1, more concrete images of optoelectronic-related equipment uses will be considered. Then, from the images of use in 2010 and 2015, major products are extracted and the technologies used to realize major products will be described. Based on the results from these, market sizes of the optoelectronic industry will be estimated. At the same time, products, which use extension of already existing technologies, and products to be on the market after 2002, which use innovative new technologies, are differentiated for making the estimates.

In this chapter, the eight subject fields of optoelectronic industry are categorized as indicated in Figure 2.1.1.2 below. As the materials and device field is consisted of technologies and products that are the bases for other fields, they are considered as the module and devices of the eight fields. In estimating market sizes, the estimate in each field is further sub-divided for different regions (Japan, North America, Europe, and Others.) From these, the most prospective markets in the world in 2010 and 2015 and the positions held by Japan can be made clear.

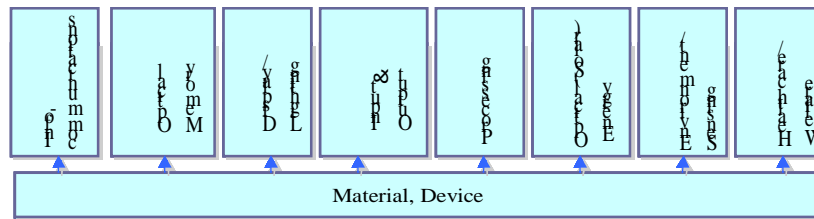


Figure 2.1.1.2 Categories of fields of optoelectronic industry

2.2 Estimation method of future market sizes of the optoelectronics industry

2.2.1 Outline of the estimation method

In this chapter, by basically setting the standard year for 2002, the market sizes in 2010 and 2015 will be estimated based on various data and their extended trends will also be estimates as well. As a procedure, first the world market (demand) sizes are calculated for the existing and new products. Then, while considering the market proliferation conditions in different regions (Japan, North America, Europe, and Others) for different fields, world and regional market sizes will be calculated. As for each region, after considering macroscopic regional values for each field (population, GDP, etc.) and proliferation order of technology and products in different fields, the regional market sizes are calculated.

2.2.2 Estimation method for each application field

The estimates are calculated mainly for the major products in the fields categorized in Figure 2.1.1.2, assuming that the estimate figures are indicative of the market sized of the whole products in the fields. The figures used for the estimates are based on figures publicized by various research organizations and they include the following sources: Production Amount Statistics by the Optoelectronic Industry and Technology Development Association; Machinery Statistics by the Ministry of Economy, Trade and Industry; Trade Statistics by Ministry of Finance, and so on. If in case such figures cannot be used due to nonexistence of the data or for other reasons, macroscopic indicators such as demands for related optoelectronic products and the like are used for making the estimates. Especially for new products that would have been put on the market by 2010 and 2015, macroscopic indicators will be used as references for calculating the market size.

2.2.3 Method for estimating regional markets

Market sizes will be calculated in view of regional characteristics. It is assumed that the differences in the regional market sizes of the optoelectronics industry are approximately dependent on the GDP values in each country. For that matter, the GDP figures of Others region are consisted of GDP figures in China, India, and other Asian countries. This means, therefore, that the effects from the values of these countries will be major ones in Others region.

In the meanwhile, independent from the GDP, it can be considered that there are regional characteristics that are peculiar for different fields. For example, as far as the telecommunication equipment market is concerned, there is a trend for the markets in the United States to emerge ahead of those in the Japanese and European markets. In order to reflect such trends, the proliferation orders for different regions are set as can be seen in Figure 2.2.3.2 and these will be reflected into estimates of market sizes. If and when special conditions exist concerning market trends in different fields, these will be applied over the others.

Field	The order of popularization				Main reason
	1st	2nd	3rd	4th	
Info-communications	NA	Japan	Europe	Others	NA is ahead with communication using optical technology.
Optical memory	Japan	NA	Europe	Others	Japan is ahead in terms of popularization of optical discs for Audio Visual application and so on.
Display/Lighting	Japan	NA	Europe	Others	Japan is ahead with new displays, such as FPD.
Input & output	NA	Japan	Europe	Others	NA leads Digital still camera and office device/appliance market.
Processing	NA	Europe	Japan	Others	Advanced countries, the majority of which are in NA and Europe, have taken a lead in processing using optoelectronic technology.
Optical (Solar) energy	Japan	NA	Europe	Others	Japan is technologically advanced in this field. Governmental support has facilitated the popularization of solar energy. This trend is considered to continue furthermore.
Environment/Sensing	Europe	Japan	NA	Others	Europe is highly conscious of environment-friendly measures. Japan and Europe lead the sensing market. NA leads the human interface related market.
Medical care/Welfare	NA	Europe	Japan	Others	Europe and NA lead the new medical care fields, such as remote controlled health care, etc.

NA: North America

Figure 2.2.3.2 Regional proliferation for each application field

2.3 Future perspectives of optoelectronics products and technologies

2.3.1 Info-communications

As the factors that will lead the telecommunication market, there are the following: introduction of optical network in the access system in the advanced countries in line with the large quantity data distribution, represented by the image information; expansion of the transmission volume in the trunk and metropolitan system; and introductions of optical system in the telecommunication infrastructure in the developing countries. At the same time, in the future, there will be increased replacement of existing communication networks by the optical communication networks. This will expand the market sizes for transmission equipment and circuits outside of the trunk system networks. Since, especially, the multi-point connections will increase, which is estimated to increase the market size of the transmission equipment considerably. In addition, with the fusion of telecommunication and broadcasting, new markets will be created through the replacement of broadcasting equipment by optical communication equipment. This is estimated to contribute to enlargement of the markets.

At the same time, in order to satisfy the rapidly increasing transmission volume needs that would continue into the future, it can be estimated that there will be proliferation of optical communication equipment that realized higher transmission speeds and the number of wavelength multiplexing that greatly surpasses the current performance and functions. Based on these trends, the estimate results of the market sizes categorized into the new products and existing products will be shown in Tables 2.3.1.3 and 2.3.1.4 and Figure 2.3.1.3.

Table 2.3.1.3 Estimate of market sizes for new/existing products (unit: trillion yen)

	2002	2010	2015
Existing	1.5	4.0	8.2
New	-	1.7	10.2
Total	1.5	5.6	18.4

Table 2.3.1.4 Average growth rate of new/existing products (unit: %)

	2002 -2015	2002 -2010	2010 -2015
Existing	14.3	13.4	15.7
New	-	-	43.4
Total	21.6	18.5	26.6

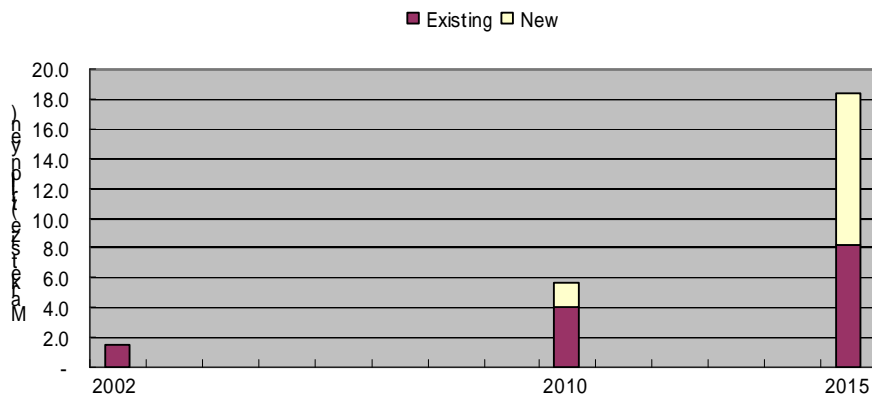


Figure 2.3.1.3 Estimate of market sizes for new/existing products in the info-communications (whole world)

Currently, the market is enlarging pulled by the United States and the trend is expected to continue into the future. The total picture is such that, in the trunk and metropolitan networks, as the North American carriers make capital investments, other advanced countries follow suit in improvement and development of their telecommunication networks.

Based on these trends, the estimates on the market sizes in the four regions have been made. The results are shown in Table 2.3.1.5 and Figure 2.3.1.4.

Table 2.3.1.5 Info-communications market sizes in each region
(Unit : Trillion yen)

	2002	2010	2015
North America	0.6	2.1	6.9
Europe	0.4	1.5	4.9
Japan	0.2	0.6	2.0
Others	0.3	1.4	4.6
Total	1.5	5.6	18.4

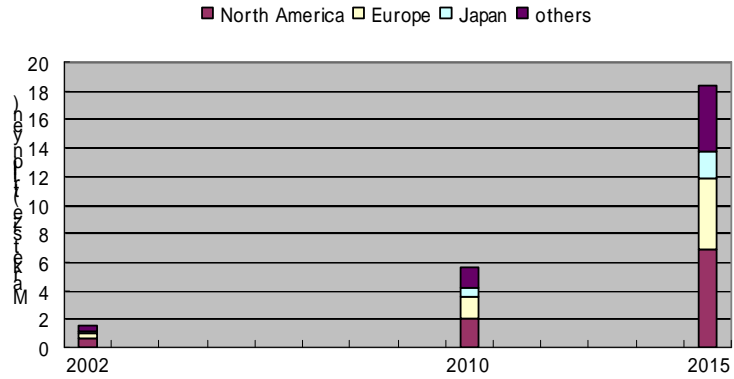


Figure 2.3.1.4 Info-communications market sizes in each region

2.3.2 Optical Memory

In the optical memory market, the markets enlarge in line with the two different uses: audio visual (AV) equipment and PC's. In the AV uses, the optical memories for DVD and post-DVD will be used in large quantities as the replacement for VTR. In the future, optical disks will emerge, using blue LD as the light source, which would make enriched recording and playing of contents possible.

In the PC uses, there will be transition from the conventional CD storage to high-density DVD and post-DVD storages. With the optical disks and optical-magnet disks, protection against data crashes at the time of reading/writing is better and there is additional merit of managing data off line. As the security needs heighten into the future, demand is expected to increase at the same time. Also, with the increased popularity of digital electric appliances, the demands for Network Attached Storage (NAS) with which data is stored in networks via PC. The expectations for NAS is backup storage of HDD by tapping into its characteristics of crash protection and the like by the optical memory.

The uses of optical memory can be expected to expand to archival information storage, which require long-term storage as with the case of works of art and documents in the museums and libraries.

In all of these uses of optical memory, the amount of information increases dramatically as the number of equipment and devices connected to network increase and as the quality of the information improves as in the case of 3D images. This means that the demands for optical memory will show drastic increases as high-density recording is possible with this kind of memory. The demands for new products that use new technology will increase and these include: post-DVD product that use blue LD, optical-magnetic hybrid memory, next-next-generation memory (adjacent memory, cubic memory, hologram memory, etc.)

Based on these trends, the estimates for the market sizes for new and existing products have been calculated and the results are shown in Tables 2.3.2.3 and 2.3.2.4 and Figure 2.3.2.5.

Table 2.3.2.3 Market sizes of new/existing products of optical memory (unit: trillion yen)

	2002	2010	2015
Existing	5.0	5.9	6.0
New	-	3.4	8.8
Total	5.0	9.3	14.8

Table 2.3.2.4 Average growth rate of new/existing products of optical memory (unit: %)

	2002 -2015	2002 -2010	2010 -2015
Existing	1.4	2.1	0.3
New	-	-	20.9
Total	8.7	8.1	9.7

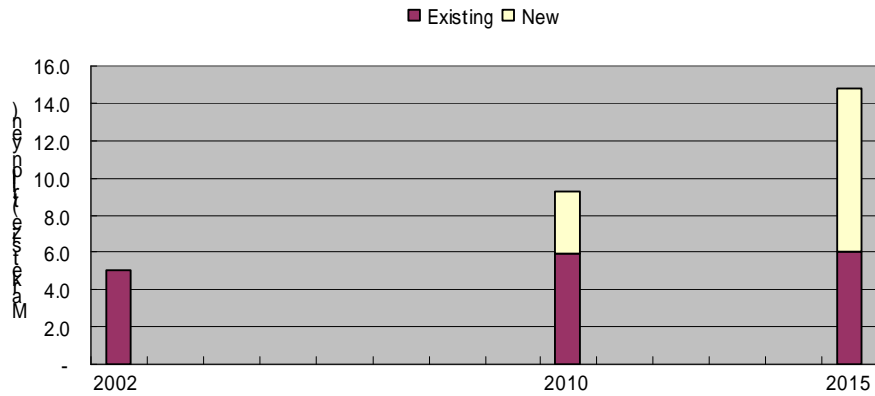


Figure 2.3.2.5 Market sizes of new/existing products of optical memory (Whole world)

Currently, as far as optical memory is concerned, the major product is DVD and North America is the leading market, followed by Europe, Others, and Japan. This is considered to be in reflection of the proliferation of telecommunication networks. In the future, optical memory is expected to become much more popular as the amount of image information will increase as the info-communication electric appliances proliferate; and amount of information handled will increase as the services using communication network becomes more popular. Based on these trends, the estimates for the market sizes for these products have been calculated for the four regions and the results are shown in Tables 2.3.2.5 and Figure 2.3.2.6.

Table 2.3.2.5 Market sizes of optical memory in each region
(Unit: trillion yen)

	2002	2010	2015
North America	2.5	4.7	7.4
Europe	1.0	1.8	2.9
Japan	0.5	0.9	1.5
Others	1.0	1.9	3.0
Total	5.0	9.3	14.8

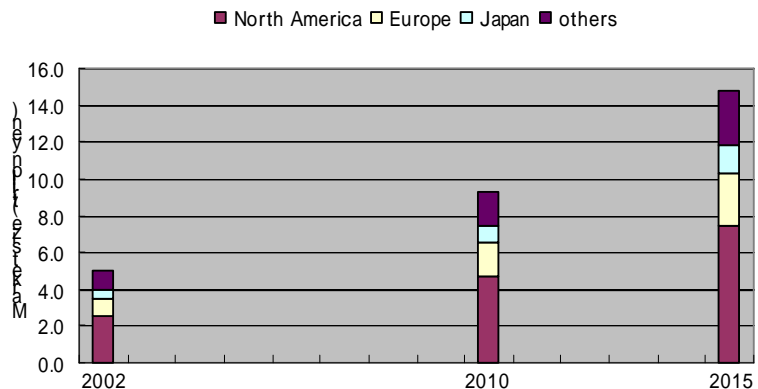


Figure 2.3.2.6 Market sizes of optical memory in each region

2.3.3 Display/Lighting

It is expected for the displays to proliferate in the current form for the time being, but displays will output PC and TV broadcasting as necessary in the future. Therefore, displays can be expected to proliferate as they are installed in various places in homes and offices. As displays suitable for future borderless society and ubiquitous network society, there are electronic paper/paper displays, which makes it possible for the display market as a whole to continue to grow into the future. The market sizes are expected to continue to expand for such display devices as LCD displays and PDP displays. At the same time, thinner displays such as electronic paper/paper displays will be put on the market gradually, using organic EL display and electrophoresis displays.

In the lighting market, with the support from the coming of the environmentally harmonizing society, lighting equipment using white LED lighting and organic white lighting and the like will begin to become popular.

Based on these trends, the estimates for the market sizes for new and existing products have been calculated and the results are shown in Tables 2.3.3.3 and 2.3.3.4 and Figure 2.3.3.1.

Table 2.3.3.3 Estimate for market sizes of New/existing display/lighting (unit: trillion yen)

	2002	2010	2015
Existing	10.4	17.8	26.0
New	-	1.6	4.3
Total	10.4	19.4	30.3

Table 2.3.3.4 Estimate for average annual growth of new/existing display/lighting (unit: %)

	2002 -2015	2002 -2010	2010 -2015
Existing	7.3	7.0	7.8
New	-	-	21.5
Total	8.6	8.2	9.3

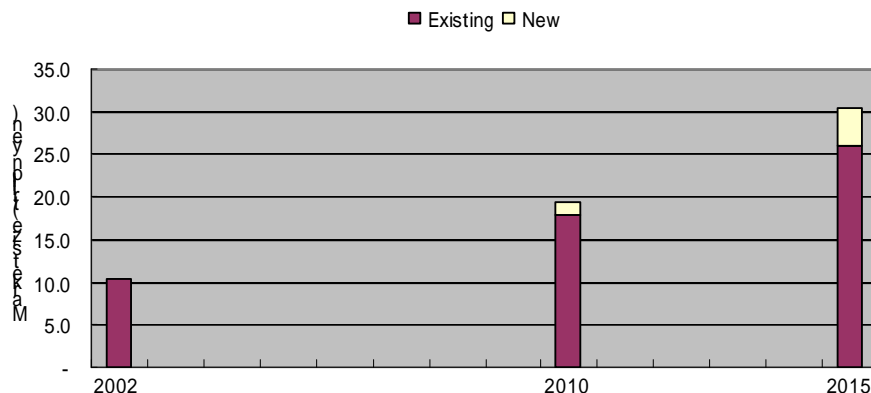


Figure 2.3.3.1 Estimates of Market sizes for display/lighting in existing/new markets (Whole world)

The breakdown of the market sizes for display and lighting are shown in Tables 2.3.3.5 and 2.3.3.6.

Table 2.3.3.5 Estimates for new/existing market sizes of display/lighting (Unit : trillion yen)

	Display			Lighting		
	2002	2010	2015	2002	2010	2015
Existing	6.4	13.3	21.1	4.0	4.5	4.9
New	-	1.4	3.7	-	0.2	0.5
Total	6.4	14.7	24.8	4.0	4.8	5.4

Table 2.3.3.6 Annual average growth rate for new/existing market sizes of display/lighting (Unit: %)

	Display			Lighting		
	2002 -2015	2002 -2010	2010 -2015	2002 -2015	2002 -2010	2010 -2015
Existing	9.6	9.6	9.7	1.5	1.6	1.5
New	-	-	22.1	-	-	17.9
Total	11.0	11.0	11.1	2.4	2.2	2.6

Regardless of regions, displays and lighting have already proliferated and this is considered to make the proliferation speed about the same for all regions. However, as for the new products, the proliferation speeds are somewhat different for advanced and developing countries. This is essentially due to procurement power differences. At the same time, as for products of novelty such as electronic paper/paper displays, proliferation is expected to begin in countries where information contents are rich for displaying them, such as North America and Japan. Based on these trends, the estimates for market size have been calculated for different regions and the results are shown in Table 2.3.3.7 and Figure 2.3.3.2.

Table 2.3.3.7 Estimate for market sizes of display/lighting in each region (Unit: trillion yen)

	2002	2010	2015
North America	3.3	6.0	9.3
Europe	2.6	4.8	7.3
Japan	2.4	4.4	6.8
Others	2.2	4.3	6.9
Total	10.4	19.4	30.3

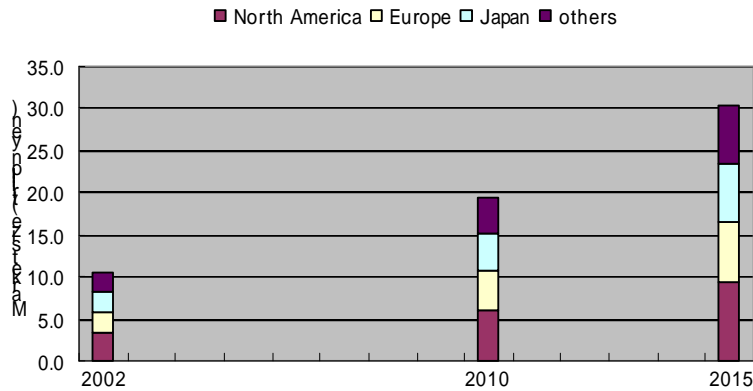


Figure 2.3.3.2 Market sizes of display/lighting for each region

2.3.4 Input & output

In the future society, input/output devices is expected to occupy a very significant position as one of the sensing function in the human interface equipment. Based on this view, the future images of the equipment on the extension of the conventional input/output devices and equipment conceived from the application point of view will be described.

The input devices such as DSC and DVC will be fused with mobile terminals and will be made into high definition TV compatible. By combining with various usage scenes, the market sizes of the input devices will greatly increase. At the same time, the office equipment such as MFP or the output equipment will increase their demand by proliferation into Asian and other countries where demands for office use will increase. On the other hand, as far as equipment that is lead by applications is concerned, these will increase along with the increases in the services in the health, security and education-related areas with the advent of ubiquitous network society. The TV phones and TV conference system and extensions of these used in remote diagnosis and communication between the aged and their grandchildren in remote locations are expected to increased. These can also be used in remote education. As new products, VR and AR are expected to grow in education and medical uses. For example, in remote education, easy to under-stand lectures will be available for teachers and students as they share quasi-real loci. The same holds for remote treatment and surgery. In these areas, important functions are created by coping with varied use forms but the compatibility with the networks and display functions will be necessary for 3D images and pictures.

Based on these trends, the estimates for the market sizes for new and existing products have been calculated and the results are shown in Tables 2.3.4.3 and 2.3.4.4 and Figure 2.3.4.1

Table 2.3.4.3 Market sizes for new/existing product of input & output devices (unit: trillion yen)

	2002	2010	2015
Existing	7.5	10.0	12.0
New	-	1.7	3.3
Total	7.5	11.7	15.3

Table 2.3.4.4 Market sizes for new/existing of input & output devices (unit: %)

	2002 -2015	2002 -2010	2010 -2015
Existing	3.7	3.7	3.7
New	-	-	14.2
Total	5.6	5.7	5.5

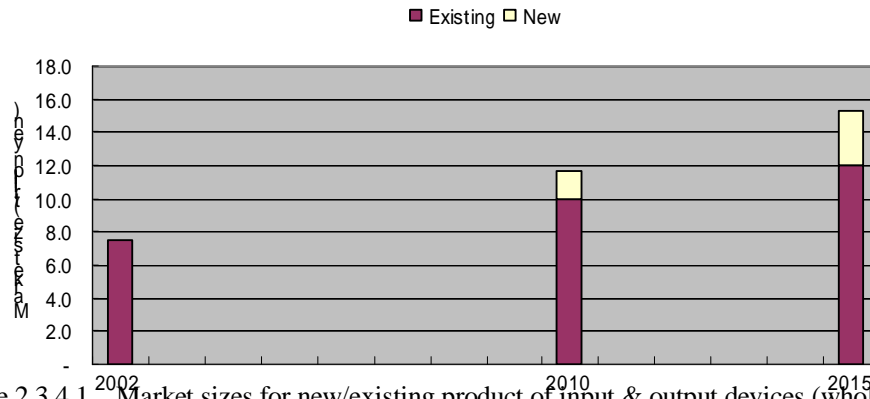


Figure 2.3.4.1 Market sizes for new/existing product of input & output devices (whole world)

DSC and DVC first become popular in North America, Europe and Japan where comparatively purchasing power is high. Then, as the prices come down, they become popular in Others regions, where purchasing power is relatively weaker. In the area of office equipment, the MFP has emerged that use the network, and these will become popular first in North America where telecommunication infrastructure is developed. These will then become popular in Europe and Japan, followed by Others region where new office demands will increase. On the other hand, equipment that emerges out of applications (TV phone, TV conference system, VR, and AR) would likewise require telecommunication infrastructure to be developed for proliferation. These will also become popular in North America first, then Europe and Japan, followed by Others region. Based on these trends, estimates of market sizes are calculated for the four regions and the results are shown in Table 2.3.4.6 and Figure 2.3.4.2.

Table 2.3.4.5 Market sizes of input/output devices in each region (Unit : trillion yen)

	2002	2010	2015
North America	3.1	4.9	6.4
Europe	1.6	2.3	2.9
Japan	1.3	2.0	2.6
Others	1.6	2.5	3.4
Total	7.5	11.7	15.3

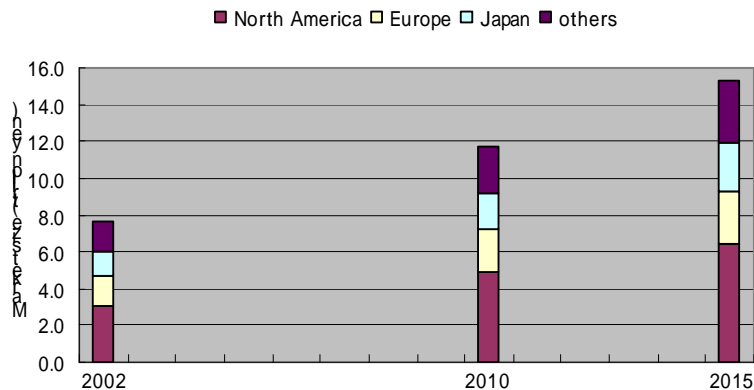


Figure 2.3.4.2 Market sizes of input & output Devices in each region

2.3.5 Processing

In the field of processing, along with the increased needs of minute processing such as nano technology-related areas that use laser processing equipment, the market size will expand. It is considered that there are great influences of the market movements of exima-laser application production equipment used for lithography. Contribution from new processing equipment is also expected to be made in the future from: exima-laser processing equipment using laser and EUV laser; and new processing equipment using enlarged output solid laser and femt-laser. Based on these trends, the estimates for the market sizes for new and existing products have been calculated and the results are shown in Tables 2.3.5.3 and 2.3.5.4 and Figure 2.3.5.1.

