



EU-Japan Centre for Industrial Cooperation

PHOTONICS FOR LIFE SCIENCE AND INDUSTRIAL MANUFACTURING – BUSINESS AND COOPERATION OPPORTUNITIES IN JAPAN

Market overview for EU SMEs involved with lasers,
optics and photonics

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EXECUTIVE SUMMARY

The research (over 20 meetings with companies and organizations, 10 events and information analysis) for this market overview was done and the market overview itself was written in six months period from 2017 October to 2018 April by the author in Japan.

Japan is still a very relevant market for photonics with 30% global market share in 2015, including overseas production. Even though Japanese companies do manufacturing overseas, but the R&D and headquarters are mostly still in Japan. According to OITDA, Japan's total domestic industry in 2015 is valued at 68 billion EUR. If including the overseas production, OITDA reports 126 billion EUR. However, the overall numbers are not growing over the recent years and the global share is decreasing. Except for the slightly increased production in the manufacturing technology (9,2%), measurement & image processing (4,6%) and medical technology & life science (according to Photonics21, OITDA does not separate this segment) following the global trend.

In total, over 180 Japanese companies related to photonics were reviewed for this report. This number does not include research institutions and distributors. The majority of the companies – 152 were related to industrial manufacturing and only 29 to life science and medical applications. The most prevalent types of application are related to laser processing equipment, optics, laser components & laser systems and followed by spectroscopy in the life science sector. Japan has a very small number of remaining laser producers and the market is dominated by overseas companies. Also, many of the companies in Japan have a very long history, over 50 yearlong and up to over 150 years and unsurprisingly not many new companies compared to Europe.

Around 40% of Japanese companies have some kind of presence in Europe. Big corporations like Sony or Panasonic are actively scouting technologies for investment and even smaller companies like Hamamatsu Photonics are becoming more active in such activities. M&A is usually a more often approach for Japanese companies to the development of collaborations.

Over 50 photonics distributors were identified in this report. Usually, distributors do not have exclusivity for the suppliers and in the relevant chapter the reader will find descriptions, lists and some tips on how to choose the distributor.

There are a lot of associations and societies in Japan. In the report, the reader will find 24 associations and 18 societies. Many of them are not the best way to approach companies, as associations often seemed like formal organizations or closed research institutions, but their member company list is a good place to identify target companies.

There are many universities, institutes and other research organisations throughout Japan and not a small part of them are involved with the photonics related research. Some of those institutions, laboratories and the science funding scheme are introduced in this report. Worth the notice is that in 2018 there is a joint funding opportunity with Japan (managed by JST) and Germany in optics and photonics area. The top research institutions related to photonics are the University of Tokyo, Osaka University, RIKEN, AIST and Kyoto University. Most of the photonics related organisations are located in Tokyo, Osaka, Ibaraki, Kyoto, Shizuoka and Saitama areas.

Regarding the funding, in recent years it was reduced, but due to suffering research performance government is again opening up the wallet. The effects of that will not be visible right away.

In addition, analysis on public procurements related to laser, spectroscopy and optics was also done. The results are presented in the relevant chapter. There the reader will find the top purchasing organisations, top companies that won the sale and amounts involved. In a quick summary, The University of Tokyo, RIKEN and AIST bought the most. From the suppliers, dominant were spectroscopy manufacturers, overseas companies and distributors. The amount of top 20 most recent procurements in each category amounted to around 16 million EUR.

For the report, 36 relevant exhibitions and over 20 conferences in Japan were identified. Most exhibitions are related to manufacturing in different sectors, then followed by purely photonics related and a few medical & life sciences related exhibitions. Conferences, on the contrary, are all related to various photonics sectors, but not to manufacturing. Top photonics exhibitions are OPIE, Science Photonics Fair, Photonix and All about Photonics. EU-Japan Centre, JETRO and SME Support Japan are all also organising company visiting events and missions to and from Japan with good support for SMEs. Currently the most relevant to photonics mission is the Cluster Support Mission on Nanotechnologies with the EU-Japan Centre for Industrial Cooperation¹⁵².

From the market entry point of view, to be successful in Japan SMEs need to be patient, do the research and know that it will not be fast nor cheap. The price of the mistake in Japan is higher than elsewhere. Target companies with the proposal during the R&D stage and know that first of all, approval from the engineering project leader will be needed, that is before the management will decide to go along. The good news is that in general, Japanese companies are starting to be more and more open for collaborations.

INTRODUCTION

This report and the research leading to it was done in the framework of the MINERVA Fellowship program by the EU-Japan Centre for Industrial Cooperation. The whole project took 6 months to complete from 2017 October to 2018 April. In that timeframe, over 20 meetings with companies and organizations, 10 events, information analysis and writing of the market overview itself were performed.

This market overview does not include thorough explanations of the technology, so the reader is expected to have some background knowledge about photonics. The aim is to introduce the Japanese photonics industry and help to determine the first steps entering the market.

The first chapter is the market overview with the information about the global, European and Japanese photonics, related to industrial manufacturing and life science & medical applications. The second chapter is the introduction and analysis of the photonics companies in Japan, with an information about where are the companies and what they are doing. In addition, relationships with Europe are analysed and distributors, association and societies are introduced. Chapter three is about research and research funding organisations in Japan. Furthermore, public procurement analysis was done to understand from who the universities purchase their equipment. Chapter four is dedicated to exhibitions, conferences and business events with the recommendations for the EU SMEs and EU organisations. Finally, chapter fifth rounds up the overview with the discussion about the challenges and opportunities in Japan.

METHODOLOGY

Under industrial manufacturing segment, there are laser materials processing systems, lasers for production technology and optics. Also, measurement and image processing with machine vision, sensors and various measuring systems. In the medical technology & life science segment the following products – laser systems for medical therapy and aesthetics, spectroscopy systems, endoscopes, microscopes, medical imaging, ophthalmic and other diagnostics systems for pharmacy and biotech R&D.

Information was gathered through conversations with companies (Hamamatsu Photonics, Sony, Fujikura, Sigmakoki, Edmund Optics Japan, Coherent, PI Japan and others), associations (OITDA, PETRA, EPIC and others) and institutions (CEA Leti, CNRS and others) to understand the situation in Japan's photonics industry. In addition, a variety of written information sources were analysed to produce this report. To get information about public procurements, EU-Japan Centre's Tax and Public Procurement Helpdesk services were used. Attended events were Semicon Japan, EPIC PIC workshop, Nepcon Japan, Jewellery Japan, Nanotech Japan, Battery Japan, LED Next Stage, JSAP Spring Meeting, Fiber Optics Expo and Science Photonics Fair.

1. PHOTONICS MARKET OVERVIEW

In 2015 the global photonics products' market was 447 billion EUR*†. The European photonics industry was 69,2 billion EUR and that is 15,5% of the global market share. In comparison, domestic Japanese photonics industry was similar – 68 billion EUR. Since 2011 to 2015 the growth in Europe was 1,3% from 65,6 billion EUR. If we would exclude photovoltaics, European photonics production was 66,6 billion EUR with 17% share of the global market (391 billion EUR). The growth in the same period without photovoltaics was 3,9% (from 57,1 billion EUR). The Japanese photonics industry in 2015 was shrinking (-5,1%).

It is also interesting to note that the European photonics industry grew much stronger than the industrial production in Europe (0,1% vs 3,9% if without photovoltaics). But the growth of the photonics industry in Europe was actually almost twice less than the global photonics market growth at 6,7%, excluding photovoltaics. One of the big reasons for this slower Europe growth is China. China is increasingly taking bigger and bigger share of the global photonics production that results in market share losses for all the other major producing countries.

1.1. SECTORS OF PHOTONICS

Like electronics, photonics products are being used in many different applications and a wide range of sectors. Photonics21 summarizes them in ten segments shown in chart 1. Under Productions technology segment there are laser materials processing systems, lithography systems, laser for production technology and objective lenses for wafer steppers. Under Measurement and image processing – machine vision, spectrometers and modules, binary sensors and various measuring systems. In the Medical technology & life science segment the following products – lens for eyeglasses and contact lenses (not included in the further overview about Japanese industry), laser systems for medical therapy and aesthetics, endoscopes, microscopes, medical imaging, ophthalmic and other diagnostics systems for pharmacy and biotech R&D.