Table 2.3.5.3 Estimate on market size of processing in each region (unit: trillion yen)

	2002	2010	2015
Existing	1.6	3.0	4.8
New	-	1.3	3.2
Total	1.6	4.3	8.0

Table 2.3.5.4 Estimate on market size of of processing in each region (unit: %)

	2002 -2015	2002 -2010	2010 -2015
Existing	8.6	8.1	9.5
New	-	-	19.7
Total	13.0	13.0	13.0

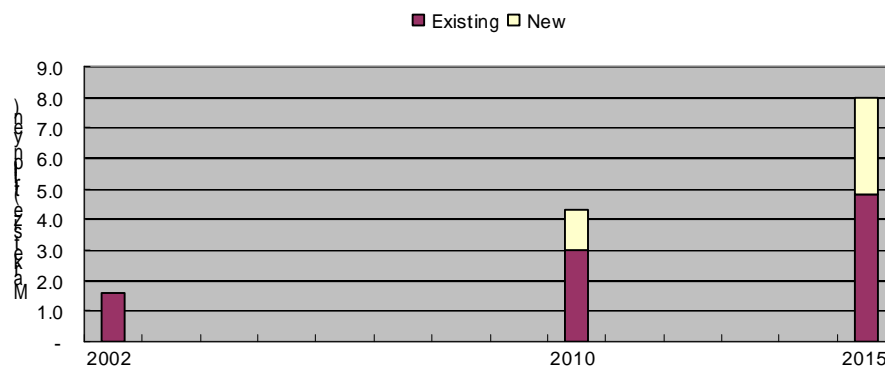


Figure 2.3.5.1 Market sizes for new/existing product of processing (whole world)

As far as processing equipment is concerned, the technological level is high in North America and Europe and the market sizes are also large in these regions. In these regions, especially, processing equipment in the high-price zone using advanced technology have proliferated, thus the possibility is high for these equipment to be made de fact standard. Due to, however, activation in the Asian region industry in Korea and China, the demand tends to expand, making medium- to low-priced products to proliferate. Based on these trends, estimates of market sizes are calculated for the four regions and the results are shown in Table 2.3.5.5 and Figure 2.3.5.2.

Table 2.3.5.5 Market size of processing in each region (Unit : Trillion yen)

	2002	2010	2015
North America	0.5	1.3	2.4
Europe	0.4	1.0	1.9
Japan	0.4	1.1	2.0
Others	0.3	0.9	1.8
Total	1.6	4.3	8.0

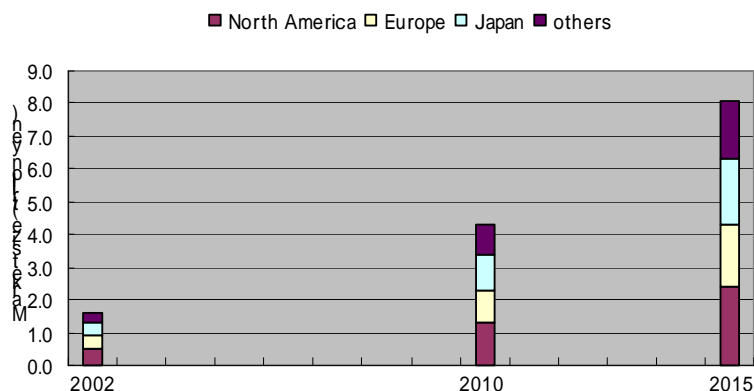


Figure 2.3.5.2 Market size of processing in each region

2.3.6 Optical (Solar) energy

The market size in the optical energy area will be enlarged by the improvements in the cost-effectiveness in the solar energy power generation system and environment measures in the industry. Especially, as the power generation cost is lowered, introduction of the systems will accelerate in the industrial use. At the same time, uses of built-in plant and building solar energy electric power generation modules will trigger explosive expansion of market size. In the future, new products with high conversion ratio and new application will also proliferate, using compound thin film and color-sensitive solar batteries. Based on these trends, the estimates for the market sizes for

new and existing products have been calculated and the results are shown in Tables 2.3.6.3 and 2.3.6.4 and Figure 2.3.6.1.

Table 2.3.6.3 Estimate on new/existing market size in the optical energy area (unit: trillion yen)				Table 2.3.6.4 Estimate on new/existing market size in the optical energy area (unit: %)			
	2002	2010	2015		2002 -2015	2002 -2010	2010 -2015
Existing	0.3	1.4	3.9	Existing	21.2	20.3	22.7
New	-	0.6	3.2	New	-	-	39.6
Total	0.3	2.0	7.2	Total	26.9	25.8	28.7

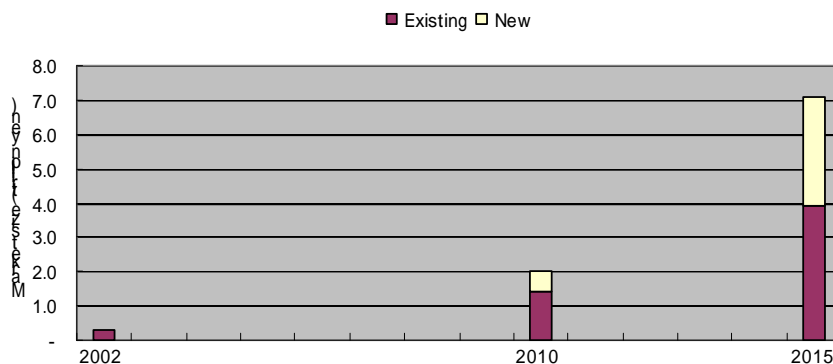


Figure 2.3.6.1 Estimate on new/existing market size of optical energy area (whole world)

As far as the solar energy power generation system is concerned, the production and proliferation in Japan is the most advanced and these currently occupy large part in the world market. On the other hand, in Germany and the United States, by such measures as providing subsidies and the like, the incentives are provided in solar energy power generation system. In the future, in the advanced countries like these three countries will see implementation of the system. Also such countries as Korea, China, Taiwan, Thailand, Malaysia, etc. will promote introduction of solar energy power generation system as their economies become activated. In addition, even in countries where electric use is low, the needs for the introduction of solar energy power generation system is high, and in 2015, there is a possibility for the market size of others regions to surpass those of Japan and the United States. Based on these trends, the estimates have been made for four regions and the results are shown in Table 2.3.6.5 and Figure 2.3.6.2.

Table 2.3.6.5 Market size of optical energy in each region
(Unit : trillion yen)

	2002	2010	2015
North America	0.0	0.6	2.1
Europe	0.1	0.4	1.7
Japan	0.2	0.6	1.8
Others	0.0	0.4	1.6
Total	0.3	2.0	7.2

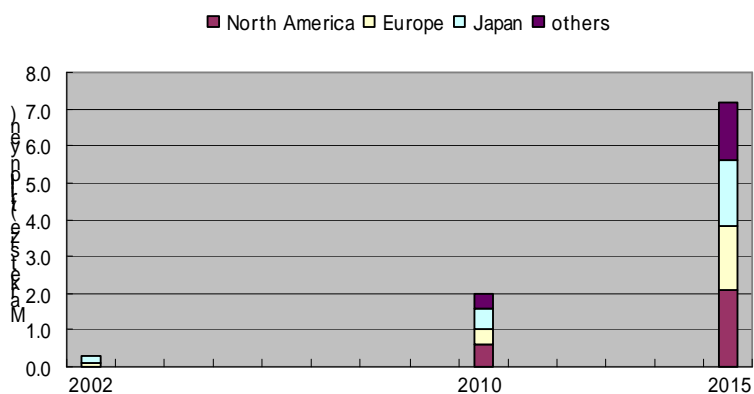


Figure 2.3.6.2 Market size of optical energy in each region

2.3.7 Environment/Sensing

The current optical catalyst market is in the burgeoning stage and it is expected that the market size will expand rapidly in the future. For the time being, products for external and internal building material will be the driving engines for market expansion. Lower prices and improvement in the anti-friction characteristics would rapidly enlarge the product market for transportation infrastructure. At the same time, products for environmental cleaning equipment products would become popular as the reaction efficiency improves.

In the area of sensing, there are sensing equipment and devices for our daily life which include: various riders and spectrometer for macroscopic sensing of global environment; Intelligent Transport Systems (ITS) for urban and daily life-related sensing; crime prevention security-related equipment; surface inspection apparatus and spectrum analyzer; failure position detection apparatus; etc. With the arrival of the environmentally harmonizing society, however, there will be increased demand for sensing demand in areas surrounding people for health management and security purposes. At the same time, for realizing traffic safety, expectations are high for optical equipment such as laser and camera sensors for vehicle and road-side mounted sensors. These can be expected to show large growth as network connected equipment. Along with the growth in the telecommunication area, the optical measurement equipment market can be expected to expand.

Based on these trends, estimates have been calculated for new/existing products and results are shown in Tables 2.3.7.3 and 2.3.7.4 and Figure 2.3.7.2.

Table 2.3.7.3 Estimates for new/existing market size in environment/sensing area (Unit: trillion) yen

	2002 -2015	2002 -2010	2010 -2015
Existing	6.5	7.6	4.8
New	-	-	21.7
Total	11.4	11.9	10.5

Table 2.3.7.4 Annual growth rate of new/existing market size in environment/sensing area (Unit: %)

	2002 -2015	2002 -2010	2010 -2015
Existing	6.5	7.6	4.8
New	-	-	21.7
Total	11.4	11.9	10.5

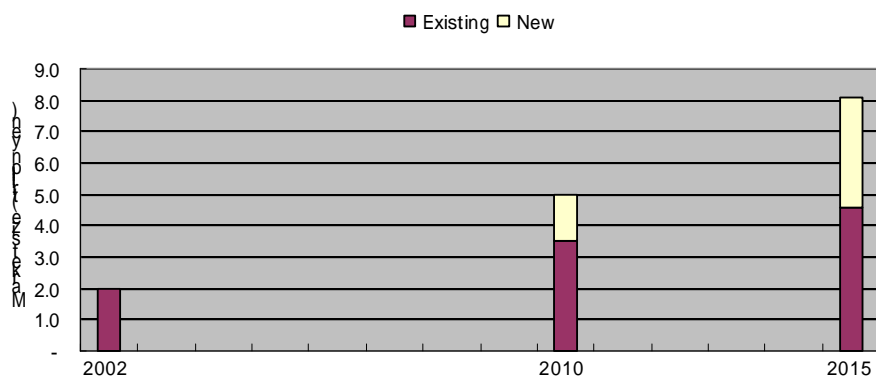


Figure 2.3.7.2 Estimates for new/existing market size in environment/sensing area (whole world)

As far as optical catalyst is concerned, Japan is leading the product development but market is rapidly expanding in Europe where environment awareness is high. Possibility is high, therefore, for Europe to become the driving engine of the world market along with Japan. In the sensing-related equipment, network connection would be important and, in this regard, the development will be mainly in North America, Europe and Japan. Based on these trends, the estimates have been made for market sizes in the four regions and results are shown in Table 2.3.7.5 and Figure 2.3.7.3.

Table 2.3.7.3 Market size for each region in environment/sensing area

(Unit: trillion yen)

	2002	2010	2015
North America	0.6	1.4	2.4
Europe	0.5	1.3	2.1
Japan	0.4	1.2	1.8
Others	0.4	1.0	1.8
Total	2.0	4.9	8.1

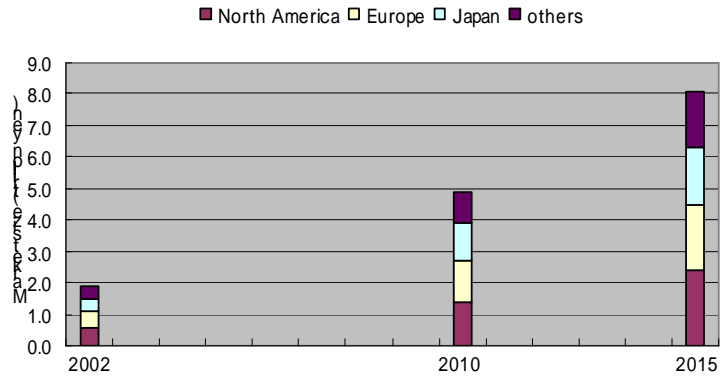


Figure 2.3.7.3 Market size for each region in environment/sensing area

2.3.8 Medical care/welfare

In line with the shrinking birthrate and the aged society, in the future in the advanced countries, the needs for health management among the aged and children are expected to become higher than the conventional level. This would make it necessary to have easy-to-use and low-priced health management system, so that health management can be carried out wherever we are. Due to these needs, demands for capsule-type endoscope and blood sensors are expected to grow. At the same time, expectation is high for artificial vision, which adjusts the human eyesight as human welfare equipment.

In the medical care, needs will be higher for less offending methods such as the interventional radiology (IVR) compared to CT and endoscope. Less invasive endoscope (capsule-type endoscope) and virtual endoscope will become more popular. Furthermore, toward the tailor-made treatment, the demands for gene analysis will become higher than ever and sequencer-like equipment that use laser will become much popular.

Thus, in the medical care/welfare area, optical equipment for installation can be expected in every scene and it is one of the most prospective areas. Based on these trends, estimates for markets sizes for new/existing products have been calculated and the results are shown in Table 2.3.8.3 and 2.3.8.4 and Figure 2.3.8.4.

Table 2.3.8.3 Market size for new/ existing market size in medical/welfare area (unit: trillion yen)

	2002	2010	2015
Existing	0.7	1.1	1.2
New	-	1.4	3.3
Total	0.7	2.5	4.5

Table 2.3.8.4 Annual average growth rate for new/ existing product in medical/welfare area (unit: %)

	2002 -2015	2002 -2010	2010 -2015
Existing	3.6	4.6	2.0
New	-	-	19.5
Total	14.9	15.9	13.1

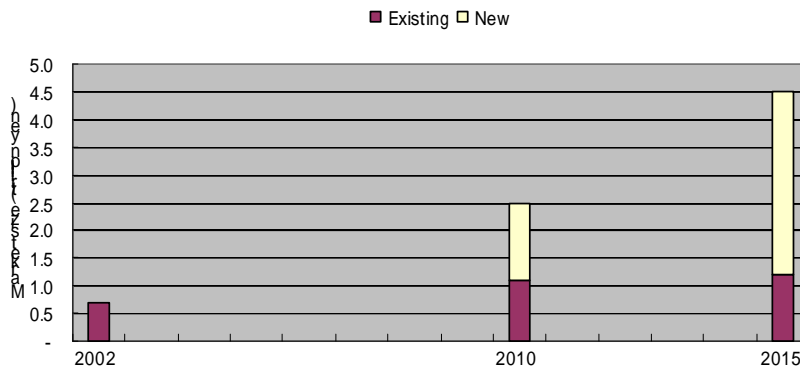


Figure 2.3.8.4 Market size for new/ existing market size in medical care/welfare area (whole world)

In medical care/welfare area, the characteristics are such that the weight of the US market is large. Conventionally, National Institute of Health (NIH) regulation-led US market has been the target of medical care/welfare products. Thus, what has become de facto there has been used in other markets. It means that the US market is the first market where new medical care/welfare equipment is marketed. This trend is expected to continue into the future. Based on these trends, estimates for the market size has been calculated for the four regions and the result of those is shown in Table 2.3.8.5 and Figure 2.3.8.5.

Table 2.3.8.5 Market size of medical care/welfare in each region (unit: %)

	2002	2010	2015
North America	0.3	1.1	2.0
Europe	0.2	0.7	1.2
Japan	0.1	0.4	0.8
Others	0.1	0.2	0.4
Total	0.7	4.9	4.5

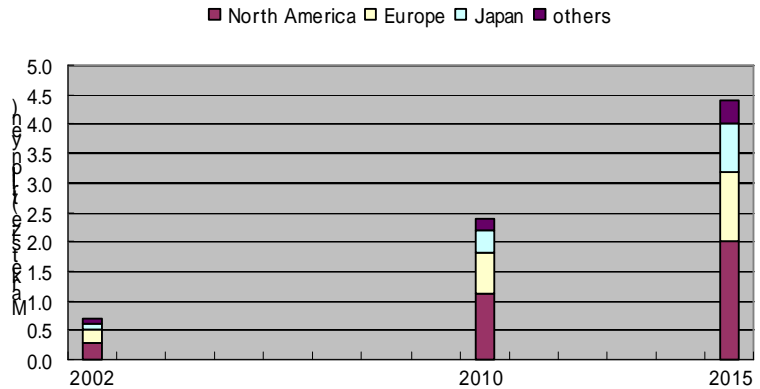


Figure 2.3.8.5 Market size of medical care/welfare in each region

2.4 Future perspective of the optoelectronics industry

2.4.1 Market estimates in each area

The market sizes for each industry area shown in 2.3 are summarized in Table 2.4.1.1 and Figure 2.4.1.1.

Table 2.4.1.1 Worldwide market size of optoelectronics industry and average annual growth (Unit: trillion yen, %)

	Market size (unit: trillion yen)			Average Annual Growth Rate (%)		
	2002	2010	2015	2002-2010	2002-2010	2010-2015
Info-Communications	1.5	5.6	18.4	18.5	28.6	21.6
Optical Memory	5.0	9.3	14.8	8.1	9.7	8.7
Display/Lighting	10.4	19.4	30.3	8.2	9.3	8.6
Input & Output	7.5	11.7	15.3	5.7	5.5	5.6
Processing	1.6	4.3	8.0	13.0	13.0	13.0
Optical (Solar) Energy	0.3	2.0	7.2	25.8	28.7	26.9
Environment/Sensing	2.0	4.9	8.1	11.9	10.5	11.4
Medical care/Welfare	0.7	2.4	4.5	16.6	13.1	15.3
Total	29.0	59.8	106.6	9.5	12.2	10.5

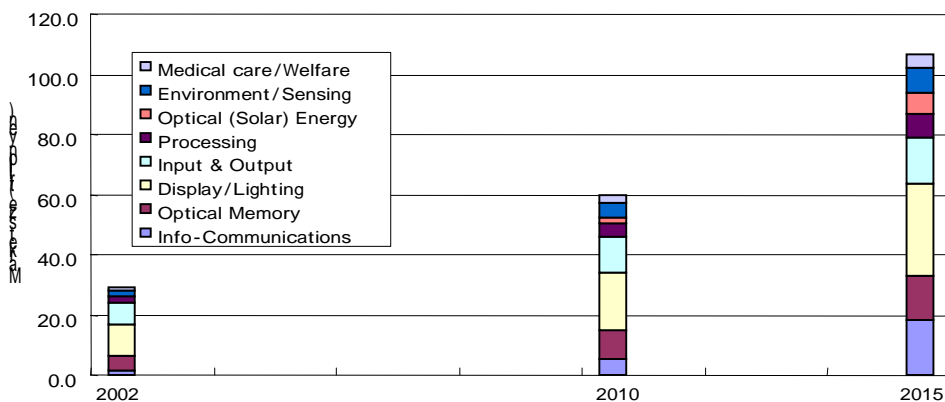


Figure 2.4.1.1 Worldwide market size of optoelectronics industry

In the worldwide market, the estimated market size was 29 trillion yen in 2002. The figure will expand to 60 trillion yen in 2010 and 107 trillion yen in 2015. The average annual growth rate is about 9.5% from 2002 through 2010 and about 10.5% from 2002 through 2015, which means the growth rate is higher after 2010.

When viewing estimates for different industry areas, the share for display/lighting, telecommunication, input/output, optical memory is large, which occupy 3/4 of the whole, and these areas are the driving engine of the market size enlargement. At the same time, optical energy and medical care/welfare will maintain relatively high growth rate through 2015 and expand the market size.

2.4.2 Estimates for each region

The regional market size in each industry area shown in 2.3 can be summarized as in Tables 2.4.2.1 and 2.4.2.2 and Figure 2.4.2.1. There are differences in market size growth rates in different regions and the annual market shares in world market change each year. From 2002 through 2015, the Others region maintain the highest growth rate of 11.1%, followed by Europe's 10.0%, North America's 10.2%, and Japan's 10.2%.

Table 2.4.2.1 Estimates for regional market size

(unit: trillion yen)

	2002	2010	2015
North America	10.9	22.1	38.9
Europe	6.7	13.8	25.0
Japan	5.4	11.2	19.2
Others	5.9	12.6	23.4
Total	29.0	59.8	106.5

Table 2.4.2.2 Regional annual growth rate

(Unit : %)

	2002 -2015	2002 -2010	2010 -2015
North America	10.2	9.2	12.0
Europe	10.6	9.5	12.5
Japan	10.2	9.5	11.3
Others	11.1	9.9	13.2
Total	10.5	9.5	12.2

■ North America □ Europe □ Japan ■ others

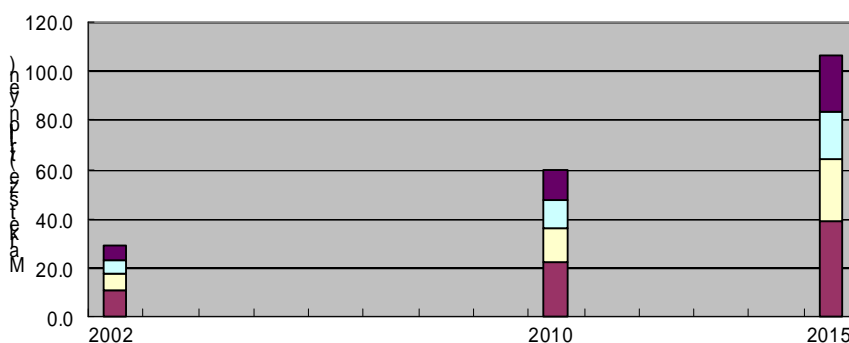


Figure 2.4.2.1 Estimates for regional market size (whole areas)

The market size for North America will be approximately 39 trillion yen in 2015 and the region continues to be the largest market. At the same time, the North America has the largest market size in all optoelectronic areas except the optical energy. The largest market size will be held by display/lighting and it will be 9.3 trillion yen in 2015. The next largest is telecommunication, which will be 6.9 trillion yen. In North America, it can be expected that the capital investment is the largest in telecommunication equipment. Also, the input/output equipment area is by far the largest worldwide. On the other hand, optical energy is the industrial area supported by the Japanese Government and this area is yet to be developed in North America and other regions. It can be expected that, through 2015, Japan will be leading the optical energy area.

The market size in Europe will be about 25 trillion yen in 2015, which makes it the second largest market size

among four regions. In Europe, the market size is the largest in display/lighting, which is 7.3 trillion yen. This is followed by telecommunication's 4.9 trillion yen and optical memory's 2.9 trillion yen. In Europe, the growth rate is high in optical energy and the average annual growth rate is 30% from 2002 through 2015.

The market size for Others regions will be about 23 trillion yen in 2015. And in this region, the market size is the largest in display and lighting, which is about 6.9 trillion yen, which is followed by telecommunication's 4.6 trillion yen. In the region, the growth is large in optical energy and medical care/welfare.

The market size in Japan will be 19 trillion yen in 2015. The largest one is display/lighting which is 6.8 trillion yen, followed by input&output's 2.6 trillion yen and info-communications' and processing's 2.0 trillion yen.

2.4.3 Overview of the whole market

(1) Total areas

When sorting out the market sizes in different region, which is shown in 2.4.2, and market size in different industry area, which is shown in 2.3 in terms of time series data, we get tables 2.4.3.1 and 2.4.3.2.

The overall trends is that, along with the increases in the equipment in medical care/welfare, input/output, display, the amount of information handled increase drastically. It can be considered that due to the two factors of increased opportunities for obtaining information for health management and quality improvement in the information in conversion of two-dimensional images into three-dimensions, the amount of information handled phenomenally increases. Because of this, info-communications and optical memory markets forming the infrastructure for handling the information increase as a trend.

At the same time, as the terrorist attacks in various parts of the world occur, instability is expected to continue into the future and it can also be considered that needs for individual security management is expected to grow. As measures in response to these needs, individual authentication and information security will be carried out. Furthermore, for individual authentication, demands can be expected to grow for optoelectronic industry in view of the individual authentication through cameras. Likewise, demands for telecommunications equipment can be expected to grow due to increases in telecommunication traffics for cryptography in information security. In the trunk networks, which is the forte for optoelectronics industry, when various information is made into cryptography, investments can be expected due to increase in the telecommunication volumes. Thus, the demands for optoelectronics industry can be expected to increase even at the time of contingency.

Table 2.4.3.1 Estimates of market sizes for each area and region (Unit : trillion yen)

	2002					2010					2015				
	North America	Europe	Japan	Others	Worldwide	North America	Europe	Japan	Others	Worldwide	North America	Europe	Japan	Others	Worldwide
Info-Communications	0.6	0.4	0.2	0.3	1.5	2.1	1.5	0.6	1.4	5.6	6.9	4.9	2.0	4.6	18.4
Optical Memory	2.5	1.0	0.5	1.0	5.0	4.7	1.8	0.9	1.9	9.3	7.4	2.9	1.5	3.0	14.8
Display/Lighting	3.3	2.6	2.4	2.2	10.4	6.0	4.8	4.4	4.3	19.4	9.3	7.3	6.8	6.9	30.3
Input & Output	3.1	1.6	1.3	1.6	7.5	4.9	2.3	2.0	2.5	11.7	6.4	2.9	2.6	3.4	15.3
Processing	0.5	0.4	0.4	0.3	1.6	1.3	1.0	1.1	0.9	4.3	2.4	1.9	2.0	1.8	8.0
Optical (Solar) Energy	0.0	0.1	0.2	0.0	0.3	0.6	0.4	0.6	0.4	2.0	2.1	1.7	1.8	1.6	7.2
Environment/Sensing	0.6	0.5	0.4	0.4	2.0	1.4	1.3	1.2	1.0	4.9	2.4	2.1	1.8	1.8	8.1
Medical care/Welfare	0.3	0.2	0.1	0.1	0.7	1.1	0.7	0.4	0.2	2.4	2.0	1.2	0.8	0.4	4.5
Total	10.9	6.7	5.4	5.9	29.0	22.1	13.8	11.2	12.6	59.8	38.9	25.0	19.2	23.5	106.5

Table 2.4.3.2 Average annual growth rate for each area and region (Unit : %)

	2002/2002					2002/2010					2010/2015				
	North America	Europe	Japan	Others	Worldwide	North America	Europe	Japan	Others	Worldwide	North America	Europe	Japan	Others	Worldwide
Info-Communications	-	-	-	-	-	18.3	18.4	18.5	19.0	18.5	26.3	26.3	26.6	27.4	26.6
Optical Memory	-	-	-	-	-	8.1	7.9	8.1	8.3	8.1	9.7	9.6	9.7	9.8	9.7
Display/Lighting	-	-	-	-	-	8.0	8.1	8.0	8.6	8.1	9.0	9.0	9.0	10.0	9.3
Input & Output	-	-	-	-	-	5.7	5.1	5.7	6.3	5.7	5.5	4.7	5.5	6.2	5.5
Processing	-	-	-	-	-	12.8	12.9	13.0	13.4	13.0	12.7	12.7	13.0	13.7	13.0
Optical (Solar) Energy	-	-	-	-	-	37.3	25.5	15.2	58.4	25.8	30.2	30.2	24.1	31.3	28.7
Environment/Sensing	-	-	-	-	-	10.9	11.0	14.8	11.5	11.9	11.1	11.1	7.6	12.0	10.5
Medical care/Welfare	-	-	-	-	-	16.6	16.6	16.6	16.6	16.6	13.1	13.1	13.1	13.1	13.1
Total	-	-	-	-	-	9.2	9.5	9.5	9.9	9.5	12.0	12.5	11.3	13.2	12.2

(2) Market size for existing/new markets

When summarizing the products that are extensions of existing technologies and products that use new technologies in 2.3 in different areas, we get tables 2.4.34 and Figure 2.4.3.2.

Table 2.4.3.3 Estimates of market sizes for each area and existing/new technologies(unit: trillion yen)

	2002			2010			2015		
	Existing	New	Total	Existing	New	Total	Existing	New	Total
Info-Communications	1.5	-	1.5	4.0	1.7	5.6	8.2	10.2	18.4
Optical Memory	5.0	-	5.0	5.9	3.4	9.3	6.0	8.8	14.8
Display/Lighting	10.4	-	10.4	17.8	1.6	19.4	26.0	4.3	30.3
Input & Output	7.5	-	7.5	10.0	1.7	11.7	12.0	3.3	15.3
Processing	1.6	-	1.6	3.0	1.3	4.3	4.8	3.2	8.0
Optical (Solar) Energy	0.3	-	0.3	1.4	0.6	2.0	3.9	3.2	7.2
Environment/Sensing	2.0	-	2.0	3.6	1.3	4.9	4.6	3.5	8.1
Medical care/Welfare	0.7	-	0.7	1.1	1.4	2.4	1.2	3.3	4.5
Total	29.0	-	29.0	46.8	13.0	59.8	66.6	39.8	106.5

Table 2.4.3.4 Average annual growth rate for each area and existing/new technologies (unit : %)

	2002/2002			2002/2010			2002/2015		
	Existing	New	Total	Existing	New	Total	Existing	New	Total
Info-Communications	-	-	-	13.4	-	18.5	14.3	-	21.6
Optical Memory	-	-	-	2.1	-	8.1	1.4	-	8.7
Display/Lighting	-	-	-	7.0	-	8.1	7.3	-	8.6
Input & Output	-	-	-	3.7	-	5.7	3.7	-	5.6
Processing	-	-	-	8.1	-	13.0	8.6	-	13.0
Optical (Solar) Energy	-	-	-	20.3	-	25.8	21.2	-	26.9
Environment/Sensing	-	-	-	7.6	-	11.9	6.5	-	11.4
Medical care/Welfare	-	-	-	5.2	-	16.6	3.9	-	15.3
Total	-	-	-	6.2	-	9.5	66.6	-	10.5

■ Existing □ New

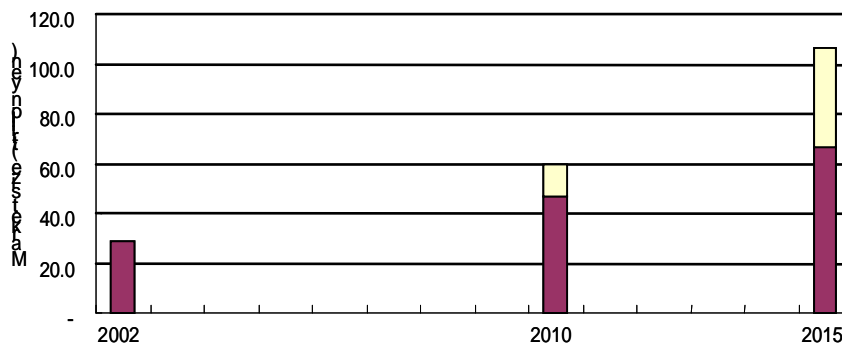


Figure 2.4.3.2 Market size of optoelectronics industry of the world: existing/new (Unit : trillion yen)

The products that are on the extension of existing technologies will continue to expand and average annual growth rate from 2002 through 2010 is 6.2% and from 2002 through 2015 is 6.6%. The product using new technology will be doubled in size from 2010 through 2015 and the average annual growth rate will be 25.8%. As far as the products on the extension of existing technologies are concerned, optical energy and info-communications products are the driving engines of the growth. In info-communications area, the products on the extension of existing technologies have not yet proliferated and it can be considered that, as they proliferate, markets will expand. On the other hand, as far as products using new technology are concerned, display, environment/sensing products will be the driving force for the growth. Expectation is high for paper displays and electronic paper products for new uses in the display areas. Among environment/sensing products, optical catalysts of optically increased sensing and, among optical energy products, organic solar batteries will be the driving forces. Both of these will expand as usage areas expand due to heightened awareness for “environment.” As can be seen in Figure 2.4.3.2, the market size will show hefty increase even only in products using existing technology and, by 2015, the market size will reach 67 trillion yen. On the other hand, products using new technology are estimated to reach about 40 trillion yen, which amounts to about 37% of the total market size. In the framework of the new and existing technology defined for this report, it can be considered that, for the market expansion, not only the further development of the existing technologies but also putting products using new technologies on the market will be important.

(3) Distinctions as a whole

As a whole, when more varied and larger amount of information is handled more than in the past, the expansion of the optoelectronics industry can be expected. In the trend, there are three major aspects and they are depicted roughly in Figure 2.4.3.3.

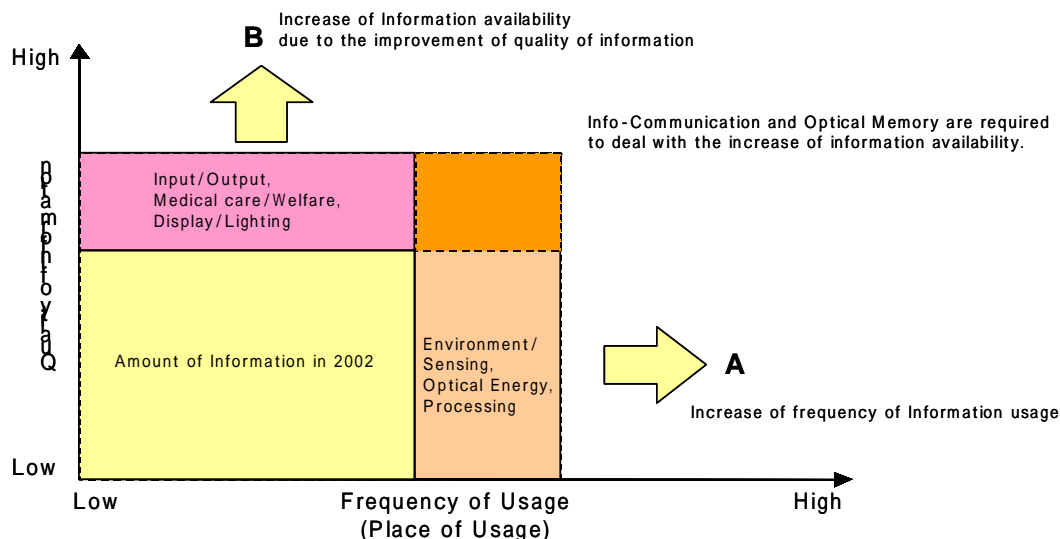


Figure 2.4.3.3 Trends in increase of information

Aspect A can be seen in optical energy, environment/sensing, and processing areas. These are phenomena of expansion in market size as the optoelectronics-related equipment in various areas are used in new parts and new applications. At the same time, included in these phenomena are environmental measurements of atmosphere and water quality in reflection of the increase awareness toward environments and activities for securing energy

through light in relation to energy conservation. Such trends are closely related to social changes such as “increasingly borderless society” and “environmentally harmonizing society” indicated in Chapter 1.

On the other hand, Aspect B are phenomena of creating applications that are more advanced than before, which make the information used more sophisticated and increase the information. In concrete terms, information is increased in medical care/welfare due to new ways of measurement as well as displays moving from two-dimensional display to three-dimensional displays. The former brings about qualitative changes in usage such as continuous health management of the elderly and new ways of physical measurement as with non-invasive measurement. The latter also brings about qualitative changes such as the change from the two-dimensional TV conferences to realization of realistic communication using AR. These trends are closely related to social changes such as “demographic aging society” and “advancing borderless society” indicated in Chapter 1.

From the above, it can be seen that the “demographic aging society,” “environment-friendly society,” and “advancing borderless society” indicated in Chapter 1 would stimulate uses of optoelectronics equipment and devices and the “spiral” movements are created as the above-mentioned changes are promoted through the proliferation of these equipment and devices. Through such changes and trends, it is expected and aspired that optoelectronics industry would be more importantly positioned than what it was conventional in the future society.

2.4.4 Summary of the market estimates

In 2002, the estimated market size out of the optoelectronics industry was 29 trillion yen. In 2010, this is estimated to be 63 trillion yen and in 2015 it will be 107 trillion yen. From 2002 through 2010, the estimated annual growth rate is 9.5 percent and, from 2002 through 2015, the rate is 10.5 percent. This means that the growth rate is higher after 2010. There are the following distinctions in these growth rates.

➤ Distinctions observed from products using existing technology (existing market) and products using new technology (new market)

Products using new technology will comprise about 22 percent of the products in 2010 and about 37 percent in 2015. At the same time, the growth rate would be about 26 percent from 2010 through 2015, becoming the driving force of the entire market. However, in the categories of products using new and existing technologies, the share of the products using the existing technology is still larger. From this point of view, it can be said that development of the existing technology will be important for the expansion of the market as a whole.

➤ Distinctions among regional markets

In the market sizes on the subject regions (Japan, North America, Europe and Others) , the order among these regions does not change from the present to the future: North America>Europe>Others>Japan. The Others region will rapidly developed but the region will not reach the market size of Europe by 2015.

➤ Distinctions among application fields

As far as the market size is concerned, the sizes are large for those four areas of display/lighting, info-communications, input & output, optical memory, which comprise three forth of the whole. As far as the growth rate is concerned, the rate is higher for medical care/welfare, optical (solar) energy as well as info-communications.

As one of the factors that bring about expansion of the market size of the optoelectronics industry, it is possible to point out the increase in the amount of information. There is improved quality of information as well as

increases in the opportunities of uses of the equipment that handle information by the factors that contribute to increased amount of information. In terms of improved quality of the information, increase of the demand for new products are brought about when the two-dimensional images are changed to the three-dimensional images, bringing about more sophisticated contents in information. (This applies to input & output, medical care/welfare, display/lighting products.) On the other hand, in terms of the increased opportunities of the information equipment uses, as processing equipment proliferate into the developing countries, this contributes to more demands for the equipment. (environment/sensing, optical energy, processing). In this manner, as the amount of information handled increases, this contributes to the expansion of the commutation equipment and optical memories due to expansion of communication networks and storage demands.

Chapter 3 Topics in Optoelectronics Technologies

-Prospective optoelectronics technologies that will flourish in use beyond 2010's – Introduction

The optoelectronics technologies that are considered prospective in the future have been taken up and perspectives have been subjectively examined up until 2015 and beyond. When doing this, technologies have been considered regardless of their market sizes and including those that have high social values. This report is not simply a description on technology and application aspects of optoelectronic technology is described. Efforts have been made to indicate approximate realization timing of practical applications as much as possible. At the same time, promotion and constraint factors for making the technology practical has been pursued as much as possible as well as measures that are considered necessary for promotion have been taken up.

3.1 Info-communications area

3.1.1 Future network and services -Evolution of photonic networks-

(1) Diversification of the future network needs

The accessibility for the broadband networks in Japan, due to rapid development of ADSL and rapid progress in the FTTH, is on the most advanced level in the world in terms of high-speed and low charges. At the same time, the traffic in the backbone networks is rapidly increasing.

(2) Diversification in the required to conditions for the networks

In the broadband networks as the infrastructure for the future information society, not only the large capacity, but other conditions are required. The number of services has increased that require low-delay characteristics and high quality as with IP phone and video phone. The requirements are also high for reliability and security in networks as the basic social infrastructure.

(3) Tasks toward creation of new network society in Japan

There are absolutely necessary conditions for the creation of the new network society in Japan based on the information technology in the future. Those are development of new network technology which supports the diverse subjects of communication, development of new mechanism of transmitting information and future-proof nature of the networks that make smooth introduction of new technology possible.

(4) Future images of networks and services

When it becomes possible to use high-definition images at low prices, proliferation of high-quality visual

services can be expected to in addition to medical care, education, entertainment, etc.

(5) Evolution of photonic network that create new services in the future

By the WDM transmission technology, more economical large capacity transmission was realized. But on the other hand, transfer technology of the network nodes has been based on electric technology and due to this, the progress in the technology was dominated by so-called Moor's law or the speed was not sufficient to amply cope with the traffic increases. As a stopgap technology for this, routing technology by the wavelength has been proposed and the technology is currently being introduced to networks as optical branching insertion system and optical cross-connection system. With this, expansion of the transfer capabilities of nodes is being realized, allowing for increases in the traffic.

3.1.2 Photonic network

-With an emphasis on Super-high-speed label processing and optical packet switching technology-

(1) Introduction

In the telecommunication networks of the future, not only the throughput of large capacity, but also scalabilities for flexibly coping with large traffic fluctuations and communication services with fine data grains are required.

(2) Evolution of the networks

The optical packet switching technology, in addition to the multiplexing effect on the wavelength axes, makes both high functionality and large capacity compatible at the same time: the high functionality is achieved by its capability for allowing the fine grain time-axis exchange and large capacity by super-high-speed transfer and a large throughput. Therefore, the optical packet switching is positioned as a ultimate technology in the development of the photonic network. At the same time, in the introduction of super-high-speed processing using passive optical circuit, the expectation is high for future reduction in electric power consumption. The practical application of the technology is expected to be made by 2010 and afterwards.

(3) Optical label processing and packet switching technology

The functions of the optical packet switching can be largely divided into the following five: routing, addressed processing, switching, scheduling, and buffering. Of these functions, as far as switching and buffering functions are concerned, attempts at making them optical technology have long been made and there are even reports on actual experiments. On the other hand, as far as the processing function is concerned, we are beginning to see many attempts in recent years. In the existing packet switching nodes, the processing is a function that consumes the largest amount of time and electric power. In other words, it is the largest bottleneck in the optical packet network. Although the element technology for realizing the optical packet switching is still in its early stages of development, presentations on this topic at academic meetings are rapidly increasing within the past few years. Furthermore, DARPA in the United States has announced last year on embarking on the research and development of new networks that introduce the most advanced optical technology activity and transfer data of optical signals, without conducting light-electricity conversion within the network.

3.1.3 From DWDM to super-high-speed OTDM and to control of optical phases

-Would the mankind be able to use light like microwaves?-

(1) Introduction

The optical communication is considered to be going into three direction in the future. The first is the super-high-speed transmission and signal processing technology. The second is the second-generation coherent communication and information processing technology. The thirds is the short wavelength and low-cost high-speed communication technology using optical fibers. These three technologies are expected to drastically progress in the next 10 years.

(2) Super high-speed transmission and signal processing technology that use super-short pulses

Although DWDM is one extremity in technology, when considering the processing of signals as a whole, wavelength control have been known to be so much more easier, in the system with high speed per channel. At the same time, this type of system has a characteristic of much smaller size and power consumption. The over-all time division multiplexing (OTDM), which conducts over-all multiplexing of high-speed signal and transmits at the transmission speed exceeding the behavioral limits of electronic circuits, has the characteristics of ease in synchronization of systems, which makes the compatibility with the conventional system high with good control. In the next 10 years, 160 Gbit/s transmission and super-high-speed optical signal processing will be realized. This will then lead to construction of photonic networks.

(3) Second generation coherent communication and information processing technology

As far as the utilization of light coherency is concerned, the mankind has not yet been able to utilize it completely as with the microwave used for the radio. It is considered that the research and development will make rapid progress in using the light phases in the next 10 years.

(4) Super-shortwave range and low--cost high-speed communication technology using a new fiber

Recently, a new fiber called photonic crystal fiber (PCF) has been created in Britain. The new fiber gives us hope for possibilities of the new super-high-speed communication.

(5) Importance of finding breakthrough technologies and developing them to full

A decade ago, no one would have foreseen the coming of internet and cell phone proliferation. This means that un-expected breakthroughs are changing the world. In the surrounding areas of the mainstream research, a very small number of researchers are bringing about major breakthroughs which completely changes the industries. In this regard, it would be most important to keep an eye on the essence of things in the project operations and research investment. It would be out of the question to fall into the trap of trifling matters.

3.1.4 Optical signal processing

-Optical digital recycling element and its application to all-optical networks-

(1) Introduction

As methods for breaking through the limits of processing of exchange and recycle and to realize sophisticated networks, the expectation is high for realization of all-optical signal processing technology, which makes processing possible without conversion between light and electric signals. Especially important is the optical signal recycling technology, which recovers deteriorated optical signals. This is a technology that would be the core of the nodes and links. Early realization of the technology is awaited.

(2) Outline of the optical digital recycling technology

Optical digital recycling technology is called 3R-recycling, which is a technology for all-optically recycling deteriorated optical digital signal. After amplifying deteriorated optical data signal, data components and noise are filtered and optical clock signals are extracted and input to the optical gate element. By using the optical data signals which have been amplified as optical gate element's control signal, it is possible to recycle optical data signals.

(3) Tasks and applications of optical digital recycling technology

It is estimated that the timing for the optical digital recycling technology to be applied to the actual system is 2007 or afterwards. In order for the technology to be widely used in trunk and local networks, it is necessary to develop the optical digital recycling element which hybrids or monolithically integrates 3R functions. By making the optical digital recycling element practical, the bottleneck of light-electricity-light conversion and limitations of the operation speed are removed. These make it possible to provide the optical network with large capacity and high functions. By applying it to 160-640Gbit/s practical time division multiplex transmission, lower-cost can be expected in comparison with the wavelength division multiplex transmission.

(4) Summary and perspectives

It is expected that, by about 2010, the digital recycling element will be assembled into every node, relay, and receiver in the network, which would realize making the links optical. It is expected that processing at nodes will be made optical by about 2015. If it is possible to build a complete optical network in conjunction with making the links optical, extremely high-speed signal transmission and exchanges are realized, which is not limited by the processing speed of electricity. This will make it possible to use the network resources effectively. By about 2010 and 2015, access that assures Gbit/s-level bandwidth will be made possible for households in general. This is expected to bring major innovations in our life through the following: receiving a digital broadcasting; high-speed downloads of high-quality contents such as high-definition television; and services such as home office, remote medical care and education.

3.1.5 Super high-speed optical device

-Next Generation super high-speed network application-

(1) Future of the transmission system

There is a possibility of forming low energy consuming and compact nodes, if it is possible to conduct super high-speed all-optical processing. When making transmissions, by multiplexing high-speed 500Gb/s or so signals in less number of wavelengths, we can achieve more efficient transmission. For such super high-speed signal processing within a node or for faster signal transmission, super high-speed light source and all-optical switches capable of processing about 500Gb/s-1Tb/s light signals are needed. It would also be necessary to have optical buffer memory for building a system.

(2) Development conditions of super high-speed all-optical devices

Light sources, distributed control elements, and all-optical switches in all of the fields of time, space, and wavelength are being developed. Basic functions of 2R, 3R, MUX, DEMUX, gating, header recognition, and fiber distribution compensation, which are necessary in optical nodes, can be realized. It is considered that a system of about 160Gb/s transmission speed in a single channel will be achieved at about 2010.

(3) Non-linear switching device using photonic crystal

There are possibilities for realizing optical switches that will operate at lower energy by combining light sealing effect of photonic crystal, low-group speed effect and nonlinearity. By about 2015, expectation is high for realization of practical level next-generation switches that use photonic crystal and optical nonlinearity.

(4) Optical buffer memory

In order to the realized the optical packet processing that is all optical, it is necessary to have optical buffer memory. By combining this and optical delay line, the degree of freedom in composing optical nodes may increase drastically. As for realization of buffer memory modules, organized research projects and funds must be secured. In order to meet 2015 deadline, it is necessary to begin the research immediately.

(5) Summary

Toward super large capacity transmission and optical nodes in or after 2010, the prototype of super high-speed optical switching devices exceeding 160Gb/s are being realized. The realization of optical buffer memory is considered to give a major impact on building optical nodes. When lineups are complete for all optical elements and 160Gb/s-1Tb/s all-optical nodes are realized, drastically lower energy consumption and small size can be realized compared to the light-electricity-light nodes. This will respond to the social needs of conserving energy and realization timing of about 2015 is expected.