European companies are generally well represented in the global market, especially in areas relating to industrial manufacturing and medical technologies. However,

* This market overview is based¹ on the data by Photonics21² 2017 photonics market review in conjunction with market analysts' group Optech Consulting. Photonics21 is European Technology Platform uniting the majority of the leading photonics industries with more than 2500 members.

† The growth is expressed through the compound annual growth rate (CAGR) and is also strongly impacted by the currency effects. For example, in EUR CAGR from 2011 to 2015 was 6,2% and in USD only 0,3%. If expressed versus a basket of relevant currencies, such as the SDR (IMF special drawing rights), market growth in CAGR was 3,4%. Be aware of this when looking at the further data, especially for a market largely outside EU.

data related photonics technologies (information, communication and displays) are dominating the world photonics industry with the 47% share. Europe does not follow that as in Europe these areas only take up 12%. In the European industry, the most prevalent areas are laser materials processing & lithography (with 50% share in the world market) and measurement & image processing (with 35% share). Other globally successful sectors are medical technology & life sciences (with 28% share), optical components & systems (with 32% share), lighting (with 25%) and defence & security (with 26% global market share).

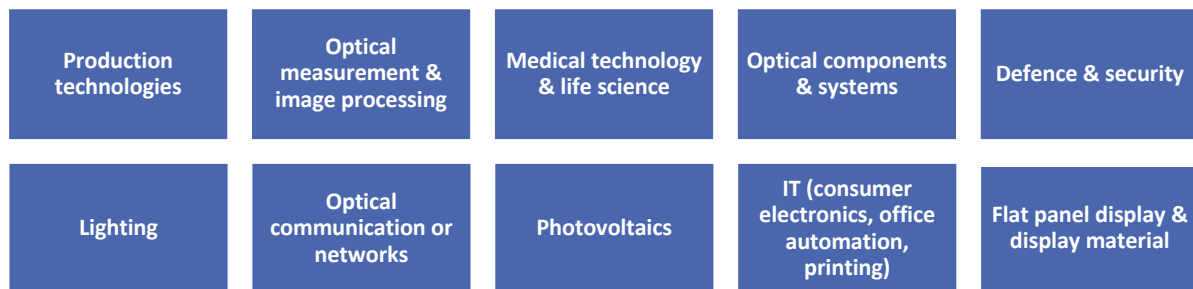


Chart 1 – Segments of the photonics industry as defined by Photonics21. Details for each segment are in the Photonics21 Market Research Study 2017¹ table 1.

From the growth in the global market share perspective, the strongest growth was observed in the manufacturing-oriented sectors – production technologies and optical measurement & image processing with the growth of 4,9% and 5,7% respectively for the 2011 to 2015 period. In production technology, the biggest boost was from the laser materials processing (10,8%). Europe is the major producer of lasers and systems. However, North America headquartered companies have continued to buy European laser manufacturers. This inevitably has led to a substantial share of the European industrial laser production being owned by North American companies.

In lithography, Dutch ASML is a major producer worldwide. The revenue of 6,3 billion EUR accounts for nearly 10% of the European production value in photonics. ASML is the clear market leader in microlithography while Japanese companies dominate the market for lithography systems for manufacturing of the displays.

The sub-segments of the optical measurement include a large variety of systems and components, mainly for industrial applications. Market growth during the last few years was supported by many of those, including binary sensors, spectrometers and fibre-optics measurement systems. However, the big growth engine before – measurement systems for the semiconductor industry, lagged behind.

Medical technology & life sciences also grew strongly with 5,3%. This sector is made up of therapeutic medical systems as well as for in vivo and in vitro diagnostics. Not included are non-photonics medical imaging systems like analogue X-Ray, NMR, ultrasound and pure oximetry systems.

Product sectors with strong growth (over 10%) are endoscopes, therapeutic laser systems and analytical systems for the pharmaceutical and biotechnology industry. Interestingly, in the endoscope group, the dominating company is Olympus. Overall production in Europe was 9,6 billion EUR – 28% of the global market share, in second place is North America with 27% share and third place goes to Japan with 22% share. Segments, where Europe was strong beside endoscopes, were microscopes and ophthalmic products.

1.2. PHOTONICS IN THE WORLD

Looking at the growth of the global photonics market, flat panel displays added the largest volume with 9,6% to 118 billion EUR. Production technology also grew substantially (6,4%) with demand increasing for laser material processing systems by 12%. The trend of industrial manufacturing moving towards automation, flexible production, controllable quality and miniaturization is driving this need for laser material processing. Other categories contributing to global market growth were measurement & image processing (5,8%), medical technology & life science (7,2%) and others.

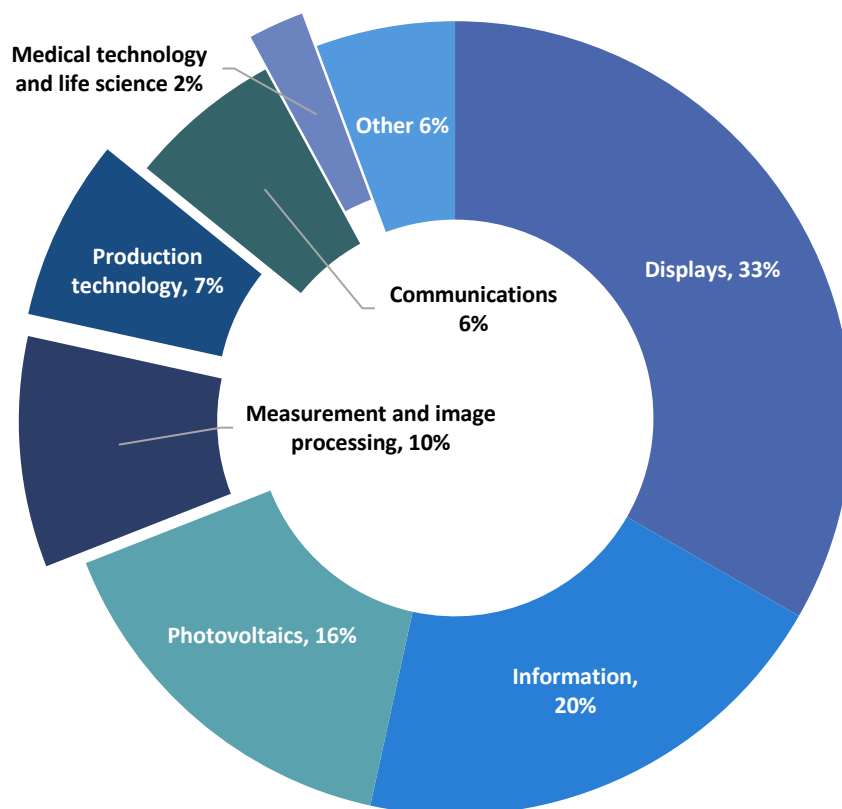


Chart 2 - Global market for photonics, totalling EUR 447 billion in 2015, breaks out into its segments as follows, according to Photonics21 market review for 2017¹.

By the origin of products, China is confidently leading in the photonics industry. It is ahead of Japan, Europe, North America, Korea and Taiwan. But when looking by the country of manufacturer headquarters, Japan is still the undefeated global market leader. China got ahead in the last four years with the global market share growing

rapidly from 2005 to 2015. In 2005 the growth was 10%, then in 2011 it got to 21% and in 2015 the growth was an impressive 27%. The major growing segments are photovoltaics, information technology, lighting, displays and communication.

In laser material processing, Chinese manufacturers also are increasing the market share of systems and lasers. The end market of the products manufactured with the help of lasers (consumer electronics and automotive) are increasingly shifting to China and so does the manufacturing of laser systems. Chinese suppliers, for now, mainly serve the local markets, but this might change as it already did in some other sectors of photonics.

This huge market share China got, first of all, at the expense of Japan and then also from all the other major photonics producing countries. In Europe, the biggest losses were in photovoltaics, communication and increasingly lighting.

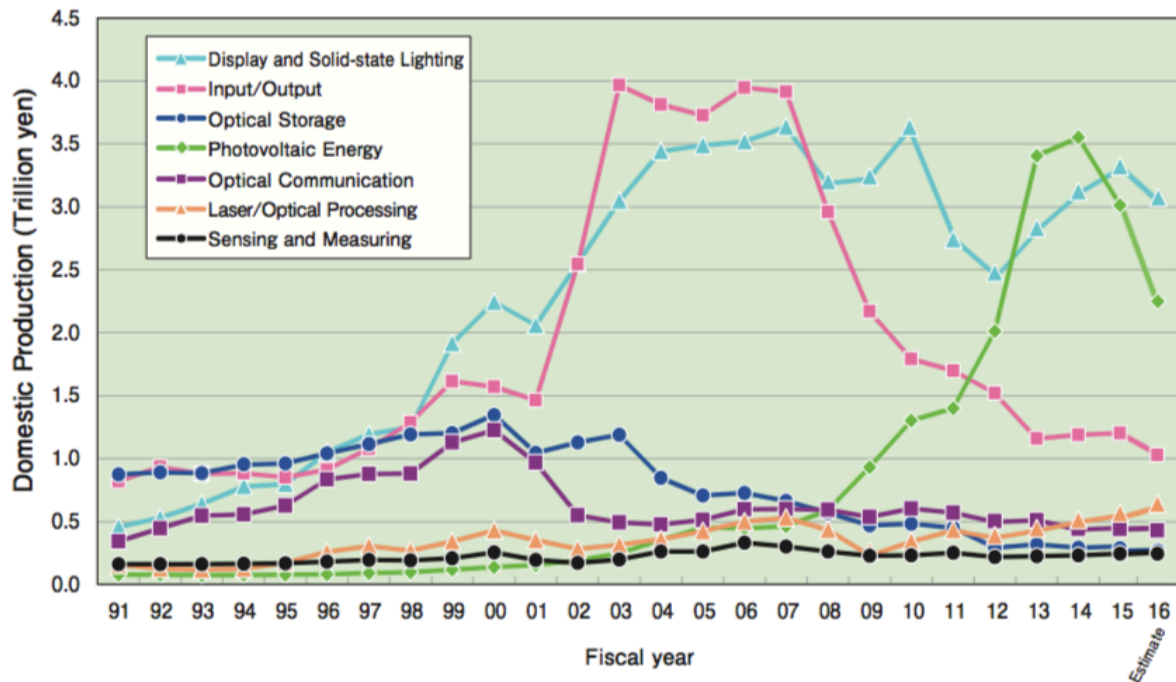
1.3. PHOTONICS IN JAPAN

The Japanese companies were pioneers in many segments of photonics, especially information technology and displays. Now, nearly half of the photonics production of companies headquartered in Japan is happening overseas, mainly in China and that makes up almost half of the photonics production there. More than ten years ago, Japan was the major producer of photonics with the global share of 34%, not including the overseas production. While in 2011 that share shrunk to 21% and in 2015 the share was only about 15%. If to include overseas production, Japan was still a major producer with 40% share in 2011 and 30% in 2015.

In 2015 the leading producer – China had a global share of 26,5%, ahead of Japan with 15,4% and Europe (15,4%), followed by North America (13,6%), Korea (12,5%) and Taiwan with 10,6%. The production shares are very different when the country of the company headquarters is used for counting. In such a case, Japan is clearly leading producer with 30%, then follow China, Europe and North America with about 14% each.

The total domestic Japanese photonics market in 2015 is valued at 8,6 trillion JPY (64 billion EUR with the EUR/JPY exchange rate 134 in 2015 and 111 in 2011) according to the data by the Japanese Optoelectronics Industry and Technology Development Association (OITDA)⁵. After the adjustment according to the slightly different product and section range compared to Photonics21, the total production volume is at 9,1 trillion JPY (68 billion EUR). If including the overseas production, OITDA reports 16,9 trillion JPY (126 billion EUR).

During the last years, the Japanese photonics production increased in the production technology, measurement & image processing and medical technology & life science following the global trend. However, Japan lost share in information technology (input/output), optical components & systems (under optical communication), communications, display and photovoltaics.



Graph 3 - Changes in Domestic Optoelectronics Production by Each Field from the Annual Technical Report 2016 by OITDA⁶.

The Japanese photonics industry has an impressive footprint in most photonics segments and, if including overseas production, it is still the clear leader of global photonics. Although, this position is seriously challenged by its Asian neighbours, especially China.

1.4. HISTORY OF PHOTONICS IN JAPAN

Optics industry in Japan has been established⁸ more than 100 years ago, beginning with the optical research lab in Tokyo in 1906. During the World War I Japanese were producing optics for military applications and since then various clusters of research and manufacturing of precision glass, filters, coating, aspheres, precision optical assemblies, electro-optics and many other products started to grow. These same clusters gave beginning to laser research, laser-based materials processing, and photolithography. Technology and growing companies like Panasonic, Olympus and Canon were at the center of these clusters and have developed a huge supply chain specifically for its technology advancement. These clusters are one of the primary contributors to Japan's economy.

The first laser in Japan was developed in 1960 and since then Japan is developing laser technologies according to the proceedings⁷ from the talk by Norio Karube from Fanuc in the 1990 SPIE conference "The marketplace for industrial lasers". The laser developments in part came from the active spectroscopic studies of the ruby crystals in the 1950s and the most of research was done in the industries' laboratories.

In the beginning, the research was basic and the main work to bring this technology to industry was done by the team including Norio Karube. The research to develop CO₂, YAG and Argon laser for over seven years was funded by the MITI and extended to the developments in the precision processing technology.

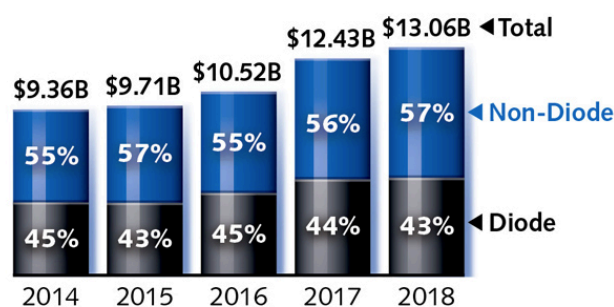
At that time, in 1990, Japan was manufacturing over 2000 CO₂ and over 1500 YAG laser units per year. The top Japanese CO₂ and YAG laser manufacturers were Amada, Daihen, Fanuc, Hitachi, Matsushita, Mitsubishi, NEC, NIIC, Shibuya and Toshiba. In 1990 the local suppliers had over 83% of the Japanese market with less than 17% of the market going to overseas producers. The majority of CO₂ systems imported to Japan were from CG, Ferranti, Photon, PRC, RS and Trumpf. Japanese laser manufacturers were producing only for the domestic market, with merely 5% export rate in 1990.

Many of these Japanese industrial companies have survived up to now, but not many of them are still manufacturing lasers. Nowadays, the majority of laser systems in Japan are imported from overseas. However, laser processing equipment manufacturers still hold an important global market share.

1.5. LASER TRENDS AT THE DAWN OF 2018

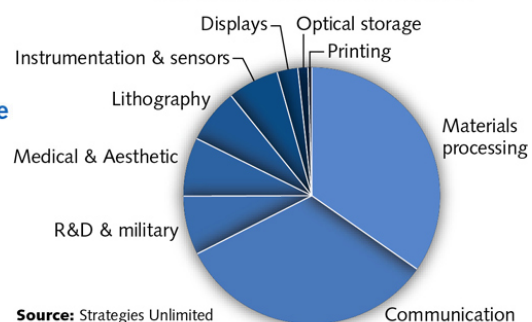
Every year LaserFocusWorld.com publishes⁹ a laser market review and forecast with the analysis done by Strategies Unlimited. This review deals only with laser and not the complete photonics industry. Looking at those reviews from 2014 it is very clear that the laser industry is growing without any breaks.