3.1.6 Light and quantum encryption communication

-Perspectives for light and quantum encryption key distribution system-

(1) Information network and the security technology that support the near future society

There are reports that, by using a quantum computer, it is possible to read the disclosure keys theoretically. This is a step toward the important technologies that secure safety. The light-quantum encryption key distribution system has a possibility for realizing the technology. This technology can also be expected to fuse with the optical communication infrastructure technology, which will support the future large capacity networks. The light-quantum encryption is a strong candidate for supporting the future network security.

(2) The principle and current status of light-quantum encryption key distribution system

In the light-quantum encryption key distribution system, random bit rows (encryption keys) are shared between the sender and receiver. In the key, only one photon is used per one pulse. Those who want to steal certain information must extract the photon for observation and then put the photon back into the communication circuit. Because of the principle of uncertainty of the quantum dynamics, it is not possible to make any observations without giving confusion to the photon's quantum conditions, and by detecting errors between sender and receiver, the existence of a eavesdropper can be detected.

(3) The future perspectives on the light-quantum encryption communication and development toward the quantum computer and quantum communication

The light-quantum encryption key distribution system will be first introduced to government organizations and the like, where highly classified information is handled. It will be introduced into the private sector in about 2010 or so and into the financial system such as banks. The light-quantum encryption key distribution system will be integrated into the info-communication network systems. It is hoped that individual users in general will enjoy absolute security in information by about 2020. The technology for handling one photon and utilize the quantum

tangling would lead to future quantum computer and quantum communication. The debut of the quantum computer will begin in about 2030 and its full scale utilization can be expected in about 2050. The quantum communication, ultimately, is expected to be the breakthrough in equipping the networks with larger capacity and it may be that building of communication networks that is completely different would be beginning in about 2050.

(4) Toward the future development of the light-quantum encryption communication

There are major obstacles to be overcome in the full-scale introduction of the light-quantum encryption key distribution system. Grappling with these tasks will involve major technological and economic tasks. National government level development support will probably be required due to the following factors: the systems to be developed have strong social infrastructure-related factors; the period prior to the full-scale utilization would be long; and the research involved is a basic research that would lead to future quantum computer and quantum communication.

3.1.7 The fusion of robot and optoelectronic technologies

- toward optoelectronic driven robots -

The elemental technologies that would make drastic improvements in robot development are sensor, actuator and communication technologies that connect them.

Sensor technology

Sensors that are widely used in robots are image sensors. The stereo vision detects one characteristic point in multiple images taken by two or more cameras. It also requires processing to detect three-dimensional position by using the principle of triangular surveying. The device that would make available the three-dimensional information needed by robots would be put to practical uses no later than 2010.

Actuator technology

Many of the actuators used in robots are electric motors. Compared to human muscles, electric motors possess very different torque characteristics. There are major problems, therefore, to be solved in order to realize human-like movements in humanoids. Although optically driven actuators are currently being developed, actuators that satisfy specifications required on the robot side are yet to be made and the expectation is that these will be made available in 20 to 30 years.

Communication technology

Magnetic actuators basically drive the current robots. This means that there is much magnetic waves in robots, which affects them. Signal and power transmission using optical communication is much desired. If this is realized along with the trends in actuators and optical devices, these would bring about major breakthroughs in these areas.

It can be expected, in about 10 years, that sensor devices that surpasses the current distance measurement accuracy by one digit or more would be made possible through application of optical technology. We will see robots that would co-exist with humans in towns and in our houses. Then, 50 years after that, we would see robots that move totally on optical technology, with cognitive and processing capabilities of two digit above the current ones. They are much lighter in weight but have more powers. They would be driven by energy sources that would last for about 100 years or the equivalent of human life. Such is our expectations for robots which would be our true life partners.

3.2 Display/lighting and optical memory area

3.2.1 Digital TV broadcasting and optical technology

- New broadcasting culture brought about by light -

(1) Introduction

When the broadcasting services are digitized, it would be a rebirth of the broadcasting and the new media would have much better pictures and sounds and they would have many functions attached to them including being bi-directional. There is a plan in place for replacing all the current analog broadcasting by 2011.

(2) Complete proliferation of digital broadcasting and coordination between broadcasting and communication

(a) Complementing radio waves

Ground digital broadcasting is distributed and transmitted all over the country using microwave distribution technology and broadcasting wave relay technology. Uses of optical fibers are conceivable as the redundancy system of the radio wave network. Using the existing fiber networks for communication, the broadcasting waves can be retransmitted through the use of wavelength multiplexing technology. Through this, it is expected that ground digital broadcasting would proliferate in the near future.

(b) Server-type broadcasting

The server-type broadcasting services make it possible for the receivers of the services to store broadcasting contents and use them by coordinating them with broadband communication. A television set will thus go beyond the framework of a simple broadcast receiver and it would become a comprehensive information terminal on which broadcasting and communication are fused.

(3) Enrichment and higher efficiency in broadcasting services: Broadcasting devices

(a) Displays

In the latter half of the 2010's, highly efficient and bright plasma display (PDP), field emission display (FED) and even newer displays will be developed and 60 to 80-inch high definition TV display could contain power consumption to about 100W. Also, for mobile and portable phone services by the ground digital broadcasting, flexible display with super-light weight for portable use would hold the key to the service.

(b) Image capturing devices (TV cameras)

TV cameras will continue to be made to perform better: with higher sensitivity, higher pixels and more compact sizes. Expectations are high for super-sensitive and compact image capturing element to be made for practical uses by combining super-high sensitivity light-electric conversion films and field emission electron source arrays.

(c) Recording devices

Recording devices for archives are required to have a large capacity (1TB or larger) and high transfer rates (1Gbps or higher). In order to achieve a large capacity in recording, the following are possible: hologram recording which records two-dimensional data in a three-dimensional pattern using Interference fringes; three-dimensional optical recording which uses photon reaction, and wavelength multiplex recording.

(d) Lighting devices

The solid plane light source will bring innovations to lighting, including design lighting and effect lighting. Electric power consumption by using solid light sources in the studio lighting of broadcasting stations would

contain heat emission, which reduces power consumption for air-conditioning. The energy conservation effect of this would be very large.

(4) Highly realistic broadcasting in the future

Research has already begun for a post-high definition TV. The goal is a large-screen super-high definition television set, with 4000 scanning lines. The expectations is high for such a set to be made for practical uses in the latter half of the 2010's.

(5) Afterword

The technologies to be realized in the latter half of the 2010's are required to have high reliability. At the same time, the technologies should match the broadcasting services and institution and social trends of the time. In these regards, the optoelectronic technologies would without doubt greatly contribute to enrichment and progress of digital broadcasting.

3.2.2 Displays with enhanced reality

- toward the realization of the ultimate environment with super-high reality -

(1) Introduction

If it is technologically possible to present or display pictures that look as if they are actually there in front of you, communication that transcends time and space or even factual relationships may be made possible. In order to realize such an image environment, elemental technologies in various fields would be necessary. Even limiting to display technologies, the display should be visible for a plural number of people and a natural 3D images must be realized. In addition, certain qualities in the images must be expressed. Compared to two-dimensional images, there are still many problems to be solved. In essence, the pictures should appeal to people's physical factors and yet the images should not create fatigue while viewing.

(2) Technological perspectives in the future

In order to display images that look like they are actually there, and in order to express the dimensions, 3D images should be created on large screen. For this, high definition 3D display apparatus will be needed. Two types of displays are conceivable: a projection type and direct view type. It appears that there are no major problems for realizing the images by developing the current two-dimension displays into further larger and higher definition displays. At the same time, for satisfying motion after-effect differences and for a plural number of people to see the images, as a principle, the current multiple vision method should be further developed.

In order to construct natural 3D-display that satisfy focus adjustments, we need to wait for the future achievements in the technology. In electronic hologram, the emergence of a new key device which is capable of direct control on wave surfaces is hoped for and this may be made possible with the progress in nanotechnology.

The methods for expressing the qualities of 3D display objects effectively would be very important for expressing high reality. Currently, the methods used are measurements of all diffusion and reflection ratios on the object surfaces and expressing them. If the psychological mechanism for obtaining the essential quality is elucidated, it is conceivable that a major breakthrough will occur.

(3) Summary

The road to ideal 3D display apparatus is long and winding. It is very probable that a fusion of a method to satisfy focus adjustments and multiple-viewpoint method would solve the problems. It is believed that high-reality

environment will be realized and explosive new markets will be created in the future.

3.2.3 Personal 3D display

- 3D-image space anytime anywhere -

(1) Introduction

The 3D image will be added to personal communication equipment as the auxiliary function of the two-dimensional display. It is considered that, by 2010, it will be used as something indispensable for human life by giving rise to a new personal space. Furthermore, in 2015 and afterwards, expectation is that 3D display emitting color ray information that is actually equivalent to the real space will emerge. By 2020, realistic 3D space images that do not make us aware of the display apparatus itself will be readily available. As the telecommunication infrastructure with super-high speed and large capacity is developed, the coming of the age of network culture of 3D displays with the network connected 3Ddisplay as the core will be expected.

(2)Future perspectives

Expectations are high for the future 3D display that, by creating a new three-dimensional spaces that were beyond imagination to date, the following blessings will be made possible: (1) entertainment tools that move our emotions; (2) realistic communication tools; and (3) tools for intellectual activation and productivity improvement. By 2010, uses of 3D display as something of a life style will come to stay. In 2015 and afterwards, expectation is that 3D displays with super-real images will emerge. By 2020, our expectation is that realistic 3D space images that do not make us aware of the display apparatus itself will be available.

(3) Toward the realization of future vision

(a) Impact

By providing virtual space of lights anytime and anywhere by 3D display personal equipment that is connected to the network, there are possibilities of creating new business areas. It can also be expected that this will lead to creation of new cultures.

(b) Measures and proposals

In order to make the 3D display a reality, it is conceivable that integral imaging is used as the basic principle and to make the number of rays extremely large. For this, it would be necessary to create trends for direct-view display panels with high-definitions and large total pixels. At the same time, technological development in optics, driving systems, storage, and transmission systems would be necessary. With technological development in these, it is sincerely hoped that 3D displays that are gentle to people and useful anytime anywhere for our lives will be realized.

3.2.4 Organic EL technology

- application to sheet display and sheet light -

(1) Characteristics of organic EL elements and sheet device

The organic EL element has the characteristic of being able to be formed on relatively wider area, high-brightness light emission with low directcurrent voltage, comparatively high efficiency, and being capable of emitting various colors. Also, as far as efficiency is concerned, it is expected to exceed 50 lm/W in several years and reach the level of fluorescent light. Through its application, a thin display that does not require backlight can be

realized. The expectation is high as the replacement for FPD in mobile used. Development is in progress with the view toward using it in TV sets in the future. There is a hope for the organic EL elements to provide new forms in display that did not exist before, such as forming on the plastic sheets and making it into flexible films.

(2) Application on sheet display

With the sheet display, first of all, there is expectation for its portability. In the card-sized display, which is only as large as telephone cards, there is no need to fill it with functions other than a display. Only the local wireless communication function is need to be installed, as with the Bluetooth. In the mobile computing scene, a display and a pointing device would be sufficient. When a roll-paper display is made, it can be normally stored in a pencil-type case and, then, it can be taken out and spread when needed. A portable display can be realized, which is equipped with sufficient number of pixels and screen size as a PC screen. The ultimate use of the organic EL technology will be a projector screen that emits light with itself and the flexibility and light weight is indispensable. For realization of such a display, major technological innovations will be needed and it is especially indispensable to develop driving devices such as a flexible transistor.

(3) Application to sheet lights

The essence of organic EL is “light emission” and it would be important application to develop it for lighting use. The organic EL can be a diffused light source as it lights up a surface. It is suitable for ceiling lights in residential housing. If the efficiency reaches 50 lm/W or higher, it has a great energy conservation effect and, since organic EL does not use mercury and does not emit ultra-violet rays, this will be its advantages. When making it into a sheet light, the degree of freedom for building will increase. There will be increased variety in interior design with the varied forms and coloring. Therefore, the “organic” EL will be most suitable for application areas where “harmonizing with humans” is the principle axis.

3.2.5 Solid state lighting

- Perspectives of LED lighting in the spotlight -

(1) Introduction

The advantage of solid state lighting is its compact size, long-life and mercury-less characteristics, which are not available with the conventional light sources. At the same time, since LED is driven with direct current, it is suitable for use with solar batteries and fuel cells, the future auxiliary power sources in future homes. If targeted for general lighting use, however, further improvements in efficiency and cost reduction are needed.

(2) Comparison of white LED with conventional general purpose lighting

When targeting lighting for general home use, compared to existing light sources, the electric power consumption of LED light sources is about one half of light bulbs and about three times as much that of compact fluorescent lights. The price of LED only is about 70 times that of light bulbs and about 7 times that of compact fluorescent lights. In the present day, the use of white LED cannot but be limited to special lighting purposes.

(3) Potentials of white LED

When the efficiency of LED reaches 120 lm/W, with the 60W light bulb-class lighting, its electric power consumption is only 6.7 watt or 1/9 of a light bulb and amounts to 3/5 of a compact fluorescent tube. Since the electric power can be reduced to 1/5, the chip can be made compact and a general-purpose package with small loss allowance can be used. Then, that costs can be scaled down to the same level as the current compact fluorescents

tube.

(4) Perspectives of the solid state lighting in the 2010's

The solid lighting as light sources is considered to be replacing the existing lighting light sources from the point of its potentials for higher efficiency and from the view of social needs on reducing environmentally hazardous materials such as mercury. It is considered that 120 lm/W can be realized in the 2010's.

For use as automobile headlights, by using several compact light sources, degree of freedom in designing and reduction of blinding brightness for the oncoming automobiles may be possible.

As for street lights, using LED's for the purpose would make the maintenance very easy and, since it does not take time when turning it on as with the case of the mercury lights, turning on and off the light is possible by combining with a sensor, which will contribute to conserving energy.

In order to realize LED lighting, efficiency improving measures for white LED would achieve better efficiency in bringing out the light from the LED chip, thus improving light output linearity in view of the electric current used. There will also be an urgent task of measures against light deterioration of the resin when the light output is improved.

3.2.6 Molecule memory

- Dawning of the human brain-type memory -

The memory capacity has been steadily increasing and the main memory in a PC of 128 MB to 256 MB is now only normal, which is about 100 times of ten years ago. As for hard disks, 100 GB hard disks are commonly found that this is more than 1000 times of what it used to be. Reflecting upon this, in the next ten years time, we would be freely handling on our desktop moving pictures, three-dimensional images, various simulation images, which means that we would be processing 100 to 1000 times larger amount of data, or the data capacity of about 100 TB. In the next generation super-large capacity memory of ten years from today, we would be in need of new memory principle based on breakthrough innovation which is not on the extension of the conventional technology.

In the nanotechnology area, active research is in progress for molecule transistors and molecule memory. Since necessary functions can be installed on the molecule level through molecule design, the data storage unit can be composed on the molecule size, or 1 nm, as far as the principal goes. In a simple calculation, in 1 cc size, 10^{21} bit (approximately one million terabyte) data can be stored. As a candidate for such molecule memory, photo-chromic molecule is conceivable as the component of such molecule memory. One photo-chromic molecule, through optical-chemical reaction, can reversibly assume two stable different states.

As for the manufacturing methods of the memory using organic molecule, we cannot but use the bottom-up methods, that is self-organizing phenomena of molecules. By fusing the conventional principle of semiconductor, on which reading and writing is conducted electrically, with the optoelectronic technology of the reading and writing optically, we can attain the molecular nanotechnology. Thus, a completely new memory system will be realized, which can be called an artificial intelligence, capable of thinking and creating. After the elapse of half a century since von Neuman proposed the basic principles of a computer, there have been long years of discussions as for the timing of the artificial intelligence surpassing human brain. But the reality is that, although the computer came to surpass human beings in its calculation speed by a large margin, it was not possible for the

computer to realize human thinking and creativity. This is because no matter how fast and large a capacity is given to the computer, with the current architecture, human brain itself cannot be produced. At the beginning of the 21st century, however, by fusing molecular nanotechnology and optoelectronic technology, there will be a dawning for human brain-type memory or computer based on this new principle, which has long been the dream of the mankind

3.3 Environment, Energy, and Life Science Areas

3.3.1 New developments in optical fiber sensing technology

- With the emphases on optical fiber nervous network for safety and security -

(1) Introduction

It is hard to say that we have seen sufficient progress in the industrialization of optical fiber sensing, but there are technologies that grew into practical uses by realizing functions that was impossible with conventional technologies. This has been the case with optical fiber gyro. And, in recent years, we can see a birth of new technology in the optical sensing area, which is coming into the spotlight.

(2) Optical fiber nervous network and material and structure that can sense pain

In civil engineering and construction area, in order to realize a structure with a function of self diagnosing damages by earthquakes and deterioration through aging, the optical fiber distributed and multiple points sensing, which is capable of detecting damages and the like in distribution, is coming into spotlight. The similar technology can be applied to diagnosis of airplane materials. By attaching optical fibers all over a structure such as building, bridge, inside walls of tunnels, dams and highways, wings and pressurized compartments of an airplane, fuel tanks, and so on, distortion, side pressure, and temperature are sensed in distribution. We named such materials and structures the “material and structure that can sense pain” and call the optical fiber that constitute sensors “optical fiber nervous network.”

(3) Development in new fusion technology area in the mid-2010’s and afterwards

A new method has emerged in the optical fiber and nervous network technology, which can achieve extremely high performance in functions that was impossible for conventional technology. The development has already begun on the “optical fiber nervous network for material and structure that can sense pain” which include; technology for sensing side pressure; technology for sensing selectively the distribution of vibration; and technology for placing optical fiber grating sensor at multiple points with lower costs.

By further deepening the practical technologies for the first generation technology, such as the multiple-point sensing technology and distributed-type sensing technologies, etc. and by developing a new technology based on new sensing principles, it would be possible for the technology of the “optical fiber nervous network for material and structure that can sense pain” to be developed into a technology area with more depth. As it has become possible to simultaneously obtain distributed and dynamic distortion, the coordinated research with users should be promoted. By analyzing such information in a synthesized manner, there emerged possibilities for completely new diagnostic method of structure and materials. “The optical fiber nervous network” as the fusion area of the photonics and material structure technology, the expectation is high for the technology to enter the time of its practical use in the mid-2010’s.

Japan is a country where many earthquakes can occur. And we have now changed the course of our country to place importance on maintenance instead of disposable products. By actively utilizing the high-level technology in Japan which have been nurtured through optical fiber communication, our expectation is high for creation and development of new fusion technology area.

3.3.2 Application of optical catalyst to environment

- Environment cleaning catalyst of the future -

The development of optical catalyst has started with the emphasis on the energy in the main. In recent years, however, the technology has been made practical and commercial as a method for completely decomposing hazardous materials and making them harmless under ambient temperature and pressure conditions. There are advantages of its safety and smaller loads on the environment.

(1) Characteristics of optical catalyst

What affected the application of optical catalyst to environmental problems in recent years have been the interest in polluting materials that exist in minute amount, heightened interests in hygiene-related matters in our life environment, and necessity of countermeasures toward pathogenic organisms that cause new epidemics. Then, subjects of application of optical catalyst expanded to removals of evaporative organic pollution materials, environmental hormone-like materials such as dioxin, and germs and viruses in our life spaces. The research and development has progress to such an extent that commercial cleansing apparatuses and systems are put on the market. Since the activity ranges of activated oxygen species of the optical catalysts are limited to surfaces of the optical catalyst and its nearby areas, the catalyst is considered safe and harmless. Such activated oxygen species strongly oxidize and decompose polluting material that exist in a minute amount and low density. Such removal of polluting materials in low density is basically considered as the application areas where characteristics of the optical catalysts work well.

(2) Application to environmental area in the future

We are beginning to see many application products of optical catalysts such as air cleaners and antibacterial tiles.

As far as the air pollution by the automobile exhaust gases in the urban areas is concerned, removal of nitrogen oxides has been researched from the early days and the effectiveness of optical catalysts has been indicated as a method to remove nitrogen oxides that are emitted into the environment. At the same time, the expectation is high for capabilities of the optical catalysts in anti-germ and anti-virus characteristics in terms of in-house air environment and life spaces.

In terms of energy consumption and the load factors on the environment, the optical catalysts are considered to possess ideal elements. In order to apply optical catalysts to as many building and housing materials, furniture and interior materials, paint materials and the like, it is necessary to develop low-cost optical catalyst materials. To date, paints that do not require thermal processing and coating materials effective for base coating have been developed. As technological development for expanding application areas proceed, the expectation is that catalyst materials that form active layers only on surfaces through spontaneous phase separation would be developed.

In order to make the “environmental optical catalyst” truly practical, it would be necessary to conduct research

and development paying ample attention to total environmental risks and costs and not only in the decomposing characteristics of the subject materials. We are convinced that such efforts would lead to technological development and practical development that would ensure utilization of optical catalyst characteristics to their fullest extent.

3.3.3 Future perspectives of solar energy power generation

- Toward Japan as No. 1 in clean energy use in the 21st century -

(1) Significance of solar energy power generation and the current condition of the technology: Japan as the world's top runner

(a) 21st century like energy security

The forte of the solar energy power generation is its cleanness in terms of the environmental load factor. In the past ten years, there have been many practical development in solar energy power generation in various areas. By the drastically lowered costs of solar battery cells in the future, the cost of the solar power generation is expected to go down. Forecasts suggest that the cost will go down to the level of water power generation in 2010 and it would further go down to the level of the heavy oil fire power generation. Solar power generation would be part of the export industry in Japan in the future. The expectation for the solar power generation is significant as the clean energy with the largest contribution to prevention of global warming.

(b) Significantly extended conversion and efficiency of solar battery

As of FY 2003, the Sanyo HIT cell has single crystal silicon area of 21.3% and there are other mass produced cells with efficiency close to 20%. And in multiple crystal silicon, Kyosera announced that their d-Blue Cell has 17.2% cell efficiency, an 11% improvement compared to similar kinds of cells. In recent years, the amorphous solar battery cells are in the spotlight due to its resource and energy conservation characteristics. This type of cells are put on the market with the module efficiency of 9 to 11%.

(c) Japan accounting for half of the world production of solar battery cells

In FY 2002, Japan shipped 279 MW of solar battery modules. This is a little over 50 percent of 520 MW of the world production of solar battery modules. As a production amount, in FY 2003, the module shipment is expected to surpass 160 billion yen.

(2) Future perspectives out of solar energy power generation

(a) Performance index and milestones in production amount of solar battery cell modules

As of 2003, the annual production of solar batteries cell was 50 MW. By 2010, all manufacturers will produce about 100 MW. By this year, in terms of the module cost, it will amounts to ¥100 per watt, which will further go down to 75 yen per watt in 2020. The bulk product conversion efficiency of 17% in sliced substrates is a figure considered to be relatively easy to achieve. On the other hand, thin film silicon products of tandem type are expected to have conversion efficiency of 13% by 2010 and 15% by 2020, which are considered to be achievable goals.

(b) Favorable conditions for market expansion and expanding application areas

The potential demands for solar power generation is considered to be huge. The reasons for this is very few transmission and distribution losses due to it being distributed-type power generation and the power generated is direct current. By the mid-2010's, in terms of compact type, wearable solar batter cells are expected to appear. As

for super-large types, several thousand KW-class water power/optical power hybrid plant and one million KW-class atomic/solar power generation hybrid plant may be built.

(c) When would solar power generation as clear energy would become a mature technology

The expected electric power generation facility capabilities using solar energy in line with an optimistic scenario would be 350 GW by 2030. When we multiply the figure with the annual system utilization ratio of solar energy power generation of 12.5%, we get 43.7 GW. With this figure, it would be possible for us to replace the fossil fuel power generation by clean solar power generation.

In order for Japan as an economic power with literally no natural resources to survive through the 21st Century, it is important to secure energy resources. In terms of solar energy technology, Japan is currently leading the rest of the world. The future of Japan could be dependent on further promotion of this industry with the whole world as the market. In the 20th Century, Japan was the world's largest energy importer. Would it be possible for Japan to become the largest exporter of clean energy? We must by all means strive to make this dream come true in order to overcome the economic hardships Japan is facing.