Laser revenues and 2018 forecast



Source: Strategies Unlimited

Laser segments 2017
Total laser sales: \$12.3 billion



Source: Strategies Unlimited

Graph 4 – Graphs from the LaserFocusWorld.com – laser revenues and 2018 forecast and laser segments for 2017.

The key drivers were consumer electronics devices and increasing production in China. Fibre lasers, LIDAR lasers and VCSELs were the leading technologies. The biggest industry since 2016 is laser materials processing followed by communication sector. The four leaders of the industry – Coherent (US), Han's Laser (China), IPG Photonics (US) and Trumpf (Germany) all performed better than expected in 2017 with the revenues for each over 1 billion USD and a significant growth.

Coherent credits the growth to the microelectronics industry, especially related to OLED, also Rofin acquisition, sales in medical device space and growth in the aerospace & defence market. Han's Laser also boosted its revenues through the acquisition of the Canadian fibre supplier and is now sharing almost 17% of the global fibre laser market. IPG Photonics revenue grew¹⁰ by over 40% in 2017 as they were taking over materials processing market (cutting, welding and 3D printing technologies) and the total revenues were over 1 billion EUR. Trumpf also grew by over 10% to a record-breaking near 3 billion EUR revenues. They credit this growth to the globally growing economy in the last years.

Consumer electronics were also behind much of the growth in 2017, in a sense of the technologies used in the devices and their manufacturing. As an example, for the manufacturing of any smartphone, laser-based processes are used in glass cutting, engraving or circuit board processing. Also, smartphones use OLED screens, manufactured in part using lasers, or even novel 3D sensors with VCSELs. Lasers are increasingly ubiquitous in our everyday lives. From the manufacturing of the things we use, various sensors everywhere, medical applications to the agriculture and entertainment.

2. PHOTONICS COMPANIES

According to the Economist Intelligence Unit¹¹, in Japan about 99% of businesses are small and medium-sized enterprises (SME). Out of them, even though only 11% are doing manufacturing, it is a big and important group next to the number of huge and world famous Japanese manufacturing corporations.

One thing to note is that many big companies have diverse portfolios of products and photonics related are usually just a part of it. For example, according to OITDA, some of the core photonics industry companies are Hitachi, NEC, Toshiba, Mitsubishi, Fujitsu, Panasonic and all of them are big corporations manufacturing a wide range of products.

Industrial manufacturing applications, compared to medical & life science, are leading by a big margin in Japan. OITDA – the optoelectronics association in Japan that is gathering the data about the photonics industry performance every year, also confirmed that the industry related to medical & life science is small, there is even no separate line for it in their yearly report about the industry.

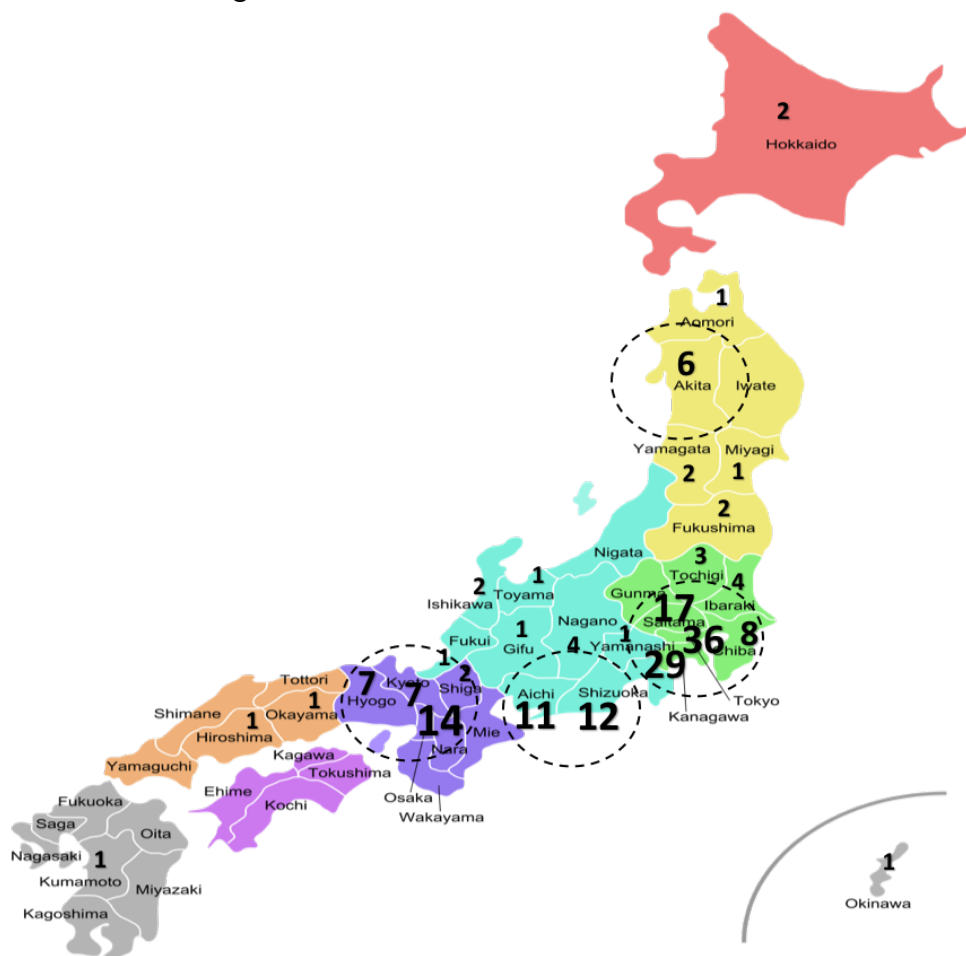
For industrial manufacturing, there are around 200 manufacturers^{12, 13} of machine tools in Japan. Some of the most famous brands include Amada, DMG Mori Seiki, Yamazaki Mazak, Okuma and Fanuc. In 2014, six out of 11 largest machine tools manufacturers, in terms of revenue, came from Japan. Also, the majority of those manufacturers now employ fibre or CO₂ lasers for machining and some are introducing metal sintering machines. A small amount of the companies, like Amada and Fanuc, also develop laser technology in-house. The main laser technology¹⁴ employed for industrial manufacturing in Japan was excimers (Gigaphoton), followed by CO₂, solid state lasers and then others, including fibre and diode lasers.

Optics production is another big industry in Japan. Established more than 100 years ago, Japan now has many optics producers supporting big corporations. There are companies manufacturing precision glass, filters, coatings, aspheres, precision optical assemblies, electro-optics, fibre optics and many more products.

In Japan the main medical device manufacturers are huge corporations making radiology equipment and components, also spectrometers and endoscopes are a big part of the industry. And the main players are companies like Canon, Olympus and Hitachi. It is a highly demanding industry and the number of companies working for it is a lot lower than industrial manufacturing. However, new developments in this industry are increasing with OCT, flow cytometry, implants, stents and imaging.

2.1. WHERE ARE THE COMPANIES?

Many of the identified companies are located in the Kanto area - Ibaraki, Saitama, Tokyo, Chiba, and Kanagawa.



Picture 5 – Map of Japan with the number of companies related to photonics in each prefecture (over 180 companies in the map).

Nowadays, the Japanese government incentivizes companies to move into other regions with financial benefits, so there are many companies spread throughout Japan. Apart from Tokyo area, other three centers are Kansai (Osaka, Kyoto, Hyogo and Shiga), around Shizuoka and Aichi, followed by the smallest one, up north, in Akita.

Only one location for each company was selected – usually a factory or R&D center related to photonics, where available. Many of bigger companies have several facilities all over Japan and headquarters are often in Tokyo or Osaka. Also, foreign companies that have established their subsidiaries in Japan and could be taken as a Japanese company were not included, some of them have factories (like Edmund Optics in Akita, Trumpf in Fukushima) and R&D centers (like Apple and Bosch in Yokohama).

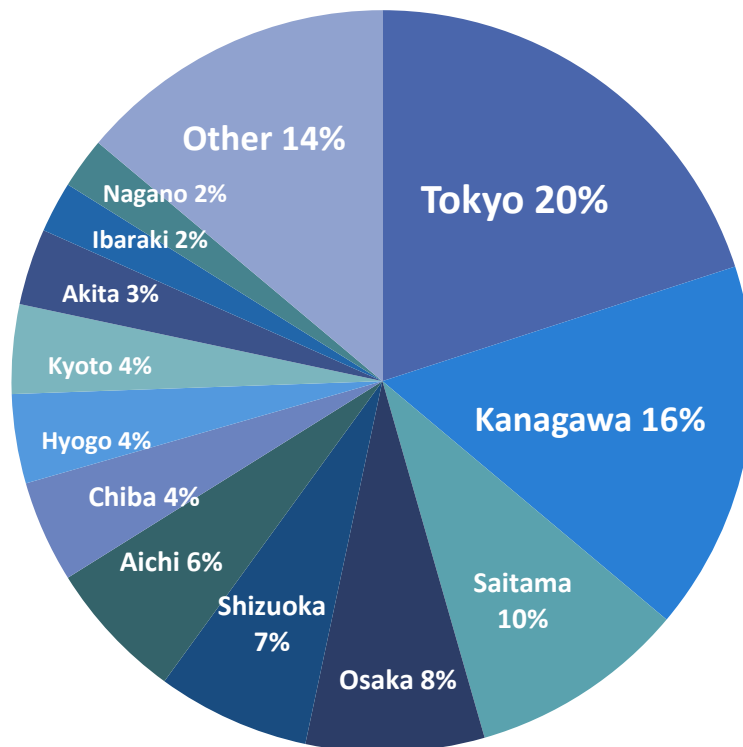


Chart 6 – The geographic spread of the Japanese photonic companies in Japan.

Interestingly, some of the top distributors also reported that from the revenue point of view more than 50% come from the Kanto area. Others could not say this specifically but agreed that a big part of the customers are there. Also, many of the distributors in this report are headquartered in Tokyo and the surroundings, just with satellite offices in Osaka, Nagoya or other areas.

2.2. WHAT ARE THE COMPANIES DOING?

As mentioned in the introduction of this chapter, the majority of the identified companies were related to industrial manufacturing applications. Assigned to this category also were companies that are making components which could be used for both, life science and industrial production, applications but are more often used for the latter. 152 companies related to industrial manufacturing were reviewed and only 29 were found to be related to life science and medical applications. In total 181 companies were identified for this report. The detailed list of the companies can be found in the file – “Photonics_Companies_&_Organizations_in_Japan.xlsx”.

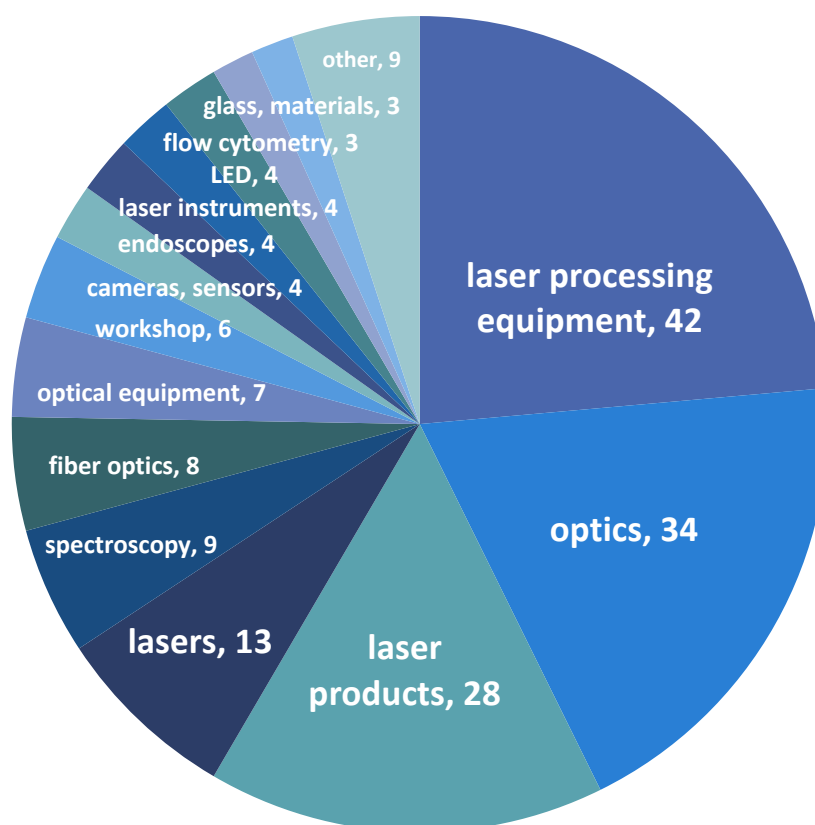


Chart 7 – The number of Japanese photonics related companies in each sector.

2.2.1. LASER PROCESSING EQUIPMENT MANUFACTURERS

The most popular category is laser processing equipment and that correlates well with the fact that Japan is among the leaders in the world of machining equipment producers. Majority of the companies are located in the Kanagawa (11) and Aichi (6) area. And about half of the companies are smaller ones, with less than 1000 employees. Most of them are producing laser cutting/drilling and welding equipment.

Enshu and Amada Myachi (Amada) are some of the companies that are making machining systems and for part of the products use lasers for processing. Enshu explicitly uses diode lasers and Amada – CO₂ and fibre lasers. Amada is producing some of its fibre lasers in-house and other than that, the main laser supplier for Amada is Lumentum. Amada is a 7000 people company and has factories in Europe and US.

Laser processing equipment manufacturers



Table 8 – Some of the laser processing equipment manufacturers.

DMG Mori is another similar company that was created when Mori Seiki has merged with German manufacturer Gildemeister. The company is producing innovative¹⁵ hybrid laser sintering and metal processing machines next to the traditional machining equipment. According to DMG Mori, their factory in Germany is working on laser technology. Another company since 2002 making hybrid laser sintering 3D printers in Japan is Matsuura. This company has about 300 employees and over 80 years of history. Ricoh – a big company producing a wide range of products is also making picosecond laser patterning equipment.

In Japan, there are companies like LaserX – application and system makers, that can develop a custom laser processing process for the manufacturer. Japan also has the world's largest 100 kW IPG Photonics laser¹⁶ at NADEX Laser R&D Center in Fukui Prefecture. NADEX is an enterprise doing business with the automotive industry and manufacturing resistance spot welding systems. This company has been developing new joining technologies within the government funded project in cooperation with the Joining and Welding Research Institute of Osaka University.

Worth the mention is Panasonic, that also produces laser processing equipment. Another thing is that Panasonic is one of the biggest battery cell manufacturers (with almost 30% of the global market¹⁷) in the world and is a big consumer of photonics products because lasers are often used for battery welding (in 2012 35% of battery producers¹⁸ were using laser welding).

2.2.2. OPTICS' PRODUCERS

In the second place are optics producing companies. There are many small companies manufacturing various optical components, some of them very specialized – for example Technical Corporation making only prisms. There are a few big companies like Nikon and Kyocera that are also manufacturers of optical components, but that is very small part of their business. Majority of the optics companies are around Tokyo (9), in Saitama (5) and Kanagawa (3). Historically, Tokyo was an area where producers like Pentax and Nikon had factories building optical systems for defence applications that grew hugely during the world wars and small optics workshops grew around them. According to very rough estimates, there are over 100 various size optics producers in Japan.



Table 9 – Some of the optics producing companies.

Sigmatokki is one of the biggest catalogue optics manufacturers associated to Hamamatsu Photonics and is also producing positioning systems and assemblies. Sigmatokki started by building solutions for R&D and now one of the main industries are semiconductors in Japan. A partner of Sigmatokki from time to time – Natsume is another optics producer. Many of the smaller optics producers can be met at the exhibitions like Science Photonics Fair in Tokyo. You can find the complete list of optics producers in the file – “Photonics_Companies_&_Organizations_in_Japan.xlsx”.

2.2.3. LASER PRODUCTS COMPANIES

Laser products segment includes manufacturers of the laser diode and other components or manufacturers of systems and equipment that is not used for laser processing. As wide as this group of companies is, it is also widespread geographically. Most of the companies are in Saitama (5), Tokyo (3), Osaka (3), Kyoto (3) and Kanagawa (3). Some of the companies in this group are well known producers like Toshiba, Shimadzu or Sumitomo – big and with a wide range of products related to lasers and photonics.