3.3.4 Optical catalyst and energy

- Establishment of dream technology of artificial light synthesis -

(1) Dream technology: Artificial light synthesis

We all know the fact that solar energy is inexhaustible but we are not yet utilizing it to full. We have in front of us the major task of developing low cost yet high-performance new solar energy utilization technologies. Just imaging what would happen if we had a magic powder to sprinkle over a pond of water to generate hydrogen with the sun light. The recovered hydrogen can be used as clean energy. What a fun it would be if we could achieve such a dream technology! And the oxidant semiconductor powder optical catalyst could be such magic powder. The decomposition process of water using optical catalyst is equivalent to the light-emission of light synthesis and it is also called one of the artificial light synthesis technologies. If it is possible to produce hydrogen from water at a low cost, it would be possible for us to use hydrogen itself as fuel. In addition, by a process equivalent to the light-absorbing reaction of light synthesis, carbon dioxide gas can be easily converted to methanol, ethanol, ethylene, and gasoline, which are useful carbon resources. Cyclic use of organic resources and non-organic resource would become economically feasible. The light synthesis would truly be a dream come true.

(2) Current status of the direct production technology of hydrogen and oxygen from water by the use of oxidant semiconductor catalyst

(a) Development the optical catalyst of ultraviolet ray responses

It was at the beginning of the 1970's, when the direct decomposition process by the oxidant semiconductor optical catalyst was discovered. The research and development in the process has been carried out actively worldwide as there was the effects from the oil shocks at that time. It was not possible, however, to conduct stable decomposition of water and a research and development on the topic came to a standstill for a while. In Japan, however, steady research and development continued and, at present time, many oxidant semiconductor catalysts of ultra-violet ray responses have been discovered.

(b) The development of optical catalyst of visible light responses

In order to achieve practical technology for water decomposition process by optical catalysts, it is necessary to establish a high-efficiency optical catalysis process which is able to utilize visible light contained about 50 percent in solar ray. In reality, in the light synthesis process, 600nm or 700nm level visible rays are used.

(3) Future perspectives

By laying optical catalyst of 3 percent conversion efficiency all over the bottom of a pond of the size of the Tokyo dome (solar pond), under the shining solar ray of a fine day in Japan, approximately 750,000Nm³ of hydrogen can be generated in a year. On the other hand, in order to drive one million automobiles equipped with hydrogen fuel cell, it is considered that one billion Nm³ hydrogen is necessary. Under this condition, in order to supply hydrogen for all fuel cell automobiles, it is necessary to have about 1330 solar ponds in Japan. This means that one solar pond for each city, town, and village would suffice. When thinking about the costs for building infrastructures and the catalyst for this process, it would be realistic research and development goals to have optical catalysis process of conversion efficiency of about 10 percent or so. With this goal of conversion efficiency of about 10 percent, the current conversion efficiency of 0.03 percent will be stepped up to 3 percent in five years (by 2010). Then in the next ten years, achieving conversion efficiency of 10 percent (2020) would be the rough road map.

(4) Concluding remarks

In order to solve the problem of global warming, it is necessary for us to shift the archdiocese from fossil fuel energy development to reusable energy development. To this end, what is needed is new technological development for better utilizing the solar light energy, which is the source of all energies of the earth. From this point of view, it can be said that the artificial light synthesis technology is the most prospective of all technologies.

3.3.5 Laser nuclear fusion technology and its ripple effects

- New world opened up by power laser -

(1) The current status and perspectives of the laser and nuclear fusion research

By the end of the 1980s, the temperature necessary for nuclear fusion ignition and combustion (one million decrease) and density (1000 times on solid density) have been individually achieved at Osaka University and other locations. In the United States and France, huge laser equipment which possess MJ-class output has been built and about 10 plans have been started for nuclear fusion gains. When progress is made according to the plans, the goal is expected to be attained by 2013 or so.

On the other hand, with the emergence of extremely short pulse super-strong laser which used chirp pulse amplification, a new concept of laser nuclear fusion high-speed ignition has been proposed. At the empirical experiment plant, stable and reliable small-scale power generation will be conducted to establish the possibilities of attractive nuclear fusion power generation in terms of economic feasibility and environmental safety. The goal is introduction to commercial electric power generation by about 2050.

(2) New science and technology created by laser nuclear fusion research

High output laser and laser explosion compression, which had been developed for laser nuclear fusion research, are used for creation of extreme material conditions: super high-temperature (100 million degrees), super high density(1kg/cc), super high-pressure (10 billion atmospheric pressure). Using these extreme conditions, new

science and technology and industrial applications are about to begin.

(a) application of high output laser

Laser equipment capable of generating kJ-level pulse energy that have been developed for laser nuclear fusion is examined for various application areas: laser induced thunder, rocket propulsion, removal of space debris, etc.

(b) Science of extreme conditions

Through utilization of extreme conditions generated by laser explosion compression and the like, it would be possible to simulate in the laboratory such phenomena as explosions of the extremely new stars and internal structure of the earth. The new study areas of relativity theory-like plasma physics and laboratory astronomy are about to be born. There are expectations for creation of new materials such as metal hydrogen and metal carbon.

(c) Laser plasma x-ray sources

From Laser generated plasma, strong electromagnetic waves in broad frequencies from microwaves to x-ray are generated. By tapping into such characteristics as high brightness, short pulse and minute point sources, various applications are expected from noninvasive inspections to living body observations. Extreme ultraviolet ray of wavelength of 13 nm, especially, is the subject of development competition worldwide and this is for the use as the lithography light source for the next generation semiconductor device manufacturing.

(d) Laser nuclear science and its application

The plasma generated by super high-strength laser is in the spot light as generation source of electrons and ions with high energy exceeding MeV. Applications are conceivable for laser acceleration, nuclear reaction, and nuclear conversion and in many other areas.

3.3.6 Laser technology in space development

- Laser opens up power in space and transportation infrastructure -

(1) Laser energy network

In the outer space, the light does not diffuse nor is absorbed and longer the distance the merits of laser transmission becomes salient. By converting solar ray in space from the stationary orbit and utilizing it on the ground, it is possible to obtain energy regardless of day or night. Converting laser energy into hydrogen would bring about highly value added energy which can be stored and transported. The laser considered here is solar excitation laser which use the sun light as the source. The solar light laser station would become the power network hub, which would transmit power to locations in need of the power. Currently, the research committee of the Japan Aerospace Exploration Agency is examining the power network for realization in 2020 to 2030, In order to conduct beam transfer to the moon or to outer planet area such as Mars would require supply of power by laser, in view of stable operation of spaceships. The power network that would operate in the solar system is considered to be developed with the target year of about 2050, when the manned Mars mission will be conducted in full scale.

(2) Laser propulsion

Another infrastructure for supporting space activities would be the transportation system, which is another application area of the laser. By using the high-temperature plasma abrasion, which is created by pulse laser, it is possible to construct a propulsion system, which further excels in fuel efficiency than the electricity propulsion

system and which does not require a high-voltage power supply. We consider that the first practical spaceship with laser propulsion would be realized as the posture and orbit correction thruster in the outer space and an orbit transfer ship from the cyclical orbit to stationary orbit. The first laser propulsion spaceship would emerge with the laser mounted on the spaceship as the power source at about 2010 and then, with the laser power network development and improvement, the usable power limitation would be alleviated through laser transmission. The scenario is that this would signal the beginning of mass transportation in space as the laser propulsion would be utilized to full.

(3) Significance of space laser system development

The outer space is the human frontier, which has long been a dream. But it is also a sad fact that the outer space is used for security maintenance among nations and the Japanese research strategy should include that view point. That is to say that Japan should accumulate the key technology of space laser and should develop technological strength of appealing the peaceful use of the key technologies to the rest of the world. That would be the way for peace and prosperity of Japan and mankind in 10 and 20 years' time. Laser has the role of opening up the frontier of science as well as expanding the frontier of activities for mankind.

3.3.7 Agriculture and optoelectronic technology

- Plant factory with complete control -

(1) Plant factory

A plant factory is for production of vegetable and young shoots automatically, regardless of seasons. The plants are grown indoors with artificial control of lighting, temperature, humidity, carbon dioxide density, and cultivation fluids. There are two kinds of plant factories: solar light utilization-type and complete control-type using artificial lighting. The complete control-type would be in the main for future vegetable products such as lettuce, spinach, and herbs. Such plants are still in the development stage but they are very close to commercialization. There is only one problem of cost effectiveness. In order for such plants to be realized and proliferated, every kinds of cost-cutting effort is needed.

(2) LED and LD as cultivation light source

The roles of cultivation light source are very important for the complete control-type plant factory. The prospective cultivation light sources are fluorescent lights and LED. These light sources do not emit much heat, which means that they can be put very close to the plants, which can make the lighting efficiency drastically higher. Compared to conventional light sources LED has the following characteristics: (1) it is possible for LED to approximately coincide with the peak of chlorophyll absorption peak and the peak of strong light reaction effect spectrum of the light form formation; (2) no heat radiation; (3) compact and light weight (4) long life ; (5) low-voltage driven; and (6) capable of pulse radiation which is favorable for photosynthesis. The red and blue LED and LD satisfies above (1). This will make the light absorption efficiency higher and will make the plants grow in good health despite comparably weak light. The red LED is especially favorable as it is low in cost and has high light emission efficiency of 30%. In case of LD, the characteristics of high efficiency and output and possibility of direct modulation with electric current would be useful in the future. The vegetables favorable for complete control-type plant would be leaf vegetables in general, such as lettuce, herb, and spinach in the main. There is no doubt that LED would be the major light source in the future plant factories.

(3) Semiconductor light element and future plant factory

Conducting intermittent lighting on plants by LED's and LD's with short light and dark intervals of about 200 μ s, the ratios of photosynthesis and growth will increase by 20 to 30% per a unit of light amount. This is because of the control on light reaction of photosynthesis. In the next stage, the possibilities of "laser plant factory" which used high-output and high-efficiency LD's compared to LED's will be in the spot light. For plants, blue rays are also necessary, so combinations of red LD, partial blue LED, and/or fluorescent light are also conceivable. Thus, the future plant factories in the 2010's will be high-rise building agriculture using LED's and LD's. They will provide the consumers with high quality leaf vegetables using no agricultural chemicals with short distribution routes. The production of young shoots, part of fruits and flower, not to mention rice is technologically possible if necessary

As for making LED light flowering timing control practical, conventionally it has been difficult to have a complete control as there are season-characteristics in flowers. If it becomes possible to control flowering timing and longer life by the wavelength of light, this will make considerably large flower business possible. In 2010's, plant factory of various flowers will be realized through blue and green lighting.

3.3.8 Future of nano bio-photonics

- pseudo brain produced by light -

Peta-byte optical memory

There is little reason for making the parliament library a size of a cube sugar. Having memory that automatically record what we see, listen, and feel would seem more attractive. This means what we see is recorded as is. By recording what we see and hear on high-definition DVD (blue ray) in stereo, this would amount to 360 GB or so. If we did this for 365 days, it would amount to 130 TB. Doing this for eight ears, would amount to astounding 1 peta byte. The future of optical memory may be even larger than what we estimate if all the people of the world had peta byte memory and peta byte recording is continued for recording history or for security with ubiquitous cameras.

Brain science and quasi ultraviolet ray

What is expected of the future memory technology is creation of an apparatus for transmitting a certain meaning from the external auxiliary memory to the brain, when we just think about something in our brain. What would be inside the brain is an apparatus for making the brain recognize the information by stimulating a certain location when a signal is received from the external memory. This will be a medical equipment to be implanted in our body or an implant micro-machine. The memory will be placed outside of the body. The key technology for realizing this "dream" would be photonics and nanotechnology. By using "quasi ultra-red ray," the light reaches to inside of the body and the electricity for driving the apparatus will be sent via the light. Then it would be possible to send control signals and data to be recorded can be sent inside the body by radio. Therefore, for example, when you think about "nano?" in the brain, at the very moment the signal is sent from the brain to outside of the body and the cube sugar memory outside the body will make quick search and tell the brain it is "minus 9 times 10."

Nano machines and nano optical processing

In vivo medical equipment would adapt to living organism on the nano-level, using in vivo adaptive materials. In short, these are the nano-machines. Their total sizes are micrometer sizes and so are the parts. Would it be

possible to manufacture such small machines artificially? By concentrating lights within certain substances by near-ultra-red ray femtosecond pulse laser, by non-linearity which is a multi-photon process, it is possible to create three-dimensional nano-cubic structure. Micro-cows in completely cubic forms which is 8 micron long (the fineness is 50 nm) and micro-spring with $2\mu\text{m}$ diameter and micro-lighting capsules have been reported.

Optical science technology and ethics

Genetic engineering and a technology will be very useful for mankind. But if and when they are put to wrong uses, they could do more harm than nuclear technology. In the science of 21st century, more than any time before, researchers, scientists, and engineers should have high social nature and ethics. If this is not the case, the future of the earth and mankind will not be rose colored. Instead, it would be totally gray

3.3.9. Remote medical care and optoelectronic technology

- safe remote medical care support system adapted to networks -

(1) What is remote medical care?

Remote medical care does not only mean medical care in remote places. Remote medical care would mean working toward the system under which “people can receive wherever and whenever certain high-level medical care.” The current institution of medical care is built on the principle of face-to-face medical care. This means that there are certain legal limitations placed on network-based medical care. By the technological development which would secure safety and operability on the same level as face-to-face medical care, social processes can be gained on the network based-system and deregulation will progress.

(2) New medical care that takes 30 years in establishment

The progress in medical care is remarkable but one comes to note that establishment of new medical care and technology make progress in units of ten years. When one wishes to have certain things in medical treatment, it is often made technologically available in about ten years. It takes another ten years for the technology to be clinically applied. Then, it takes another ten years for complete establishment of the technology. The span of the establishment of new technology is, thus, 30 years.

(3) Prerequisite for forecasting remote-medial care

In 30 years from today, it may be possible to forecast disease structures by combination of genes, life patterns and living environment. In terms of the medical treatment, reconstructive treatment and genetic treatment will be practices. Our life spaces will be expanded and mankind will be living in spaces and ocean bottoms.

(4) Telepathology (those generally used in clinical medicine by 2015)

The pathological diagnosis of microscopic images are specimen prepared for diagnosis in glass plates are sent to pathologists for diagnosis. In telepathology, however, the microscopic images will be digitized to be sent to pathologist in other locations for diagnosis. It is also possible for a pathologist to operate a microscope from another location. Both of these are called telepathology.

(5) Tele-presence medical care (those in clinical medicine beginning about 2015)

(a) e-hospital

It would be convenient if we can receive diagnosis through the network any time of the day. The development into this direction will be made supported by agent functions of the computer system for the most part. It will be beneficial if we could make selection for receiving medical care or supports at our own home or at medical

facilities. T]It is likely that the nurse robots will also be introduced.

(b) Reverse remote medical care

When one is hospitalized, often family members would accompany or visit. If the family member could see the bed-side conditions from home or if they could communicate with doctors and patients through TV telephone or other methods, we would not have to visit the hospital so often. Our responses to the patient conditions would be more flexible and suitable, which would lesson on the loads on family members.

(6) Remote capsule clinic (those that examination will begin about 2015)

It would be desirable if we could receive tests and treatments anywhere and around the clock. It is conceivable that, in the future, the medical equipment could be packaged in a place like a telephone box or the ATM's. These can also be placed at convenient stores or public facilities along with people who are qualified. The form of use of medical facilities in such ways would not be so unnatural in our life spaces in 30 years from today. For realization as medical applications, network compatible automatic and safe remote medical equipment must be developed. These would be mainly developed by utilizing optoelectronic technologies. When thinking about the society 30 years from today, it would also be necessary to forecast what would be the negative aspects of new technologies and system and what would be the new threats. In view of the new systems, it would also be necessary for us to be cautious so as not to embark on the use of the new systems until we have methods to prevent the potential dangers of the new systems.

3.3.10 Low-invasiveness optical treatment

- **Highly selective cancer treatment made possible by optoelectronic technology -**

(1) Low-invasiveness treatment of cancer that use optical technology(Photo dynamic treatment)

Photo dynamic treatment (PDT) is coming into the spotlight as the low-invasive treatment of cancer, using optoelectronics. When photo-sensitive drugs are injected into veins of a cancer patient, after elapse of a certain time, the drug will accumulate on the cancer tissues. Photo-radiation is then conducted on the cancer tissues to optically excite the drug particles and the energy of the excitation will be transferred to the oxygen in the drug, thus generative activated oxygen. By the strong oxidation power of the activated oxygen, the cancer tissue is destroyed. This is the principle of the photodynamic treatment. There is, however, an inherent problem in the photodynamic treatment that use certain new drugs, which is that fact that the effectiveness of the treatment greatly depends on the degree of accumulation of the drugs on the cancer tissues. Since the accumulation is the outcome of combination characteristics between the drug used and the organism, it is a sort of "random" characteristic over which no control is possible. What comes into play for such cases would be the application of drug delivery system (DDS), which is a technology for artificially enhancing the drug accumulation on the cancer tissue.

(2) The next-generation photodynamic treatment using laser drug delivery system

By the introduction of methods to accumulate photo-sensitive drugs on cancer tissues through laser induced stress wave, it would be possible to drastically enhance the treatment effects of the photodynamic treatment. A success has been confirmed on the introduction of Photophrin on the skin tissue of a rat. In order to make the apparatus practical, fiber transmission technology of laser light would be the key.

(3) Genetic treatment of cancer through use of laser light

Very recently, it has been proved that by optimizing the laser induce stress wave strength and pulse width, it is possible to conduct highly effective and selective genetic introduction. Through the use of this method, it is considered that it would become possible to efficiently and selectively introduce genes to cancer tissues. This methods is, therefore, hoped to bring a major breakthrough to the genetic treatment of cancer. By combining it with an optical fiber, it would be possible to build a gene introduction system like the one using catheter,

(4) Technological forecast

The photodynamic treatment using the second generation photo-sensitive drugs is expected to make progress in application to clinical testing within the next few to several years. At the same time, application research of drug delivery system on the photodynamic treatment would also make progress and the apparatus development of laser drug delivery system is considered to make a certain achievements by 2010. The application to clinical research would go into full-scale research in the 2010's. The gene introduction system using laser would yield certain results by 2010 and it can be expected that the full-scale clinical application would begin in the 2010's.

There are also possibilities for hybrid laser treatment research combines with genetic treatment to make progress. In the latter half of 2010's and in the 2020's, the low-invasive treatment technology of cancer will be established. The expectation is high, therefore, for bringing complete cure on progressive cancer, improving the quality of life of patients, and promotion of returning to normal social life.

The treatment technology taken up here would also be powerful weapons for treatment of other illnesses other than cancers. Not to mention the genetic treatment but also the photodynamic treatment is widely applied to treatments of arteriosclerosis, brain tumors, infectious diseases, and traumas and various other illnesses.

3.3.11 New optical diagnosis opened up by optical coherent tomography (OCT)

- Toward the creation of the second-generation OCT -

(1) Progress of tomography imaging technology and OCT

In recent years in medical diagnosis, tomography is often used for diagnosing the affected body parts. This means that the three-dimensional images are used for diagnosis. In the clinical areas, the imaging technology using optical tomography is still high. This is due to the following reasons: the photon energy of visible light/near-ultra-red ray is about 1/100,000 of the X-ray, which makes the light a strong tool for providing non-invasive diagnostic tool; by the use of the near-ultra-red ray, it is possible to measure the oxygen metabolism in the blood; extremely high resolution tomography imaging can be expected; and optical medical equipment is easy to use and low price.

The optical coherence tomography (OCT) utilizing low-coherence optical interference is extremely easy-to-use optical apparatus and it is possible to obtain tomography images of about 50 or so μm spatial resolution at the percutaneous depth of two or three millimeter. Since OCT uses simple imaging optics, there is no need for image re-composition technology. At the same time, OCT is an tomography technology tapping into the good characteristics of light. It is, therefore, a major technology supporting optical diagnosis into the near future.

(2) Current status of OCT

Of all the parts of our body, eye has the highest penetrability of light. It was as early as 1996 when the first practical OCT for ophthalmology use was developed. Using the OCT, it is possible to directly view the cross-section of retina, and height and width of the detachment can be accurately diagnosed.

Including the diagnosis of skin cancer, early diagnosis of percutaneous cancers through uses of OCT is expected. In Japan, the number of annual cancer patients is 190,000 and 40 percent of them are cancers of the digestive system. The application of OCT on the digestive and blood vessel surgery is called endoscopic OCT and it is a key technology in OCT for fields other than ophthalmology and dermatology. In addition, OCT diagnosis is examined for use in uterine cancers and prostate cancers.

(3) Toward the second generation OCT

The most representative of the first generation OCT has been its ophthalmological diagnosis. Its optical reach of depth is a little less than 1 mm with the wavelength of 0.8 μm band and its spatial resolution is 10 μm or larger. In comparison, the second generation OCT would have as the goal the wave length of 1.3/1.5 μm bandwidth and the optical reach of depth is 5mm ore more. Its spatial resolution is 1 μm and has the high-speed data reading exceeding the video rate. The aim is building three-dimensional images by stacking the OCT. As the light source, the super-continuum light, using photonic crystal fibers and synthetic light source of fiber ASE, and thermal light source of halogen lams are conceivable. From the point of view of practical use, the synthetic light source combining fiber ASE with different wavelength may be most favorable. It is expected that by 2010, OCT for practical uses will be manufactured. The most difficult task is improvement on optical reach depth. In the current condition, in the 1.3/1.5 μm wavelength bandwidth, the optical reach depth if 3mm is the limit. We hope to achieve the optical reach depth exceeding 5mm for practical uses by 2015. In this manner, the second generation OCT will be realized with the goal year of 2015 with the general purpose characteristics comparable to the supersonic echo. This will contribute to progress in the clinical area as the diagnostic technology.

3.4 Nano-photonics key technology area

3.4.1 Perspectives of the nano-photonics devices

- with the emphasis on the quantum dot devices -

As the key technologies in information networks, broadband, wireless, display, and storage technologies are very important. In technological innovations of these, the expectation is that the nanotechnology would play key roles. The nanotechnology is positioned as one of the four emphasis areas of scientific technologies by the Japanese Government and it is expected to be the bases of the other three. The information technology based on the nanotechnology us varied, from the targets that can be realized in the comparatively near future to those with long-term goals such as quantum info-communication and quantum computing technology.

The concept of quantum dot hetero-structure that three-dimensionally seal up electrons which is called "quantum dots," have been proposed in 1982 as an application to laser. In the proposed concept of 1982, it has been indicated that, by lowering the degree of freedom of electrons, the threshold current temperature dependency can be largely contained. The temperature does not change the gain characteristics and, as a result, the threshold current is made constant.

In the quantum dot area, quantum dot laser, quantum dot optical amplifier, quantum dot nonlinearity devices, and quantum dot light detectors are about to emerge into the real world. The expectations are high for optical circuit of the optical router and the like which will be the basic component of the router in the future photonic network and quantum dot amplifier for application to optical 3R relay. In the quantum cryptography communication, it is necessary to distribute open key cryptography and, for this distribution, the single photon

generator will play a key role. The expectation is that the quantum dot be used for this single photon generator. The expectation is also high for the realization of nano-photonics based on the new principle. In laser, the interaction between the electrons and photons plays an essential role. The nano-photonic element is an ultimate element that uses strongly connected condition of the light and electron that include the polariton laser.

It is considered that the molecular elements, the extremity of quantum dot, will also play an important role. On the other hand, in the LSI, quantum dot is also expected to play important roles in the memory with the basic component of single electron transistor and super-low power consumption element. There is no doubt, however, silicon will be the core in 20 years from today.

From the points of view of national strategies, investment in nanotechnology should lead to realization of low energy consumption society and promotion of health of the people of Japan. At the same time, it should also bring about stronger international competitiveness of Japanese industries and increases in the employment opportunities in Japan. There has been a long history of basic development in the nanotechnology and we need to be emphasizing the technology by tapping into the technological accumulation. The nanotechnology should be applied to info-communication technology first. The expectation is that, thereafter, the technology should be applied to devices tapping into the characteristics of new nano-materials such as organic flexible elements and molecule elements. There will come an age when nano-photonic elements will play the key roles including the fusion of quantum dot and photonic crystal. The quantum dot will be the basic component of future quantum computing elements in the future and expectations are very large for emergence of new “non-continuous” technology based on the quantum dot technology.

3.4.2 Photonic crystal

- Real possibilities of freely controlling the light -

The photonic crystal is an optical material that possesses the refractive index distribution of the cycle of light's wavelength. By introducing various faults into the photonic crystal, the propagation, curbing, and trapping of lights will be made possible, which will make it possible for us to freely control the light.