Some of the smaller companies are Riken Optech – producer of laser safety equipment, and Canare – a cable manufacturer that at the Photonics West 2018 announced the new developments of laser products – high-power laser diodes, fibre

coupled diode lasers, solid state lasers, laser beam profiler and delivery fibres. Canare is trying to develop a small-sized optical engine for industrial and medical purposes.



Table 10 – Some of the laser products companies.

2.2.4. LASER MANUFACTURERS

There are not many laser manufacturing companies in Japan anymore. Before, many big companies used to make some kind of lasers, but now only a few are remaining. Companies like Mitsubishi, NTT, Fujikura, Omron and Gigaphoton are still manufacturing lasers. Mitsubishi and Fanuc are manufacturers of CO₂ lasers. Fanuc is also a leading industrial robot manufacturer in the world. Spectronix is a picosecond and nanosecond laser producing company from Osaka. Most laser manufacturers are concentrated in Kanagawa (5) and Saitama (3) areas.



Table 11 – Some of the laser manufacturing companies.

Gigaphoton²⁴ is a Japanese producer of the gigantic excimer lasers used in semiconductor lithography — the “etching” of patterns into microelectronic chips that go into computers, smartphones and more. It is also one of the leading producers in the world and used to be part of Komatsu.

Fujikura is a huge Japanese company producing fibre lasers that are a very small part of their business. Fibre lasers at Fujikura started after the acquisition of Optoenergy¹⁹, that allowed having all the production steps in-house. With this advantage, they can keep the price lower and control the quality better. Since now it is difficult to grow fast in Japan, the company is planning expansion in Europe soon.

However, as for lasers, in Japan overseas companies are confidently dominating the market. IPG, Trumpf, Lumentum, Coherent and Spectra Physics are some of the most popular laser producers in Japan. All of them have established here subsidiaries or even engineering and production facilities. Adding to that, there are many other smaller overseas laser producers represented by a big group of Japanese distributors.

2.2.5. LIFE SCIENCE RELATED AND OTHER COMPANIES

From the life science applications, the leading type is spectroscopy, with companies like Jasco, Hitachi, Canon and Horiba. Most of the companies and their relevant factories or R&D centers are in Tokyo (3) and Osaka (2).



Table 12 – Some of the spectroscopy related companies.

Otsuka Electronics is one of the companies making spectrometers and has about 200 employees with almost 50 years of history. One of the recent companies is Medical Photonics – a company developing non-invasive blood test technology based on light scattering analysis in NIR spectrum. CanBas is another start-up using flow cytometry to do cell phenotype screening to help in cancer drug development by giving insights into how drugs affect healthy and not healthy cells. Most of the start-ups in Japan, especially technical ones, come from universities, the University of Tokyo is leading among them.

Fibre optics, optical equipment and endoscope producers are mainly in Kanagawa and Tokyo while scientific cameras & sensors have the most manufacturers in Shizuoka, around Hamamatsu Photonics. Most of medical or life science equipment producers are in Tokyo (10), Kyoto (3) and Osaka (3) prefectures.

Photonics related companies

HAMAMATSU

NIKKISO

Microtrac
Total Solutions in Particle Characterization

**nano
photon**

NIDEK

NEC

GLASS FOR FUTURE
Nippon Electric Glass

KIMMON KOHA

Table 13 – Some of the photonics related companies.

Microtrac, a part of Nikkiso group, is a manufacturer of optical particle analysers – laser diffraction, dynamic light scattering and image analysis systems. NanoPhoton is a producer of laser Raman microscopes in various configurations. The company is in close relations with Osaka and Kyoto universities. Nidek is another company in the life science field – a producer of ophthalmic laser systems for eye treatment. With almost 50 years of history and more than 1500 employees, this company is a big manufacturer from Aichi prefecture.

In Europe, one of the best-known photonics company from Japan is Hamamatsu Photonics. They are producing various detectors, spectroscopy solutions and other systems and components for light applications. Hamamatsu Photonics has several R&D centers in Japan and is closely collaborating with universities. With Shizuoka University they even have established a new university dedicated to photonics called - The Graduate School for the Creation of New Photonics Industries.

An example of industrial manufacturing solution, that Hamamatsu Photonics offers, is laser wafer dicing that is used by DISCO – one of the big semiconductor processing equipment manufacturers. The main applications for Hamamatsu in medical are detectors for several big Japanese medical equipment producers like Hitachi or Canon. However, Hamamatsu is also doing a lot of novel developments relating to medical and does not shy away from the collaborations with the overseas researchers, for example, some 20 years ago a researcher from the University College of London helped to develop pde-neo II – a near infrared fluorescence imager²⁰.

Hamamatsu Photonics has a whole in-house supply chain for the most important and critical products, but as they do a lot of new developments they collaborate with other suppliers too.

Hamamatsu is also doing technology scouting. In the US it is done through the subsidiary and collaborations with venture firms. And in Europe this effort just started. Hamamatsu has good connections to Vrije Universiteit Brussel²² on technology advising. Last year Hamamatsu also has participated as an investor in the TechTour²¹. Hamamatsu is motivated to keep the steady growth and new technologies are important for that.

Some companies are not developing photonics solutions but are users of it. Like Kyocera, that is offering orthopaedic implants to the local market – the potential for innovative 3D metal printing to offer customized implants. Or Nippon Electric Glass – a company producing the various shape, size and properties glass products can be a perfect fit for glass cutting and processing technologies.

2.3. WHAT ARE SOME OF THE OLDEST AND NEWEST COMPANIES?

In Japan, many of the companies have a long history. From the reviewed companies, 85 out of 152 from the industrial manufacturing group have history of 50 years and longer. And from life science & medical related group, this number is even higher – 22 out of 30 have 50 years or longer history. That is 56% and 73% of the companies. The oldest from the list is 165 years old.

Industrial Production companies	Year	Life Science companies	Year
IHI Corporation	1853	YOSHIDA DENTAL	1906
Toshiba	1875	Shimadzu	1917
Fujikura	1885	Nikon corporation	1917
Nippon Sharyo	1896	Olympus	1919
Furukawa electric	1896	Yokogawa Electric Corporation	1920
Sumitomo electric industries	1897	Topcon	1932
NEC Corporation	1899	FUJIFILM Corporation	1934
Kimmon Koha	1904	Hoya	1941
Asahi Glass	1907	Machida Mfg. Co.	1945
Yamamoto Kogaku	1911	Canon Life Care Solutions Co.	1945

Table 14 – The oldest photonics related companies in Japan.

IHI Corporation is a huge almost 30 000 people company that is involved in a diverse range of applications, from energy, infrastructure and industrial systems to space and aeronautics. The laser related activities are laser welding and joining technology developments. IHI is using laser welding even in infrastructure projects, like bridge production.

Furukawa electric is another huge company with 52 000 employees and very diverse product portfolio. Some of those products are industrial fibre lasers and flow cytometry systems. From 2015 Furukawa is collaborating with Fanuc to produce fibre laser components¹⁵¹. Kimmon Koha manufactures fibre lasers for industrial applications. The

company is much smaller compared to Furukawa or Fanuc and headquartered in Fukushima.

Sumitomo Electric, among its many products and solutions, has laser optics to offer and is developing lasers and laser powered gas sensors. Nippon Sharyo is a bit smaller company with less than 2000 people, but with products for bullet trains, energy, infrastructure and also laser processing equipment, including micromachining workstations. NEC has a long history in the optical communication industry and is producing fibre optics, next to many other products.

Asahi glass is a huge glass, ceramics and substrate in different shapes and forms manufacturer for electronics, cars and buildings. And Yamamoto Kogaku is Japan's biggest laser safety goggles manufacturer.



Table 15 – Some of the oldest companies.

From the life science and medical side, Yoshida Dental is the oldest company and is the producer of fibre laser surgery equipment for dental application, it is also one of the smaller ones with only 430 employees. Topcon with less than 5000 people is the manufacturer of laser systems for medical applications – ophthalmologic instruments for diagnostic and laser treatment.

Shimadzu, Nikon and Horiba are all huge companies manufacturing analytical equipment for life science applications. Yokogawa is making confocal scanning systems for live cell imaging.

Olympus, Fujifilm, Hoya and Machida manufacture endoscopy systems. However, according²³ to Markets and Markets in Japan the leading one is Olympus. While Canon Life Care Solutions, with about 300 people, is making OCT systems. Canon also recently bought medical equipment development and production department from Toshiba, but it is not directly related to photonics.

Looking at the table of the most recent companies in Japan, it is immediately visible that among the life science segment, only three companies have appeared from the year 2000. In the industrial manufacturing segment, there are also 3 in the table –

Mitsubishi and Ricoh have been restructured – they are old companies. From the complete 152 companies' list, 22 companies were established since 2000 (< 15%).

Industrial Production companies	Year	Life Science companies	Year
AIO Core Co.	2017	Medical Photonics	2015
Mitsubishi Heavy Industries Machine Tool Co.	2015	NanoPhoton Corporation	2003
Ricoh Industrial Solutions Co.	2014	CanBas	2000
Craft Center SAWAKI Inc.	2011	Hirox	1978
PHLUXi, Inc.	2010	Soma Optics, Ltd.	1976

Table 16 – The youngest photonics related companies in Japan.

QD laser has its roots²⁵ in the University of Tokyo and Fujitsu. Manufacturer of quantum dot lasers, that were first designed at the University of Tokyo by professor Yasuhiko Arakawa of the Institute of Industrial Science and then finished with joined forces at Fujitsu. The company has recently received the 2017 Prism award for fibre laser seeder.



Table 17 – Some of the most recent photonics companies.

Optocomb is another spin-off of The University of Tokyo, that started in 2002 as the university venture. They are developing products based on optical frequency comb technique. Currently offers distance meters, 3D scanners and multipoint vibrometers.

Brookman Technology was started in Hamamatsu in 2006 by the professor in Electrical Engineering at Shizuoka University. They specialize in the design of advanced CMOS image sensors for IR, depth and high-speed imaging.

Another interesting example from new companies is Trimatiz, the company has been producing high-speed optical attenuators, LD drivers, amplifiers and custom optical devices. Just recently they have started to market a LIDAR kit that is configurable and can be a tool for companies developing novel LIDAR applications.

2.4. JAPANESE COMPANIES AND EUROPE

During the companies' overview, the author has also looked if Japanese companies have any presence in EU. And from around 180 companies about 40% had either a subsidiary, factories or R&D centers. Generally, if the company is big enough it has a

presence in Europe, while almost all of the smaller companies have not. Most of the factories and R&D centers in EU are made through the M&A.

The majority of Japanese companies are either in Germany, UK, Netherland or France. At one-point Dusseldorf in Germany had the biggest number of companies and Japanese residents. ANA (airlines) estimates that in 2012 around 421 Japanese companies were there²⁶.

Looking to approach the Japanese company, the advice is to start from the subsidiary in Europe. People there can help with the introduction in Japan to have the best chance of success.

Even though it is perceived that it is hard to build relationships with Japan due to culture and language barriers, for a long time now there are many examples of successful EU and Japan collaborations. It is difficult to deny that approaching Japan is not so straightforward, but certainly can be done.

Fujitsu is one of the first examples that come to mind, now in the top 5 of IT service providers in the world, the company started²⁷ as a joint venture by Siemens and Furukawa Electric. In the photonics area, Fujitsu is active in optical communication technology development.

Sony is another huge corporation that has established itself strongly in Europe. In EU it started with the acquisition of German TV manufacturing plant and now there are R&D centers in Belgium, Paris and UK. The Stuttgart²⁸ technology center is actively looking for technology and potential partners to aid in Sony's product developments. Sony has several product groups related to photonics in industrial manufacturing or medical applications²⁹.

Horiba is another example of how being in EU can help Japanese company. Strong expansion³⁰ through acquisitions in France, Germany and US helped Horiba diversify the business and avoid the trap of stagnant Japanese industrial market during the crisis. And TeraView in the UK is a spinout³¹ from Toshiba corporation and Cambridge University developing fault analysis and quality assurance for semiconductor chips, as well as non-destructive inspection of high-value coatings.

On the other side, many European and US companies have some presence in Japan. Big corporations like Bosch and Apple have research centers. Companies like Edmund Optics and Trumpf have factories. CEA Leti and Fraunhofer have scientific personnel to help recruit Japanese companies for research in Europe.

Trumpf, IPG, Coherent and Spectra Physics are the major suppliers of lasers in Japan greatly overpowering few local manufacturers. All of them have local offices. Other examples include Amplitude, Precitec, PI, JenOptic or Gooch and Housego. Most of the companies confirmed that it is very important to be in Japan to do good business

here. The closer the suppliers are to the customers and the better support they provide, the better relationships they have.

European association EPIC – one of the most active associations in Europe, is also interested in Japan and has among its members Japanese companies like Hamamatsu Photonics, SigmaKoki and Sony. Moreover, at the end of 2017, EPIC organized a PIC workshop³² and brought together Japanese and European companies to learn from each other and build relationships.

2.5. DISTRIBUTORS

Apparently, in Japan main laser and optics suppliers are either overseas companies or distributors that are, in most cases, the gateway to Japanese business and R&D communities. There are two different kinds of distributors in Japan, one is big corporations with hundreds of products and the other is specialized distributors dealing with just certain kinds of products. When dealing with big corporate distributors, it is important to remember that usually, the majority of revenue for them does not come from photonics' products and because of hundreds of products and standardised processes, there can be a lack of active sales.



Table 18 – Some of the distributors in Japan.

The specialized distributors, on the other hand, are much more active in promoting the niche products. And there are a lot of distributors, only for this report, 56 distributors that are selling photonics products were reviewed. Also, very small number of distributors have exclusivity to suppliers, many of the distributors share the same suppliers, especially if the products are complementary to lasers or some bigger systems that the distributor sells. Even subsidiaries of the overseas companies use distributors in Japan. One more very important point regarding the distributor is to think about how the service will be done.

Customers in Japan desire quality, fast service and close support. If there is a need to send the equipment overseas for service, it is usually a big hurdle that is expensive and time consuming. Distributors that can provide fast and local service are in a big favour. Some of the distributors with extensive experience are capable of doing the service themselves while others need to find different ways to deal with this. The complete list of distributors with details about the represented companies and customers, where available, are in the file – “Photonics_Companies_&_Organizations_in_Japan.xlsx”.

From the data it is evident that the majority of the distributors are in the Kanto area, that is Tokyo (41), Kanagawa (7), Saitama (3) and Ibaraki (2). Also, many of the distributors have offices or partners in other regions of Japan, like Osaka. And for most of the distributors, the industry and academia are both very important.

Top 15 oldest distributor		Top 15 newest distributors	
Marubun	1844	Nanoxeed	2017
Fujitok	1945	Scansol	2015
Sanyo trading	1947	Akitech Leo	2013
Kyoei Sangyo Co., Ltd.	1947	Astron	2013
Ryokosha Corporation	1947	Hikari	2012
OSAKA KOHKI CO., LTD.	1950	Aisay	2010
Hakuto	1953	Optotec	2009
TOYO Corporation	1953	Kokyo	2009
New metals and chemicals corporation	1957	Enable K.K.	2009
Japan Laser	1968	Prolinx	2009
Kantum	1977	LxRay Co., Ltd.	2008
FIT Leadintex, Inc.	1978	Sevensix	2007
KLV	1979	Optopia	2005
Hi-Technology	1980	Edgesemicon	2004
Kyokko	1980	Japan Device	2004

Table 19 – Oldest and newest photonics distributors in Japan.

Marubun, Kyoei Sangyo, Sanyo trading, Ryokosha, Osaka Kohki, Hakuto, Toyo Corporation, New metals and chemicals corporation are the big distributors handling a wide variety of products. The remaining oldest distributors are photonics specialized ones that managed to survive for more than 30 years handling the rapidly changing and developing photonics industry. From the whole list, 20 companies were started after 2000.