(a) super-minute optical guide way] (linear fault):

In 2001m the propagation loss per 1mm was 4dB/mm and this was cut to 0.6dB/mm in 2004. In several years, it would be possible to go down below 0.1dB/mm.

(b) 120°curving guide qay (curve line fault):

The grid shape in the curve section is gradually changed and, by conducting optimum design, in as wide a range as 200 nm, the possibilities of curving has been indicated with extremely low loss.

(c) High Q optical nano resonator (dot fault):

During 2000 and 2001, the Q-value of the dot fault was about 1,000 or so but in 2004, the value even reached 100,000.

(d) Internal hetero structure:

By making the grid constant differences of hetero structure extremely small, the group speed of the light propagating in the guide way can be changed gradually and the expectation is that development of optical delay element may become possible.

(e) Tuning:

The light can be sealed up in an extremely small area and the expectation is that, using much smaller power than before, it may become possible to realize non-linear effect of light.

(f) Countermeasures for polarization dependency:

It has been proposed that, by making the air hole shape triangular, it is possible to form the band-gap in TM-like modes. This is called the secondary complete band-gap structure, which is currently being proved.

(g) Connection with the outside:

As far as connection with the outside of the photonic crystal, in 2004, low-loss connection of 0.5dB was made. By expanding the mode fields one by one from the photonic crystal to, optical capillaries, it is considered that connection with optical fibers would become possible without losses in the main.

During the past several years, the element technologies of operation and control of light in the minute areas of the photonic crystals have been steadily proved and, in the future, these will be developed into optical-electronic fusion circuits with such functions as light switching and tuning functions and optical display functions. The expectation is that these will be developed as an optical-electronic chip with all light in the main section with electronics in the control. The size and power consumption of such a chip would be two to three digits small than the current one. At the same time, the progress will be made into super-compact wavelength multiplexing light source, super-high sensitivity sensor and optical memory function that utilize high Q, and development into the next-generation communication light sources such as single photon light source. The fusion of photonic crystal with organic EL and blue LED, which will be developed into high efficiency optical diode and displays. In 10 years, the manufacturing technology of three-dimensional crystals will be improved and the “control of locus,” which is difficult in two-dimension, will be made possible. It is believed that there will be various attempts at development, which would make new controls on light possible.

3.4.3 Nano-photonics

- Paradigm shifts In optical technology -

(1) Introduction

Due to the progress in conventional optical technology, by the refraction limits of the light waves, the limit of smaller size, large capacity, and high speed are nearing. The definition of nano-photonics that would resolve this problem is the “new technology that would realize nano-size optical device, optical process and optical system that overcome the refraction limit of the light by energy transportation of the optical energy in the ambient areas.”

(2) Target timing

Practical large capacity optical memory technology using nano-photonics, optical processing of nano-size, and development of optical device in nano-size have already started. When considering the application development into measurement evaluation and bio-interfaces, the new industry and markets will be started in 2010 and, by 2020, it is estimated that the domestic production amount would reach 26 trillion yen.

(3) Future perspectives

Not only will most of the optical technologies be replaced by nano-photonics, the applications that were not possible with the conventional optical technologies will be made possible. The products and systems with high industrial and social interests are large-capacity optical memory, super-high density and speed optical devices for optical communication, photo-computer, nano-optical processing device, nano-optical measurement and analysis

system and bio-chips.

(4) Resolving global and social problems

The directions of the technological development of nano-photonics are examined in terms of need-like viewpoints as well as seeds-like view points. The goals are key technologies in 2010 and 2020 that would support: (1) improvement in the quality of life; (2) improvement in the healthy age; (3) environmental protection; and (4) borderless society.

(5) Realization of innovative new functions

The removal of short-wavelength light sources in the nano-optical processing apparatus is a paradigm shift that has been realized by using the essence of nano-photonics. Due to this, there is a possibility that laser and ultra-violet light sources would not be essential for the future optical technology.

(6) What is important in terms of national strategy

The nano-photonics is a concept and technology that originated in Japan. The development of related technology, however, has started in the United States and other countries. These include: HAMR project for large capacity memory; development plan for new optical devices and systems by fusion of optical and nano-technology at DARPA; the fourth regenerative medical project at NIH. They are aiming at large-scale market development after 2010.

(7) Elements that promote making technologies practical

As the interests in nano-photonics heighten, individual technological developments are in progress in various industries. The Ministry of Economy and Trade and Industry is conducting a project on development of large-capacity memory that go from 2002 through 2005. There are also major movements in making processing and devices practical.

(8) Afterwords

The essence of nano-photonics is realization and operation of devices that are not possible with conventional technologies. In order to realize the paradigm shifts in optical technology, it would be also necessary to have paradigm shifts in technological development, industry-government-academia coordination, intellectual property management, and business model building.

3.4.4 Optical micro-electro mechanical system (MEMS)

- Perspectives for 2015 and Afterwords -

(1) Display MEMS

The optical MEMS is the field in MEMS that have been viewed favorably. The micro-mirror array used in projector displays are the special success example in MEMS. At the same time, it is a very unique optical device. In the next 10 years, however, there will be MEMS displays with other methods. The demands for larger and brighter projection displays are strong, and in 10 years, new MEMS displays of projection types will be made practical. The expectation is also high for paper-like displays (e-paper) and, in 10 years, e-paper will be developed by MEMS technology and will be in wide use.

(2) Optical communication MEMS

In the MEMS for optical communication, in the next 10 years, the following will be made practical one after the other: optical switch, variable optical reducer, ADD/DROP module that combine these, laser light source with

variable wavelength, optical detector with variable wavelength selection, etc. These would be used widely in 10 years. At the same time, new optical communication system will emerge by fusing optical guide way device and MEMS in 10 years.

(3) Optical MEMS in the nano-technology field

There are expectations for introduction of MEMS technology for making the disk head lighter in optical disks. At the same time, in order to realize nano-level tracking, MEMS actuator will be suitable. The MEMS technology can also be used for micro-lens and light detection optics. In 10 years, the current optical disks will be replaced by man-made card-size micro-optical disks. In order to further increase the recording density, technologies to make the methods for utilizing optical technology in ambient areas practical will be researched actively. This is considered to be developed into new technologies that would be called optical MEMS technology in ambient areas. At the same time, nano-technology and bio-technology would have become keys for industrial development in 10 years. In both of these areas, MEMS technology will be indispensable. In this regard, bio-optical MEMS will be widely used in the medical field.

(4) Optical MEMS of environment and social systems

Compact optical analysis sensors are required in the areas of environmental measurement and food inspections. In 10 years, chemical compound semiconductor light source and silicon MEMS will be fused and this will be widely used as intelligent optical sensor in the ubiquitous network society. At the same time, micro optical sensor/optical communication system (micro-dust) placed within the living space of the people will be proliferated in 10 years. Micro-dust will be able to provide free-space optical communication functions anywhere and the internet-connection in 10 years will be optical communication and 10 GB/second-level communication can be ubiquitously utilized.

(5) Afterwords

In general, if the optical device can be equipped with variable mechanism, devices with flexibility can be realized. In order to control light, it would not be necessary to require large energy output from MEMS. For this reason, the congeniality between the light and MEMS is very good and optical MEMS will be most actively used in 10 years.

3.4.5 Femtosecond laser processing

- Application technology that use super-high-speed physical control -

Laser pulse with of extremely short time of 100 femtosecond has been realized and a new application areas is about to make a progress. When the pulse width becomes smaller than 1 picosecond, the expectation is that processing and none-thermal processing using multiple photon absorption will be made possible. It would also become possible to pick up electrons from atoms and molecules using the electric field of laser with the peak strength improved. Where the pulse energy is low, new measurement technology using super-high-speed and wider ranges.

(1) Surface processing

In the near future, by about 2010, an application that can be made practical in the industrial field of the femtosecond laser pulses will be the surface processing using abrasion.

(a) Controllable abrasion

In addition to metals, using controllable abrasion, it is possible to conduct foreseeable processing on ceramics and semiconductors through fitting functions.

(b) Nano-cyclic structure

When radiating a sample with femtosecond laser near the processing threshold, the cyclic structure formation has been observed and its cycle is shorter than the laser wavelength. By simply sweeping the spots on the target, diffraction grating-like structure can be created in a large area.

(c) Nano particle generation

Nano particle is generated when targeting metals, alloys, and semiconductors with the laser and, if the characteristics of nano particles are elucidated in the future, it is expected that interesting applications can be developed.

(2) Internal three-dimensional processing

One of the applications that can be expected at around 2010 is the high-density optical memory. The recording limit with this memory is estimated to be about $10\text{Tbit}/\text{cm}^3$. Since it can be used with multiple values, which could lead to improvements in increased density. As far as the device for next generation communication devices are concerned, three-dimensional photonic crystal is one of the most favored materials. The photonic crystal can be evolved into optical guide ways and optical integrated circuit and the expectation is high for it to be used widely into communication areas even before 2010.

(3) Semiconductor annealing

When and if a semiconductor behaves like a metal without grating changes, in the latter half of 2010's, this could be developed into femtosecond switching technology.

(4) Medical use of laser or application of laser on human body

One of the applications of the femtosecond laser is in the surgery in medicine, since surgical procedure can be performed without affecting the surrounding tissues when femtosecond laser is used. In dentistry, femtosecond laser is already used for treating cavities selectively by the absorption differences of laser lights. Also, it is becoming possible to introduce DNA using femtosecond laser without destroying the cell structure. This method would be also useful for evaluating the functions of genes. Without using, mechanical, electrical and chemical methods, the method to introduce 's with the laser would bring about progress in new area such as genetic treatment and DNA vaccine, and this technology is expected to be an indispensable technology for treatments using genetic engineering in the middle of 2010's,

(5) Roadmap for the femtosecond optical processing

It is expected that, in the 2010's, due to progress made in surface processing and internal processing technologies by femtosecond pulses, nano devices and quantum computing would be realized.

3.4.6 Light pulse electrical field manipulation technology

- New application through higher precision on light sources -- from the standards to material manipulation -

(1) Outline of the technology

In the extremely short-pulse laser, the shortest pulse record is on the 3 femtoseconds level and the pulse width becomes close to the light wave oscillation cycles and new development as light has emerged. In the most

recent super-short pulse laser research, the methods to detect and manipulate the carrier envelope pulses (CEP) is conceived and the technology to manipulate the light's electrical field waveform within the pulse is being pioneered.

(2) Application areas

This technology is, ideally, the technology to manipulate the oscillation electric field of the light wave on the level of the electromagnetic levels handled in electronics, and the expectation is for new application development using this characteristic.

(a) Frequency areas

As an early application, there is expectation for utilization method as light wave frequency com, which can be used as the measurement tool for communication uses. There is a possibility for it to contribute to verification experiments of basic theories through precision physical amount measurement in the future. In addition, precision control and measurement would lead to positioning accuracy improvement in the GPS.

(b) Time area

This technology will be useful for applications that require adjustments of precision timing of pulses.

(c) Further expected applications in the future

Recently, observations have been made that CEP effect occurs at the time of electron generation from the solid photoelectric surfaces. This has possibilities for bringing new developments in the research of materials and devices.

(3) Timing, effects, and significance of the practical application of the technology

By about 2010, laser systems maintained and managed by specialists will take place at universities and research organizations and these will be used for material science research and systems combined with accelerators. Then, by 2015 or so, research level images will be made clear on how to use light pulses on which electrical fields were manipulated. The movements for more wider proliferation will become full-scale at about 2010 or later. Judging from the trends of current femtosecond laser, introduction will be made into processing equipment and medical use-related equipment. This technology will be used, in conjunction with the super-high-speed device technology, for super-high-speed optical networks. At the same time, the technology will be used in processing and treatment which utilize super-short pulse lights or for making technology more precise and highly functional in technologies of laser plasma light sources. In short, the technology will make wide contribution in making the applications of optical energy into higher level.

3.4.7 Organic and non-organic nano composite optical material

- **With the emphases on realization of high-performance optical communication parts and high-definition image capturing elements -**

(1) Introduction

The refraction changes caused by temperature changes exerts unfavorable effects on optical performances related deeply with definition of images and signal processing capabilities. The demands are getting stronger, for this reason, for transparent macromolecular materials which has a very small or zero changes in refraction ratio due to temperature changes.

(2) Organic and non-organic composite optical materials

In recent years, the material synthesis of nanometer size has been made possible. The dielectric characteristics of organic and non-organic composite optical materials that form sea island structure by uniformly diffused without nm-size minute particle agglutinating can be written by the Maxwell-Garnett model.

(3) Realization of optical athermal characteristic

As an application of the Maxwell-Garnett model, making of refraction ratio non-dependant on temperature changes (a thermal characteristics). Among polymer material, as the temperature rises the refraction ratio comes down, almost without any exception. Among the non-organic materials, however, some are known to have higher refraction ratio as the temperature rises, due to distortions of the crystal grating. If such substances can be distributed in nm sizes, it can be surmised that it is possible to compensate for the lower refraction ratio in line with the temperature rises in the matrix resin.

(4) Athermalization of optical materials and its advantages

In general, the thermal change ratio of polymer materials is on the order of $10^{-4}/\square$ and it is larger by one digit compared to many non-organic materials. If the material itself can be made athermal, it would be possible to tap into the excellent forming and processing and economic characteristics of polymer materials.

(5) Application areas and industrial effects of athermal optical materials

The use of athermal optical materials will be quickly made practical in the private sector digital equipment area. On the other hand, the athermal optical materials could proliferate as materials for minute optical parts for optical communication. Expectation is high for them to contribute to reduction of system costs in optical communication network. By about 2015, the possibilities are high for low-cost high-performance devices based on athermal optical materials could be made practical.

(6) Future tasks

In order to make this technology quickly reach the practical level, close coordination between material science engineers and optical application engineers will be indispensable.

(7) Summary : Expectation for further development of organic/non-organic nano-composite optical material

There is an unfathomable significance of the fact that the width of creation of nano-composite materials has been widened greatly. On the other hand, there are well-known effects other than optical characteristics. It has long been practically used for improving heat durability, lowering hardening contraction ratio and effects for improving mechanical strength. Such effects would promote proliferation of polymer material-base precision optical parts. From these points of view, it is possible to say that, not only limited to athermal optical materials, but other organic/non-organic nano-composite optical material also have major potential to make major growth as future trunk optical materials.

Chapter 4 Toward further growth of the optoelectronics industry

Introduction

In section 4.1, the perspectives for the domestic production volume are indicated. Following that, in Section 4.2, some of the contributors from the Future Vision Planning Committee wrote on elements that would contribute to mid- and long-term development of optoelectronic industry and its further perspectives. In the last section,

Section 4.3, mid- and long-term growth factors and prospects of the optoelectronics industry are summarized based on the report as a whole. In addition, a proposing strategy for promoting the optoelectronics industry is wrapped up.

4.1 Perspectives on the domestic production volume

The domestic production volumes of fiscal years 2010 and 2015 are estimated in this section, based on the fiscal 2002 data of the domestic production volume of the optoelectronics industry in “Optoelectronics industry trend survey report” by OITDA and considering the market sizes of the optoelectronics industry in 2010 and 2015 which are forecasted in Chapter 2.

4.1.1 Comparisons between “the trend survey report and Chapter 2 as for the field categories of the optoelectronics Industry

In the survey conducted by OITDA on the domestic production volumes, the survey was conducted on two categories of optical equipment/apparatus and optical devices. The optical equipment/apparatus was categorized into the following six fields: (1) info-communications (optical transmission equipment/apparatus), (2) information recording (optical desk), (3) display, (4) input & output equipment, (5) energy (laser processing: laser application production equipment, laser for medical use), and (6) sensing/measurement (optical sensing equipment, optical measurement apparatus). The devices were categorized into the following fields: light emitting/light receiving device, optical fiber, solar cell, display device, etc. On the other hand, in this Future Vision report, the estimates on market sizes in Chapter 2 used systems as a unit and has the following eight categories: a) info-communications, b) optical memory, c) display/lighting, d) input & output, e) processing, f) optical energy (solar energy power generation), g) environment/sensing (including optical catalysis), and h) medical care/welfare.

4.1.2 Estimate of the domestic production volume

According to Chapter 2, the size of optoelectronic market of the whole world was 29.0 trillion yen in 2002 (5.4 trillion yen of this was for the Japanese market). On the other hand, according to the Trends in Optoelectronic survey by this Association, the actual domestic production was 6.2 trillion yen in 2002. Then, what would be the domestic production values for 2010 and 2015? In order to estimate this amount, the following assumptions were made:

- (a) The growth of the domestic production value would be in line with the world market growth rate.
- (b) Based on the trends for further progressing globalization, the increase portion of overseas production should be compensated.

Of these two assumptions, (1) is indicated in Chapter 2 and, for 2002 through 2010 is 10.9% and 2002 through 2015 is 12.1%. As for (2), The Manufacturing White Paper by the Ministry of Economy, Trade, and Industry states that, for 2002, average of all industry was 17.1% and, in the past 10 years, there has been approximately 10% increase. Based on this trend, the ratio of overseas production for 2010 is assumed to be 25% and that for 2015 30%.

With the base point of domestic production value in FY 2002, and in line with the above (1) and (2), based on the annual growth rate of optoelectronic products in the world market and estimates of overseas production ratio, the estimates of domestic production values for 2010 and 2015 have been calculated and the results are shown in table 4.1.2.2 and Figure 4.1.2.1.

Table 4.1.2.2 Estimate domestic production values for FY 2010 and 2015

FY	Domestic Production Volume	Annual Average Growth Rate	Remarks (Compensation factor)
2002	6.2 trillion yen	—	—
2010	12.7 trillion yen (Existing: 10.1 New: 2.6)	9.5%	$(100-25)/(100-17.1)=0.90$
2015	23.0 trillion yen (Existing: 14.7 , New: 8.3)	10.7%	$(100-30)/(100-17.1)=0.84$

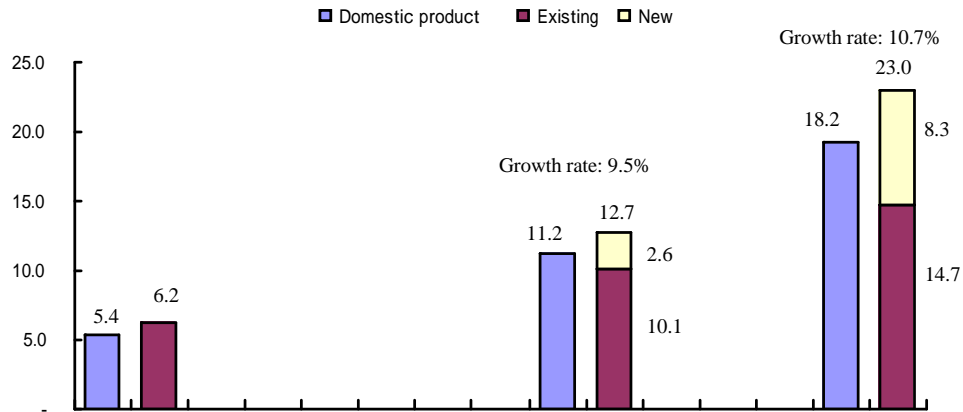


Figure 4.1.2.1 Estimates of domestic production for 2010 and 2015 and Japan market

The figure 4.1.2.2 shows the trends of domestic production in graphs since the beginning of Trends survey (1980) and the above estimate figures for 2010 and 2015.

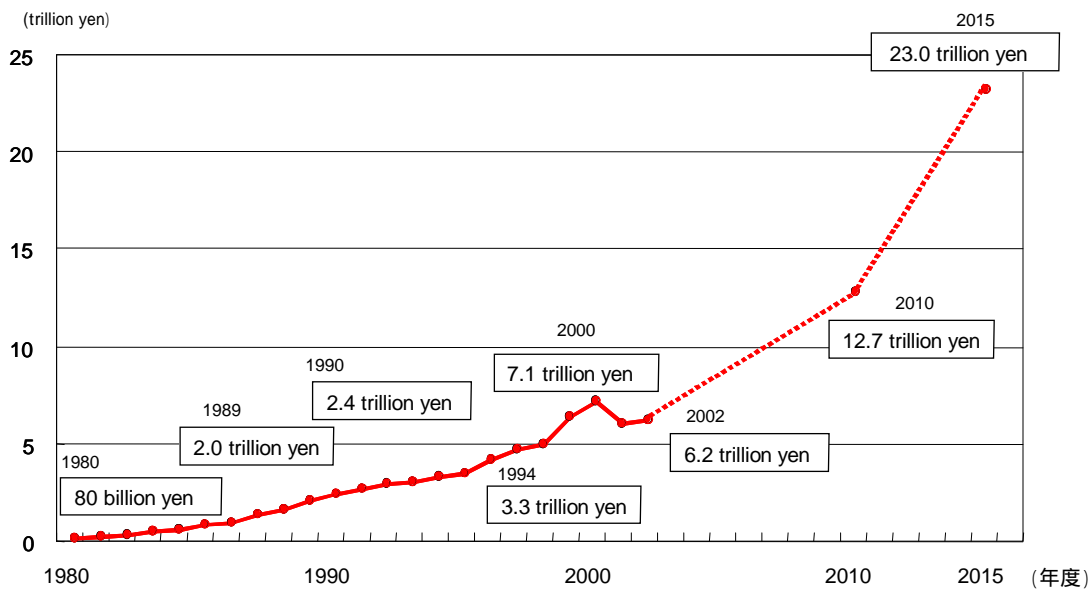


Figure 4.1.2.2 Transition of domestic production (existing and new)

In addition, the breakdown of estimated domestic production values is shown in Figure 4.1.2.3 for different fields in Trends survey (optoelectronic equipment/apparatus in six fields (1) – (6) plus (7) solar battery: total of seven fields.)

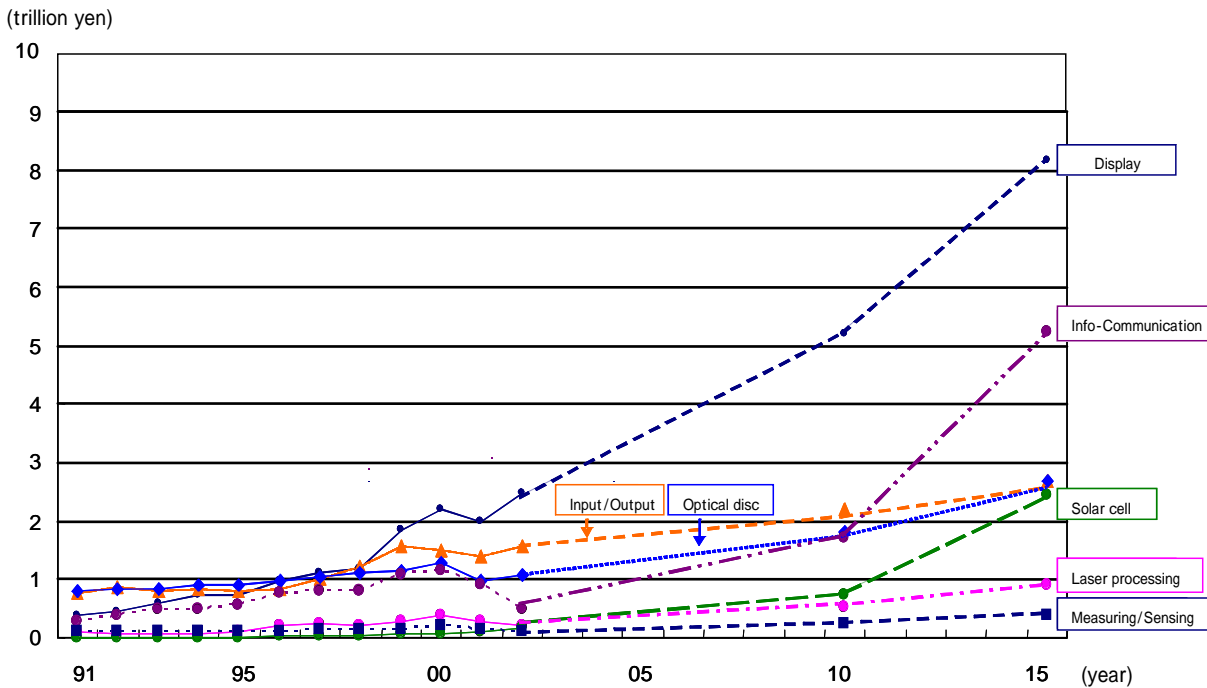


Figure 4.1.2.3 breakdown of estimated domestic production volumes

4.2 Mid- and long-term growth factors and prospects of the optoelectronics industry

4.2.1 Optoelectronics industry to be the key player in next stage economic growth

The Kondratieff's wave is an expression of major waves in changes of economic trend and recent upward trend has been supported by electronics. Until about 1960, the Kondratieff's wave was driven by automobile and chemical industries in the main. This was followed by the waves of electronic wave, which started about 1950. After 1950, the growth industry was electronics driven. The growth of electronics, however, will end about 2005 and it is estimated to be followed by a new wave, which can be called "wave of intellectual property." One of the important technologies to support the new wave is the new optoelectronic technology.

The optoelectronic technology has been developed as the breakthrough technology of the telecommunication technology using electronics. The characteristic of the light used at that point was that of the short wavelength of light. In the wavelength multiplexing technology, however, a characteristic possessed only by light is used and that is the fact that many wavelengths can be multiplexed on one fiber. In the age of electronics the optical communication technology proliferated with the trunk networks in the main. In the future, however, this will extend to homes and broadband information routes will be provided. The optical communication in the electronic communication age used optical technology in part of the elements that comprised the communication system. In the future, in contrast, majority of the elements that comprise the system will be using optical technology.

Providing information routes to homes and evolution of optical communication system itself would greatly contribute to the growth of new knowledge-based economy, which would be the driving force behind the

long-term wave that would follow the electronic wave.

The new optoelectronic technology is bound to give major impacts to other areas. In the semiconductor area, the new light sources will reach practical level that will make further minute processing possible. In the energy and environment areas, widespread use of optical catalysts and practical uses of new types of solar batteries are expected. In the human genome plan, in the analyses of basic arrangement that comprise the DNA optical technology has been used. In the future, active use of optoelectronic technologies will progress in the sustained manner in the bio-medical fields.

In the next generation, long waves are expected to show characteristic of being optoelectronic driven. By high-level utilization of “light” as resources will enrich security, safety, and comfortableness and that is considered to realize sustained growth, which will lead to the next 50 years of the Kondratieff’s wave.

4.2.2 Expectations for the optoelectronic industry

In the metropolitan Tokyo area, most of the traffic signals now use LED lights. LED lights have 100 times longer life compared to conventional light bulbs and they are groups or mass of semiconductors. Therefore, even if one of the LED’s fail, the functions as signals are maintained. That means, maintenance work is less necessary for LED lights. On top of that, electric power consumption is about one eighth of the light bulb. The LED signal lights, therefore, are excellent signal light materials.

New markets are being created for LED’s one after the other: various lights used for automobiles: buttons of vending machines: and flash lights for mobile phones with cameras. The major uses of LED, however, will be at home and offices. LED’s that emit natural light-like rays have already been developed. In Japan, the 15% of electric power consumption is said to be for lighting. If all the lights can be replaced by LED’s, the energy consumption for this will be reduced to one eighth. Proliferation of LED lighting, therefore, could be the savior for “Japan without energy resources.”

Software needed for tapping into new functions

The optical circuits that come to exist may not necessarily be used to tap into their fullest capabilities. The hardware technologies are developed one after the other, but the software is not catching up with them. The software may not be provided with the hardware and it may come as the users put the hardware to work. When a million Mbps optical circuit goes into home, there may have developed services that have been inconceivable before.

The same can be said about the LED lighting. LED’s can emit any kind of colors and they can be very compact. The colors emitted by LED’s are vivid. When the equipment using LED’s proliferate to wide areas and many lighting designers and architects take the equipment into their hands, there will be unexpected new ways of utilization created.

Many of the manufacturing industry is coming back to Japan

The domestic production amount of optoelectronics industry in 2015 is estimated to be 23.3 trillion yen. What would happened to this amount when some epoch-making inventions of software is added to that? Japan is leading the rest of the world in many elemental technologies that support the optical industry: optical fiber, LED, optical switch, optical displays, etc. The level of proliferation of optical circuits in Japan is one of the highest in the world. These situation should be utilized to the fullest extent. As can be evidence by the Japanese animations that are very

popular the world over, the competitiveness of Japan is being improved. Therefore, epoch-making ideas in the use of optoelectronic technologies may be and can be created.

The manufacturing industry that went overseas from Japan are beginning to come back. The intention behind the moves is that of keeping the competitive core technologies in Japan and using them as the driving force behind corporate growth. The legal systems in Japan, such as corporate law, anti-monopoly law, principles of corporate accounting, labor law, and tax systems, shifted in the direction of supporting corporations within the past 10 years. When a corporation succeeds in achieving “selection and concentration,” it can grow within Japan and the environment for it is being developed and improved. Under such circumstances, the key to success will be the future possibilities and development potentials of the technologies selected as the keys for them. The optoelectronic technologies are in fact such technologies. There is nothing more joyous than to see Japanese economy reviving its splendor in the first half of the 21st Century.

4.2.3 Awareness of being the core industry in the age of post-industrial capitalism

In the post-industrial capitalism, the major industries are information industry, software industry, creative industry, and cultural and entertainment industry. In such a new economy, the optoelectronic industry is a major industry, since it is a trunk technology for building networks. On top of that, the optoelectronic industry is an industry necessary for her software-like products. The optoelectronic industry is, furthermore, technology that is absolutely necessary for selling the products, as with the network retailers. Using the optoelectronic technology, products are manufactured and, with the click of a mouse, products can be marketed all over the world. This is the post- post-industrial capitalism economy. And in this economy, the optoelectronic industry is the infrastructure and trunk industry as well.

Creative Economy Initiative

The Blair administration in Britain, beginning with 1998, posted “Creative Economy Initiative” as their slogan and decided to shift toward the “pop industry” as the main industry. Under the Ministry of Culture, Media and Sports, the Creative Industry Taskforce was established which was led by the Ministry of Culture. The task force conceded that the following 13 industries will be the core: (1) computer software, (2) design, (3) publishing, (4) TV and radio, (5) music, (6) movies and video, (7) arts and antique, (8) advertising, (9) architecture, (10) interactive leisure software, (11) design and fashion, (12) performing arts and (13) crafts. Britain was to be the leaders in these areas in EU and the final goal was to be the world leaders.

Britain’s Pop Industry Boom

That total revenue of the creative industry and curriculum was about 22 trillion yen in 2001. This was twice the growth rate of GDP. According to a report by the British government, there are four reasons for the rapid growth. The first is the globalization and internet. The second is quick distribution of the software-like products through the internet. The third is that the created industry can be used as weapons to compete with developing countries. The fourth is the differentiation of corporations in such a way as to revive British industries.

Old industries revived

It has only been five years since the British government started on the development policy for the creative industry. There have been, however, the following effects: the first is “reviving effects of the old industries;” the second is “cultivating work that could bring about riches;” and the third is “effects of local area promotion, which

made Disney and Sony invests in the local areas.”

Thinking about optical technology and optical industry, one is always reminded of the software that are created by them. It can be considered that the true competitiveness is in this creativity power. Japan is considered to be strong in this competitiveness. In the United States, a concept of the gross national cool (GNC) has been proposed. Through the concept, it has been pointed out that the future national power will be initiated in GNC instead of GNP. In fact, that country leading in GNC is Japan and the United States is also strong and yet they have a fear that US would fall behind Japan. Looking from the hardware, software is really the demand. Because of severe demands from the software side, the hardware is developed further. A good example are cellular phones. The most astounding usage was developed in Japan and the digital business culture started in Japan is controlling the rest of the world. Japan’s optoelectronic industry is inherently strong as exemplified by this.

4.2.4 Future of the optoelectronic technology viewed from the Technological Forecast Survey

(1) Introduction

Ever since 1971, the Ministry of Education, Culture, Sports, Science, and Technology has been conducting the Technological Forecast Survey every five years or so. The 7th Technological Forecasts Survey was publicized in 2001. The technologies related to this report will be picked up from the survey in order to provide the overview of the optoelectronic technologies of the future.

(2) Optoelectronic technology seen in the Technological Forecast Survey

The Technological Forecasts Survey has as subjects 1085 technologies but, as optoelectronic related technologies, 62 are taken up here. By sorting out these according to the field categories of the Future Vision, relatively many of them relate to telecommunication, display/lighting, optical energy, and laser-related technologies. This means that, when viewing through the period to 2030, these areas have the potentials for giving major impacts to the society, economy, and our daily life. It is, therefore, important for the industry to cope with these areas.

(3) The realization timings of the technologies

Of the 62 technologies, 35 of them are expected to be realized by 2015. The rest of the 27 technologies are forecast to be realized by 2016 or afterwards. Among the former, no integrative characteristics are found, but among those that have been forecast to be realized later, some trends can be seen. One of them is that, among optical energy related technologies, super-high conversion rate solar battery, production using sunlight, and the sunlight electric power generation in space are forecast to be realized about 2020 or later. At the same time, realization are forecast for optical integrated circuits in the telecommunication area and the artificial vision technology in the medical/welfare area also at about 2020 or later. It means that time is needed for these technologies to be realized due to high hurdles in view of the technology. It would be important, therefore, to search for measures to accelerate technological development in these.

(4) Support in terms of political measures

The Technological Forecasts Survey has asked about the effective measures to be taken by the Japanese government in order to promote the technological development for the realization of the technologies. As far as the 62 technologies are concerned, quite naturally, “expansion of research and development funds to be provided by the government” is strongly wanted. For the technologies in the medical/welfare area, fusion of life science and

electronics is hoped for.

(5) Future of optoelectronic technology

Of the 62 optoelectronic-related technologies, when looking at 10 years from today to 2015, or in short-term and medium-term, key technology areas such as the device, network, and material are in the main. On the other hand, medium-term and long-term science and technologies for the period of 2015 afterwards, as keywords from the seeds side, “fusion area,” and “compound area,” and as keywords from the need side, “safe and secure” and “environmentally oriented” are considered to be important. In medium-term and long-term point of view, therefore, efforts in this line would become necessary.

The “fusion area,” and “compound area” signify needs for pioneering new technologies that did not exist before and the production technology using sun light and artificial vision technology, for which later realization timing was forecast, are in these areas. As technologies of “safe and secure” and “environmentally oriented” solar battery-related technologies and the like can be named.

4.2.5 Environment/security and optoelectronic industry

Civilization and environmental problems

In the global society of the 21st century, both in terms of local areas and on the global environmental level, we will be facing the great problems of environmental changes. By placing measures against change elements that are related to humans and grappling with improvements on natural environments, expectations are that new industrial areas will be developed.

Environmental measurements and optoelectronics

Measurements and analysis concerning spectrum information on materials are important in grappling with environmental problems, and as an industrial frontier where pioneering aspects are strong, the expectations are high as future prospective areas. Optical sensors excel in anti-explosion characteristics and, at the same time, expectations for them are high in that they have good qualities beyond the conventional electronic sensors and mechanical sensors. What is indispensable in improving system qualities of the environmental measurements is the fusion with network technology. As the development and improvements on environmental measurement and the standardization make progress, along with the development and improvements of the ubiquitous network, rapid growth of the optical sensor markets can be expected. In the future, along with the communication technologies as the backbone, we can expect that sensing technology using optical waves will show growth as major pillar.

Sunlight as clean energy

It can be expected that there will be major shifts toward the utilization of natural energy in the 21st century. Among these natural energies, the solar energy electric power generation is the most favored as the clean energy source. In this area, Japan is the technological leader in the world. In the current condition, however, spontaneous growth of the market is not making progress in view of the costs. Among the energy sources of the world in 30 years from now, the ratio of the solar energy power generation will be less than 10 percent and the forecast is that the ratio will not reach 90 percent until the end of the 21st century. The further technological innovation, therefore, will be needed in order to change the forecast.

Security and optoelectronic technology

Surveillance sensors are beginning to be installed in private spaces of individuals. This is not only for the purpose of reacting against invaders from outside but it is also for individual health management and measures for illnesses which include providing cares for the elderly. The needs for securing safety and security on the individual level through surveillance system is getting higher. There will be increased needs in the future for provision of information as entertainment. Along with it, however, environmental surveillance and securing safety would be important. We would want to walk public spaces such as roads in security and we would like to sleep, feeling safe at night. For these, sense of security should be maintained. The information needs will also be strong for safety securing service systems on the individual level such as health management. For these needs, various optical sensing technology can be utilized in conjunction with the networks, such as the image processing. In these regards, therefore, there is no doubt that new markets for optical measurement sensing will not only increase in Japan where there is shrinking birth rate and the aged society will be progressing and also on the global level.

4.2.6 The optoelectronic industry contribution for strengthening of competitiveness

What supports the industrial competitiveness of Japan are innovations. Realizing high-level functions and performances, which are demanded despite higher prices of products and services, are the only source of competitiveness in Japan. What make promotion of innovation and security of competitiveness' possible are advanced technology and industry. Into the period of about 20 years into the future from today, the industries that can maintain competitiveness continuously are: advanced devices, automobiles, and robots. The key technology supporting them are nanotechnology, optical technology, and ubiquitous networks.

Along with nanotechnology and ubiquitous networks, the optical technology remains one of the key technologies and it supports the competitiveness of the above mentioned three industries. At the same time, the optical technology would be applied in these industries as a matter of course. Chapter 3 of this report introduces these topics from various areas, in view of the future of optoelectronics industry as a key technology. The optoelectronics industry, for example, is introduced as the key technology area that relate widely with such fields as an environment, energy, and life sciences.

The first area where there is contribution from the optoelectronic industry is the advanced device industry. Competitive devices used in the optical communication systems have been realized in Japan. One of the achievements in the 1990's have been the devices for wavelength multiplexing. Making the blue LED practical has been a major achievement of the optical industry in Japan. Through development efforts both in the public and private sectors that took a long time, it has become possible for the blue LED's to be used in the lighting area as an advanced device. When LED's are widely proliferated in the lighting area, a major energy conservation effects can be realized. As given as examples for nano-photonics in Chapter 3, there are possibilities for numerous advanced devices to be realized in the future.

Contributions for automobile and Robot industries will be major ones. The optical technology has become one of the cores of competitiveness in these industries. LED's have already been used widely for lighting and display uses. At the same time, optical sensing technology also has already contributed greatly in pursuit of automobile safety and creature safety. It is certain that LED's will promote strengthening of competitiveness of the automobile industry.

Robots are expected to proliferate into scenes that are closely related to our life. Then, what would become

important would be the more advanced interface with people. It can be expected that optoelectronic technologies to be used in display and sensor devices in order to realize that. Networking robots is also sure to progress. In this aspect also, it is certain that optoelectronic technologies will be used often with the communication technology as the representative one. In coping with hazards and in uses for medical field, it would be necessary to: remotely conduct surveillance on the actual scene and feed back the results in real time and to transmit a large amount of information that are needed instantly. The optical technology has the potential for widely coping with such needs.

The devices with high-level functions that cannot be produced in other countries will be automatically in demands from other countries. This kind of condition will be the ideal one, which can be produced by having innovations. The competitiveness of the optoelectronic industry which other countries cannot but recognize will maintain and strengthen competitiveness in many industries such as the automobile and robot industries in Japan.

4.2.7 Optoelectronic industry as measures for coping with hollowing out

Catching up is an effective methods for countries and corporations to develop. When technological developments are not maintained, the countries and corporations are caught up. Then, the hollowing out will progress. In recent years, Japan has been the subject of catching up in many areas. After the 1980's, especially, Japanese corporations have rapidly proceeded to take their production bases outside of Japan in search of less expensive labor and lands. This resulted in accelerating the catch-up by the countries where they went. By transferring technologies to countries that have capabilities for catching up and when the technology is absorbed, these countries quickly caught up with Japan.

A typical example of this can be seen in active matrix-type liquid crystal. In 1994, Japan had more than 80 percent production share in this product. In 2001, however, this came down even to about 50 percent, while at the same time, the production shares in the Asian regions rose to 49 percent. The largest factor in the increased share of the production in the Asian region was the production by the Japanese corporations in the region. In order to produce products that are on the same level as those produced in Japan, it was necessary to provide various guidance with the cooperating companies and employees who will be producing the product. After providing such guidance, the catch-ups began and accelerated. When viewed by the Japanese side, this was the occurrence of hollowing out and its acceleration. Although research and development in the area continued in Japan but the speed of the catch-ups were greater than the progress in Japan. The results were the occurrences of hollowing out.

There are two ways to cope with the progress of hollowing out. One is to maintain and keep important technology within the country. Another is to create new industrial technology in place of the exported technology. In order to make the latter possible, it would be necessary to have many seeds for the future, so-to-speak. In order to do this, we would need a technological area with potentials for producing many seeds that would create new industries. The most representative of such an area is the optical technology. The entire view on this was summarized in the perspectives for the optoelectronic industry and perspectives of the markets. From the telecommunication to medical care/welfare area, or in eight areas, products using numerous new technologies and new markets are considered.

In the optical communication area, where efforts for making the FTTH practical is steadily proceeding, further active uses of optical technology can be foreseen. In order to realize this, developments of new technology and seeds of the industry are proceeded. In the memory area, which is another representative information technology

as with the telecommunication, development is pursued in view of realization of new seeds. The possibilities are significant, in addition to the new seeds created as optical technology, for many seeds to be created by fusion with other technological areas. By the existing or new optical technologies to be transferred to other areas, there emerge multiplication effects for creating new seeds. In nanotechnology, various medical care and biotechnology related developments are pursued and various scenes are conceivable in relation to such developments where optical technology is actively used. Through this development and through fusing with other technologies, the optical technology will produce new seeds for industrial technologies. Through these, there will be effective complementation for hollowing out of industrial technology that will progress by catch-ups from other countries.

4.2.8 A proposal for industrialization of terahertz optics

(1) Introduction

In recent years, the terahertz optics have come into the spotlight. Conventionally, the lights (radio waves) in these frequency bandwidths have not been used very often as it has been difficult to generate and to receive them. In Europe and in the United States, active research is being carried out on the national projects level. There are representative example of applications where dangerous things that are concealed in clothes can be seen. In the United States, safety and security have become the key words and this technology is related to these. In Japan, there are various research in terms of application of the technology, which are in progress. As a technology that is related to safety and security, it would be important to “develop terahertz optics.”

(2) characteristics and utilization of terahertz lights

Terahertz waves are in the border area of “light” and “radio wave” and they have characteristics of both. The optical energy of terahertz waves are only about one millionth compared to X-rays. As an example of applied research using the characteristics are: detection of narcotics, anthrax, plastic bomb, etc. in an envelop; diagnosis of skin cancer; and detection of knives and the like hidden underneath clothing, etc.

It could be that terahertz optics-related products to break out all of a sudden and the markets could become the same sizes as the use of current microwaves and X-rays.

(3) Problems for acceleration of terahertz optics

The reason why terahertz bandwidth has not been utilized is that there has not been ways to generate it in a simple manner. One way to generate the terahertz optics is to radiate the super-short light pulses generated by femtosecond laser on the light conducting antenna. If we could have a simple wideband wavelength variable terahertz light source, the users of terahertz optics would multiply rapidly, accelerating applied research and commercialization.

The next important task, then, is developing key corporations. At present time, it is not possible to compose a system without using overseas product in the core unit. Unless it becomes possible to compose a system with domestic units and products only, competition with foreign corporations will be lost. Not only that, proliferation of the technology among engineers and researchers would not be possible. Since there are many medium-size corporations with excellent technologies, it would be necessary to build environments where advanced technology like terahertz light can be grappled with.

(4) Summary

When we compare the computer world with the current terahertz world, the free electron laser would be the mainframe computers of the past and the femtosecond laser would be the minicomputer. With the emergence of microcomputers, nowadays, we have come to have several computers that have better performance than the old mainframe computers at our own home. There are possibilities for the terahertz optics to have breakthroughs by an epoch-making invention which is like microcomputer. By investing in the research and development in the terahertz-related optics as with the United States and Europe, the research conducted by the forerunners in Japan would be put to use effectively.

4.2.9 Strategic viewpoints for technological development in the optoelectronic industry in the age of structural conversion

The end of high-growth age

The strategy to follow Europe and the United States in the high-growth age in the post-WWII period is gradually coming to an end due to rapid progress in the technological development capabilities among Asian countries. The industries and society in Japan has already entered conditions of structure conversion.

The lifespan of products after WWII period has been actually only about 20 years and the peaks are still coming down. The time needed for development is becoming shorter year after year. The success or failure depends on whether it is possible to create ideas on products and technological development. Many corporations are, through “selection and concentration,” attempting to converge on the themes of in-house development to produce No. 1 products. They are, in fact, searching for opportunities to “promote industry-academia cooperation in order to utilize the research result at universities.”

Changing strategic concepts

The new markets and seeds will be born when we go beyond our imaginations. The most important task lies prior to deciding upon the themes. That is where the individualities and identities of the players come to shine in the brightest manner. Then, once the themes are selected, one just makes efforts to achieve the goal, utilizing all possible tools, ideas, wisdom and labor. New technologies and products will never come from market research only. The creation of these will be achieved by new ideas that are born in the brains and hearts of individuals and teams.

Adaptive power for environmental changes

In the social environments, there could be unexpected changes. When natural calamities attack, the expectations rise toward research for optical industry applications concerning hazard prevention. The expectations are higher now for contributions from the optoelectronic industry against energy crises, terrorism, SARS, energy, safety, and prevention of infectious diseases. Major innovations are asked from the optoelectronic industry in view of info-communication society, shrinking birthrate society, and increasingly borderless society. There are many unforeseeable elements in the changes in the social environment and, in the face of these, what can an industry contribute is asked.

Forecast in the face of uncertainty

It would be difficult to make forecasts, but making forecasts for the sake of themselves, we would be going through the following changes: from mass production to production of single products; from the age of large corporations to personal businesses; from mass media to individual networks; and from the age of organizations vs.

organization to organizations vs. individuals. In overseas markets, a large research project for military use would pull hi-tech single-product production. Japan should play a role of replacing military demands with basic science. The investment in basic science in Japan is still totally lacking. Conventionally, in Japan, mass-production industries took initiatives and hi-tech single-product production has not been Japan's forte.

Industry-academia cooperation and venture businesses

It is most cost effective to transfer results from universities for technological development with high specifications. It would also be necessary to provide supports for developing technologies originating in the universities as venture businesses. For this, drastic deregulations are necessary for faculties at universities and universities as corporative persons. In that regard, deregulation is the key for technological development capabilities in Japan.

4.2.10 Intellectual property strategy of optoelectronic industry

(1) Intellectual property strategy and competition with individuality

In a situation where much manpower is lost from the industries established within a country, and if the high-level know-how in low-technology is being lost, then, the intellectual property strategies would be useful. If this can be called the defensive strategy, then, naturally, the offensive strategies also exist. The values are not found for intellectual property by just possessing. The values for intellectual properties, instead, are created by utilizing them. The intellectual properties themselves would become active by creating intermediary organizations between the organizations and the areas of knowledge, wisdom, know-how, and skills that cannot be separated from individuals and organizations. The cost-management department like management style of intellectual property management in terms of the defense and management of their rights is supposed to be dead by now. Rather, the brains of the corporate management should be instilled with profit-department-like management style.

(2) Increased variety in the intellectual property businesses

The business scenarios of intellectual properties have become much varied during the past several years. The intellectual properties with clear relationships with cash flows are separately made into business as tools of fund raising. The intellectual properties with unclear relationships with cash flows are managed by creating liaison organizations of management with emphasis on profit coefficient. In the information disclosure scenes for IR, the net asset ratio of intellectual property has come to be considered more important. Furthermore, based on the ecological cycle theory of the technological development, the strategic decision of placing the intellectual property produced as the results of research has come to be important. In such trends where intellectual property business is becoming active in full-scale, the optoelectronic industry will be positioned and, it is likely that it has already been so positioned. It should be made clear, therefore, what is the intellectual property strategy as the optoelectronic industry.

(3) Intellectual property strategy as industry and the intermediary organization

When planning to sealing up the value formation process created by certain intellectual properties of the optoelectronic industry within a country, the business comprising elements that become necessary directly and indirectly would create an industrial system by itself. The strategy for maintaining the relationship with this industrial system comprising elements is the intellectual strategy as an industry. When sharing a new invention that was obtained through cooperative research development, the coordination system among industry,

government, and academia will be created. If and when among certain intellectual property strategy and plural number of corporate groups that are in the optoelectronic industry certain differences of benefits emerge, a consortium of intellectual property to avoid the friction will become necessary. (An organization with the managed trust system would be desirable.) The creation of “functions as intermediary organization” within the coordination system among industry, government, and academia would also be the intellectual property of the optoelectronic industry. It would also be necessary to create a system for the corporations to “maintain their existence.”

As for the intellectual property strategy of the attack side, the basic thing would be to build and promote technological topics that have been picked up as technological areas that would bloom in the future. In this, however, the view is needed that technological topics are independent from each other and they are rather coordinated among themselves. Another of the intellectual property strategy of the attack side would be the standardization tasks. In executing “public benefit” and “shared benefit” concerning the intellectual property rights, the posture would be necessary to take a leadership as an industry and it would be important to how to make the concept clear from the intellectual strategy point of view.

In order to promote the intellectual property strategy as an industry, it would be necessary to create and establish intermediary organizations between corporations and the national government and in the coordination system among industry, government, and academia.

4.2.11 The wider-area network that would promote industry-academia coordination

In the past, the broadband telecommunication network has always been the goal to be attained in the past. This has already become part of the social infrastructure. For its realization, the optical technology has played a major role. The optical network is now about to be extended to our homes. From now on, all activities would have as a pre-requisite the existence of networks.

From self-regulation to coordination and cooperation

The forms of corporate organization and the relationship with the customers are, in general, decided by the interaction costs. In this regard, the development of telecommunication networks would lower the information exchange costs with outside of the corporation. This means it would be more advantageous to conduct trades with outside via networks than hold organizations in-house. Networks make outsourcing relatively advantageous and outsourcing would lead to more open systems. In order to ask outside people to do some work, ordering conditions or interfaces need to be indicated to the outside corporation. If there are a plural number of procurement partners and if the contractors begin trading with a plural number of clients, the interface would become de facto standard. Thus, in the network society, from business to research and development, having organizations in-house would be disadvantageous and outsourcing (coordination and cooperation) would become relatively advantageous. The expectations for venture business and industry-academia cooperation have these as the background.

The source of profit in the age of post-industrial capitalism would be the knowledge and information. What creates the knowledge would be, in the end, the exchanges among different and varied organizations and individuals. The effects of drastically reduced cost of interaction through the networks are not limited to cost reduction. Through interaction, coordination and cooperation, the creation of new knowledge is promoted. This is the largest role of the network.

Universities are open platform of meeting and exchange

When viewed from the industry side, why is it necessary to have industry-academia coordination? Why is it that special importance came to be placed on the industry-academia coordination in the European and American societies? An organization in which different and varied people meet with each other and have exchanges and soon they will soon leave the organization. The organization that has this as its inherent function is the university and there are no other organizations like that. If knowledge is born out of inter-exchanges, that would mean the research has been conducted. If the knowledge born is taken in as one's own added value, that would be receiving education. In order to know the future value system, the universities are in privileged positions. It is the university that "would create new knowledge while transcending time." The corporations have the responsibility for providing services to their current customers and if the corporations do not satisfy the customer needs, the corporations will stop existing. Then, the present would be the starting point and development of sustainable technology should be but emphasized. To this, the universities is capable of "viewing the present from the future." The very difference of future value and present values will be the source of profit of the post-industrial capitalism. The university revolution that seeks the source of industrial values in university has the common basis with the essence of the age of post-industrial capitalism.

4.2.12 Expectations for national research and development strategy in the optoelectronic and telecommunication technology

(1) Introduction

The bursting of the IT and telecommunication bubble economy gave a major blow to the optoelectronic and telecommunication industries. The expectation, however, for progress of IT technology is steadily increasing and the roles to be played by the optoelectronic and telecommunication industries in the future are major ones. As the expectations for the strategy of the optoelectronic and telecommunication industries in Japan, the way the national project should be operated is taken up below.

(2) Current status of research and development strategies in Japan, the United States and Europe

When viewing the concrete forms of policies for science and research among major countries, in Japan, based on the 11th Science and Technology Basic Plan, between 2001 and 2005, 24 trillion yen is planed to be used. On the other hand, the federal research and development budget in the United States is extraordinarily large and comes to total of \$127 billion (FY 2004). Especially, after the terrorist attacks on September 11, the budget related to national defense and countermeasures for bio-terrorism have been drastically enlarged. In Europe, the Research and Development Framework Program (FP) is promoted by the entire EU along with individual programs in different countries and the 8th FP (2002 through 2006) is in progress with the budget size of 3.63 billion Euro.

Compared to active investment and grappling with the next generation key technologies in North America and Europe, it is difficult to say that Japan is amply taking the lead. In the future, further coordination among industry, government, and academia should be promoted and it is necessary to build schemes that would aim at technological development which would influence the rest of the world.

(3) Roles and necessity of the national technological strategy

National projects are technological development for carrying out national roles and their goals are development and improvement of key technologies that are necessary for reforms in economic systems, reforms in industrial structure, national policies to establish and build up the nation with technology, and international

industrial competition and cooperation strategy.

(a) Due to emergence of modular-type projects from the United States, the international competitiveness among Japanese corporations was relatively lowered. Promotion of national projects are desired in the hope for formation of business structure that would prevail in competition and introduction of new system and economic principle. The national projects should be established and operated for measures to reform industry and business, which would include market formation and startup of businesses.

(b) Many of the hardware supporting the “broadband networks” and “ubiquitous information society,” are not found in the current technological stocks and new technological development is required. The national projects are expected to play important roles in such position as smooth reallocation of riches and profits to technological investments.

(c) Distribution of risks in national projects are important in the sense of completing the risk balance sheets. In the future, discussions on the next generation research and development in Japan will be necessary. These should distribute and share effective utilization of research and development resources among in-house corporate research, national projects and coordination among industry, government, and academia.

(4) Establishment of technology and project operation

The national projects should always be leaders of reforms and they should not be in any way imitating policies. The emergence of creative national projects would be the power behind making Japan a leader in continual progress and world.

4.2.13 Technological development toward fusion of optical communication and optical information processing

(1) Introduction

The process of introduction of optical technology into communication networks would progress in three phases. The first phase is the “optical transmission system” which uses the optical fiber as the transmission circuit. The second phase is the “optical communication system,” in which switching is conducted while maintaining light, and third phase is the realization of “optical info-communication system,” with the introduction of information processing by the light.

(2) Development of optical transmission system and development of optical communication system

Ever since the optical fibers have been introduced, “optical transmission system” has been smoothly developing and enlarging and it has established itself as the infrastructure for supporting the current advanced information society. In the future, toward the realization of network with the optical technology in the main, the photonic router which is high-speed and large in through-put at the same time will be put to practical use. This will be then developed into the “optical communication system” in which optical transmission and optical switching have been fused. These are the important tasks for the next several years.

(3) Toward the realization of optical information system

(a) Outline of the optical communication system

In the third phase “optical info-communication system,” the section that have been relying on electronic processing will be replaced by optical processing and the system is highly functional by tapping into high speed characteristics of light and super-parallel processing characteristics.

(b) Optical signal processing device technology

The example of devices that have optical signal processing are: optical amplification device, wide-bandwidth and high-speed wavelength conversion element, optical bi-directional stabilizing element, large-scale optical space switch, various filters such as optical noise filter, rectifying and compacting device for optical pulse, optical buffer memory, etc. It is essential to combine and integrate these elements.

(c) Grappling for realization

Realizing these technologies within about a span of 10 years is not easy. In the “optical transmission system,” since the excellent functions “that are only possible with light” have been used, the system has been made into a practical one in line with the necessity to do so. In the “optical communication system” and the “optical info-communication system” functions “that are only possible with light” are not yet clearly visible. In order to have a breakthrough on this dilemma, a national project that would combine the industry, government, and academia as a synthesis would be proposed. This project is largely consisted of two project groups. The first group is consisted of a plural number of project groups for realizing functions “that are possible only with light.” The initiative is taken by the academia with participation from government. The researchers working on the most advanced area would take part from the academia and government. In the second project group, researchers from industry and government and part of academia would participate and they would work to integrate the above-mentioned new functional devices and system proposal into practical devices and system.

Of the above, putting together the first groups quickly would greatly affect the conditions of the info-communication society and, in that regard, it is a crucial task. The start of organized grappling as soon as possible is hoped for.

4.2.14 “Closed adjustment” or “open combination”

When a manufacturing concern puts together materials and parts necessary for producing its products in-house, this is called vertical integration. The industrial structure in which such corporations play major roles is called “vertical” industrial structure. In contrast to this, a manufacturing method in which individual companies that handle materials and parts and an assembly companies coordinate with each other for manufacturing the same products is also conceivable. In this method, horizontal coordination of independent groups of companies is at work and this is called the “horizontal” industrial structure. In the horizontal industrial structure, the small scale of the companies does not necessarily work to the disadvantage. This means that there is much room for venture businesses to be active.

Due to proliferation of info-communication networks, how to proceed with work is changing in all industries. What makes major contributes to formation of networks is the optical technology. Whether info-communication network exists or not may change the way work is proceeded with. This would be the change in division of labor which may bring about changes in industrial structure.

“Open combination” and “Closed adjustment”

The product architectures are classified into “open combination” and “closed adjustment” types. The “open combination” architecture products tend to have relatively simple correspondence between the product functions and modules. The modules have high independence with each other and, by simply keeping the interfaces, independent module design is possible without taking into consideration the designs of other modules. The “open

combination” type architecture has such characteristics and, by individually designing and manufacturing modules and combining them, it is possible to come up with usable products. In contrast to this, the “closed adjustment” type of product has complicated relationship between the functions and modules. Without adjustments of modules among themselves, the products with architecture of “closed adjustment” type would not achieve excellent functions.

If an industry has a standard interface, this would be an open type. If the interface is used only within a company, it is a closed type. In typical product examples, the “open combination” types are found in PC’s. The “closed combination” type would be the mainframe computers. The “closed adjustment” type would be the passenger cars.

The fortes among the Japanese corporations have been, in general, “closed adjustment” type, which are produced by in-house work and adjustments. Through the progress of digitization, interfaces are simplified in general. At the same time, decrease in the interaction costs through the use of networks would be favorable for open type of work. This means that, in the network age is congenial with “open combination” type of products and PC’s are the typical case. In sum, conventional Japanese type of corporations and their work may not be congenial with the network age.

The reduction of interaction costs provided by the networks would naturally work with automobile industry. This would lead to open-type production trends. In computers, we have seen shifts from “closed combination” type mainframe computers to the “open combination” type PC’s. This type of shifts could very well happen in the automobile industry. In the present day automobiles, some have electric motors and engines and these are controlled by digital electronic parts. The control over digital electronic parts in turn is conducted by the software. This means that the software development could determine the values of a passenger car, which would make it a combination type of product. This possibilities cannot be ignored in automobile production.

4.2.15 Creation of integrated products and services with the optical technology at the core

(1) Introduction

In all of the optoelectronic-related fields, Japan has been playing the role of product supply bases for the rest of the world. The scheme of conducting technological developments domestically and expanding production lines in Asian country is not uncommon in the optical technology-related industries. Furthermore, there emerged tough international competition in technological development itself. One should think about what strategies to take in the severe price competition and industrial competition in the future, in spite of the not-so-large anxiety factors in short-term view. In planning for the future vision for the next five to ten years in view, strategic grappling would be necessary.

(2) The sources of power to create new industry

It would not be necessarily easy to establish supremacy that would leave others behind with a large margin by a single new technology. In other words, many of the innovative products and services would be brought about by integrated new technology, which is considered to work to the advantage for Japan in and by itself. Among developing and industrializing countries and new corporations, it is possible to differentiate with others by a single technology. It would be difficult relatively, however, to simultaneously and in integrated manner to combine multiple advanced technology into products. Fortunately in Japan, however, it is not difficult to find corporate

groups of world class in all of the areas of materials, design, processing and information, when restrictions on in-house technology are removed. With real capabilities in good ideas and integration of technologies, corporations in Japan can have sufficient competitiveness against newly industrializing forces of single technology type.

(3) Optical core technology development and importance of industry-academia cooperation

It is becoming increasingly difficult to secure precursor profit by integration only of existing technology and technology development with novelties are required as the core of integration. In Japan, there are researchers at universities and national laboratories who are enthusiastic about developing new optical technologies. On the other hand, there are industrial workers who are working enthusiastically for creation of new industries. By bringing about industry-academia coordination and promoting it, clear merits of cooperation become increasingly visible. Not a few themes exist where researchers in Japan are leading the world or in potential positions for doing so; new material development by nanotechnology; development of new laser and lighting sources; new circuit technology such as photonic crystal; development of design simulation tools; optical information processing method; and optical and quantum information technology. For making these as core and establishing new industries, structural considerations are needed.

(4) Suggestions as a summary; measures for promoting integration of optical and information technology

As concrete measures for such integration, the following two elements can be pointed out. First, it can be suggested that integration of technologies should be enhanced by public subsidies for research. Conventionally, majority of the proposals for competitive research support called for pioneering work in innovative element technologies. In most of them, views to introduce comprehensive points of views on technology have been weak and it was difficult to find the actual routes for realizing them. Secondly, in addition to bringing up manpower that have deep capabilities in their specialty, there is an urgent task of providing them with opportunities for cultivate comprehensive capabilities in technology. This should be done in various aspects of engineering-related higher education. In the education from elementary school to high school, the education system of “integrated subjects” has been introduced and trial and error are continuing. The young researchers on the graduate school level who specialize in engineering and science fields should be encouraged to acquire comprehensive power for creative thinking through participation in internship, active participation in industry-academia cooperative research projects, which is a task that is very urgent in nature.

4.2.16 Overseas production and international cooperation development

(1) International conditions surrounding optical industry

The optical industry cannot but be engulfed in the major trend of globalization. In the age of the global economy, products are manufactured in the most suitable location selected from locations all over the world and the products are sold around the globe. Many free trade zones will emerge and the trade among different countries will become activated. Salient trends will be specialization into the industries in which each country has the competitive advantage.

(2) Overseas production in the optoelectronic industry

According to survey results on overseas production of optoelectronics products, from 1996 through 2001, the

amount of production has been on the increasing trend. The production shifts of optoelectronic products will be carried out based on the following elements: technological maturity of the products, needs in the overseas market; manufacturing costs; trends among other companies in the same industry and so on. Many cases of shifts to overseas production are seen in order to cope with: resolving trade friction among advanced countries; evading trade barriers of tariffs in the developing countries and so on. On the other hand, there are the following factors for not shifting to overseas production: small-scale in production, containment on investment, instability in overseas country, quick measures for coping with new product demands domestically, necessity for carrying out research, development, and production in an integrated manner in the creation period of hi-tech industry and so on.

(3) Overseas production in the automobile industry

Optoelectronic industry could learn many things from the automobile industry. In case of Japanese automobile industry, hardships in the past worked as the lever for further growth: emission regulation; trade friction: yen hike crisis, and so on. In terms of the number of automobile produced, the industry has become the world power. In 1980's, the United States put in place import restrictions, which triggered the overseas production of automobiles by the Japanese automobile manufacturers.

According to the estimates on the market size of the optoelectronic products, the world market will be 60 trillion yen in 2010, which will expand to 107 trillion yen in 2015. By that time, it is expected that the optoelectronic industry in Japan will go into the period of maturity. In the maturity of an industry, the overseas production strategy will play a key role for its future destiny. A huge investment is needed in overseas production, which will be a great risk factor as a business. In view of the great success example of the automobile industry, which followed the principle of "competition and coordination," the optoelectronic industry in Japan should specialize into its fortes.

(4) Evolution of cooperation toward the near future

"In the increasingly borderless" future society where there is increased exchanges, in the optimum global location, an industry will be specializing in specific areas of competitive edges. Japan has had conventionally fortes in optical industries and technologies and has enhanced its international competitiveness. Currently, Japan is leading the world in optical fiber communication, optical memory, display/lighting, input/output, optical energy and such new advanced areas of environment, and nanotechnology. Toward the future, rapid internationalization of economies will progress, which would require measures for increasingly borderless society in industry and technology, and the intellectual property strategy will become especially important. At the same time, for the further growth of optoelectronic industry with high international competitiveness, strengthening of international competitiveness backed up by international cooperation will be indispensable. In order to proceed with such international cooperation under competition, through cooperation with some of the optoelectronic industry promotion organizations in various locations, promoting mutual exchanges of market and industrial information of the various economic blocks would be effective.

4.2.17 Optoelectronic industry and venture businesses

(1) Backgrounds of venture business booms

For many of the major corporations in Japan, their roots are the venture companies that started with a small group of engineers in the ruins after the war. They have achieved growth with their own technology and product

development and have built their position today.

The Japanese industrial structure, with major corporations at the pinnacle, is now faced with a major change in its direction from the effects of the burst of bubble economy at the beginning of the 1990's and with the footsteps of the catching up Asian countries closely behind. In recent years, industry, governments, and academia have been attempting to develop venture businesses. Private sector incubation facilities have increased in their number and supports from venture capitals are becoming more commonplace. NPO's and companies providing guidance for know-how of starting up have emerged. Spin-offs not only from universities but also from corporations will enjoy developed and improved environment for establishment of new venture businesses.

(2) Optoelectronic industry and venture businesses

The optoelectronic industry is an industrial area where Japan will be able to take the leading position in the future. The optoelectronic technology has the characteristics of key technology, relating to various industries. By combining such technological fields such as electronics, mechanics, and biotechnology, the expectations are high for the optoelectronic industry for its creation of industrial technologies in wide areas, not only in the telecommunications but in manufacturing in general and agriculture, environment, and medical care/welfare. The business models of the optoelectronic industry should shift from the conventional telecommunication industry toward the new business models of environmental measures and the aged society. Furthermore, the industrial area that utilize light energy is expected to make full-scale growth from the aspects of environmental measures in the future. In every field, "aiming at only one rather than No. 1," the chances for the active optical venture businesses are expected to increase.

(3) Strong points and weak points of Japanese businesses

Japanese businesses traditionally tended to show individuality in development of elemental technology on the one hand, but they tended to be behind in system applications and marketing development, which are the weak points. The Japanese optoelectronic industry tended to overwhelm the rest of the world in terms of originality, performance and quality, fell behind in system and marketing developments. In one word, the conservative nature of the domestic market is the obstacle for business development.

(4) Promotion of exchanges with different fields

Venture business must make efforts to pioneer new markets for themselves with the one and only technology and know-how as the base. When doing that, they should not stick with the existing markets and should promote exchanges with different fields more actively for pioneering new businesses. In order to create new optoelectronic industry ahead of the rest of the world, from the points of view of bringing up optoelectronic venture businesses, it would be important to actively and speedily promote the opportunity for matching the "isolated" developer who hold excellent optoelectronic technological seeds and needs in the different fields.

(5) Social contribution of venture businesses

In the United States, conducting evaluations on venture businesses have been established. In this regard, the Japanese venture business should be evaluated from a long-term point of view and they should be provided with supports so as to tap into their specialty and flexibility. This should be promoted into the future. For this, not only the industry-academia coordination but activities to make closer organic coordination among corporations will be needed. And as an industrial policy for supporting that, expectation is high for the national government's initiative based on between-ministry ideas. At the same time, making independent networks of engineers and researchers in

the private sector that does not depend on the National Government would be necessary as spontaneous posture for grappling with the effort.

4.3 Proposing strategy for promoting the optoelectronics industry

At the past three future vision developments, each time various strategies were proposed for promotion and development of optoelectronics industry in Japan. And some of them led to growth of the optoelectronics industry thereafter. When considering with the mid- and long-term points of views, as has been pointed out in the above section, the optoelectronics industry is expected as one of the driving forces of the next long-term upswing economic cyclic wave (Kondratieff 's wave), or the cycle wave of the knowledge and information. In this version of Future Vision, accordingly, it is meaningful to study what should be done by the optoelectronics industry toward 2015 for further growth would be summarized as a proposing strategy for promoting the optoelectronics industry.

In this section, the following seven items were summarized at this time Future Vision, based on the contents of Chapter 1 through Chapter 3, and some proposing strategy like items in the above section. These seven items might be essentials for the further growth of the optoelectronics industry toward year 2015.

- 1) Coping with an advancing borderless society
- 2) Creating market/stimulating demands
- 3) Facilitating research and development
- 4) Strengthening of intellectual property/standardization strategy
- 5) Reinforcing education and cultivating experts
- 6) Developing and supporting start-up or small businesses
- 7) Utilizing regulation policy and promoting deregulation

From the optoelectronics industry point of view, some details were explained below about the seven items.

(1) Coping with an advancing borderless society

Some proposing strategies are indicated as follows for the issues of how to strengthen global competitiveness and secure employment in the advancing borderless society (advent of networking and globalization)

* Promoting innovation that cannot be followed by others in terms of keeping and strengthening of industrial competitiveness

* Keeping on creating seeds of new industrial technology to cope with the hollowing-out of industry

* Facilitating corporate or business activities in the international framework

(2) Creating market/stimulating demands

In the advancing global age, it is necessary to hold as many as comparative advantage technologies. In addition, market expansion strategy is necessary for industrial growth. While product development complies with the market needs, the mechanism for a creating market and stimulating demands are the key. Proposing strategies relating to these are as follows:

* Continuous development of innovative new products “that can only created by optoelectronics” and pushing out these into the market.

* Creating market by free market process, guidance with regulations, and providing incentive policy

* Development that would provide more benefits to users and expanding contents industry (increasing traffic)

* Utilizing events

* Priority purchasing by central and local governments

(3) Facilitating research and development

Optoelectronics industry has an aspect of core or basic industry among all. From this point of view, the investment of research and development should give higher priority. Some proposing strategies are shown below, which should be promoted intensively.

* Promoting long-term national projects and public support to basic research areas

* Promoting integration of optoelectronics technology and information technology

* Facilitating tie-up among industry, government and academia with a view towards fusion and complex of various technologies and promoting technology transfer

* Developing technology roadmap and providing information

(4) Strengthening of intellectual property/standardization strategy

As has been mentioned in coping with an advancing borderless society, in the borderless age, not only corporate level but national level intellectual property strategy will be more important. Hence, from the optoelectronic industry points of view, proposing strategies for strengthening intellectual property and standardization are shown below.

* Strengthening intellectual property rights for protection of intellectual property, promoting aggressive intellectual property strategy and international collaboration

* Establishing the intermediary agency for something like arbitration and utilizing the policy system

* Accelerating standardization

(5) Reinforcing education and cultivating experts

What is crucially important for enhancing industrial competitiveness for the present and future is to strengthen researchers and engineers especially for younger generation, who will become key persons in the future, in optoelectronics both in quality and quantity.

* Promoting introduction of education system that would enhance ability to integrate technology

* Advancing education and training for working people (personnel exchanges from the academic sector to the industry sector and vice versa)

* Developing global-minded people

(6) Developing and supporting start-up or small businesses

The 1990's was so called lost decade in Japan. For reviving from the slumps in economy and industry, there have been various policies implemented recent years proactively. The following two points are especially important for the optoelectronics industry.

* Enhancing preferential tax treatment for research and development investment as an industrial policy

* Strengthening developing and supporting policies for start-up or small businesses

(7) Utilizing regulation policy and promoting deregulation

Here, the followings are taken up from the optoelectronics industry points of view, although utilizing deregulation policy and promoting deregulation are the two sides of a sword.

* Utilizing deregulation policy (for example, environment protection, or energy saving)

* Enhancing deregulation furthermore

What have been specifically pointed out in the above seven items may overlap with the proposed strategies in the past three future visions by OITDA, and there are many common items with the “New Industry Creation Strategy” and “Intellectual Property Promotion Plan 2004” or the other proposals by the Government in its industrial policy. This means that some strategies and proposals should still keep on being implemented without any change from the time of the past future visions, and some of them would be more effective when promoted at national initiative, instead of by one company or organization among industry, government and academia.

The above seven summarized items of proposing strategies should be preferably implemented surely and steadily in the rapidly and qualitatively changing society which represent advancing borderless society, environment-friendly society, and demographic aging society. At the same time, it would be essential to work for making the positive growth interaction cycle of the two elements of “market creation” and “innovation in the optoelectronics technology,” which were pointed out throughout this report, and it is the key how to make it real the potentiality of the optoelectronics industry, so that it would be firmly the driving force of the economic growth in Japan in the days to come.