Japan Laser is the biggest specialized photonics distributor representing companies such as Newport, Amplitude, Crylas, Quantel and Lasos. An interesting fact is that Japan Laser was in part founded and associated to JEOL, a Japanese scientific equipment manufacturer. Japan Laser is very active and can be met at most local industry events.

Kantum is another photonics related distributor. It is also a joint founder with Jenoptik of Jenoptik Japan. Kantum Electronics started from the Ushikata – Japanese producer of measurement instruments. Specializing in lasers and scientific equipment, Kantum is also interested in new suppliers, for life science example – related to ultrahigh resolution microscopy or filters.

Akitech Leo is new but with the founder that has over 40 years of experience in photonics in Japan. The company is mainly focused on high quality nanosecond lasers and the complementary products. Even though Akitech is a small company they are covering big region geographically with partners throughout Japan. And the modular quality lasers they sell are easy to service on site.

Phototechnica also has competent staff and engineers. Some of the people at the company have very long experience in the photonics industry and long lasting good relationships with some of the core suppliers. Phototechnica represents such companies as Avantes and Light Conversion.

Tokyo Instruments has a good example of how the supplier can be close to the end customer. They are employing suppliers' engineers dedicated to servicing and installing certain products. For the engineer, this is a huge learning experience about the market and the distributor has a competitive edge. Tokyo Instruments is in the same group with Unisoku – an SPM and optical instruments' producer and represents companies like Ekspla, Andor and many more.

Autex, another one of the top distributors in Japan, pointed out that the communication between the distributor and the supplier has to be seamless. In Japan, it is especially important as the customers are very demanding. Also, suppliers have to be ready to visit the customers with the distributor frequently and when Autex participates with a big booth at main exhibitions in Japan they invite suppliers to present to the potential customer on the stage. Autex is representing brands such as Menlo Systems, Teem Photonics and a wide variety of others.

Most of the distributors are open for the discussions related to new products and suppliers.

2.6. ASSOCIATIONS AND SOCIETIES

Associations are a good place to start looking for companies in the relevant fields of applications. In Japan, where bureaucratic ways are still very strong, there are many organizations that companies are involved with. However, trying to approach companies through the associations often can be difficult, as associations generally seemed like formal and closed organizations. Over 40 of them relevant to photonics for industrial and life science applications in Japan were reviewed.

General Electronics Associations	
	ELECTRONICS AND INFORMATION TECHNOLOGY
	Japan Electronics Packaging and Circuits Association
Photonics Associations	
	一般財団法人光産業技術振興協会 Optoelectronics Industry and Technology Development Association
	一般社団法人日本オプトメカトロニクス協会 OPTOMECHATRONICS
	Photonics Electronics Technology Research Association
Laser processing Associations	
	一般社団法人 レーザプラットフォーム協議会 LASER PLATFORM
	次世代 レーザープロセッシング 技術研究組合 NEXT GENERATION LASER PROCESSING
	Technology Research Association for Future Additive Manufacturing
Other Associations	
	日本光学測定機工業会 OPTICAL MEASURING
	LED
	OPTICAL GLASS MANUFACTURERS

Table 20 – Photonics and industrial manufacturing related associations in Japan.

Associations varied from simple organizations uniting just a few companies to the ones that have facilities and laboratories to help with the developments for the members. Most of the associations are also actively involved in the standard's development and can certainly influence the industry. Societies are important too. The big ones organize big events with opportunities for companies to promote their products. And usually companies are more actively involved in the activities of societies than associations. The complete list of identified associations and societies can be found in the file – “Photonics_Companies_&_Organizations_in_Japan.xlsx”. More than third of organizations did not have any English website.

2.6.1. INDUSTRIAL MANUFACTURING ASSOCIATIONS

There are 16 associations related to industrial manufacturing in this report. The two associations that have the most members are Japan Electronics and Information

Technology Industries Association (JEITA – 379 members) and Japan Electronics Packaging and Circuits Association (JPCA – 374 members). They unite companies making electronic equipment and components. Electronics manufacturing is one of the leading industries in Japan. JEITA and JPCA were recommended by OITDA, because many of these companies are also involved in products related to photonics development, like Sony, Panasonic and Hitachi.

JEITA is organizing CEATEC Japan - one of the biggest electronics exhibition and conferences in Japan. Concurrently with this show, there is also the photonics exhibition - InterOpto. And JPCA is an organizer of the International Electronic Circuits Exhibition, it includes advanced packaging, processing technology, organic devices and smart sensing.

2.6.2. PHOTONICS ASSOCIATIONS

Associations directly related to lasers, optics, imaging and photonics are all smaller and there are not so many bigger companies developing only photonics related products.

Optoelectronics industry and technology development association (OITDA) is the main association for the companies related to photonics in general. This association gathers information from the domestic companies and provides yearly Japan's photonics market overview. The association is involved with many industry events and tries to collaborate with the overseas. However, it is not very active outside of Japan. Many of the 76 members are major photonics players in Japan.

Japan Optomechatronics association (JOEM) is an association of 28 industrial manufacturers who are using optical technologies for imaging, analysis or processing. JOEM has five different parts of the organization – Light Sensing, Optical design engineering, Digital Imaging Technology, Photon Technology and Optical Part Production Engineering.

Photonics Electronics Technology Research Association (PETRA) is an association focusing on RnD activities for its 14 members related mostly to optical communication technologies. PETRA, developing photonics devices, packaging and integration technologies, is a spin-off from OITDA and also a member of European EPIC association.

According to the experts, PETRA is at the forefront in the PIC field. They have a close core group of big Japanese companies, together with the universities and government funding to develop PIC technologies. However, getting into collaborations is very difficult, because the organisation is rather closed.

2.6.3. LASER PROCESSING ASSOCIATIONS

The Technical Research Association for Future Additive Manufacturing (TRAFAM) established in 2008 focuses on the development of 3D printing technology in Japan. 37 members are universities, research centers and big industrial manufacturers.

The Laser Platform Association (LPF) was established to provide a medium for the collaboration between universities and SMEs in Japan that want to develop laser applications for industrial manufacturing. It has Osaka and other universities among its 21 members and a list of members with information about what processing technologies each is using.

The Next-generation laser processing technology research association (NGLPTR) unites Kyoto University and industrial companies to develop laser processing technologies using ultra-short pulses. There are 7 private members, including Panasonic, Hitachi and Samsung.

2.6.4. OPTICAL MEASURING, LED AND GLASS ASSOCIATIONS

Japan Optical Measuring Instruments Manufacturers Association (JOMA) is uniting 30 companies and organizes Measuring Technology Expo³⁴. The chairman and the management are from the companies like Nikon, Mitutoyo and Olympus. Japan LED Association (JLEDS), established in 2007, unites 50 LED and related manufacturers. Japan Optical Glass Manufacturers' Association (JOGMA) consists of 11 optical glass manufacturers like Ohara, Shott, Hoya and Nikon.

2.6.5. LIFE SCIENCE ASSOCIATIONS

While industrial manufacturing had over 16 relevant associations, there is only 5 association related to life science in this report. The two biggest organizations are Medical Technology Association of Japan (MTJAPAN) and Japan Medical Imaging and Radiological Systems Industries Association (JIRA) with close to 200 members. The first one includes a wide range of medical device manufacturers that account for more than 50% of Japan's medical device market, from those, not a big part is related to photonics. However, many of those companies could be users of laser processing in their manufacturing. The second one – JIRA is related to radiological imaging like X-ray, PET or MRI, with big companies like Canon, Hitachi and Fujifilm as members, several of these same companies also develop spectroscopy solutions.

Life science and medical technology associations			
	MTJAPAN Medical Technology Association of Japan		MEDICAL IMAGING & RADIOLOGY
	JOIA Japan Ophthalmic Instruments Association	OPHTHALMIC	 MEDICAL OPTICAL

Table 21 – Life science and medical technology associations in Japan.

These two associations reflect the biggest medical device industries in Japan – radiology and medical devices. Photonics is generally not a big part of it. Although, now more and more companies are expanding into new and novel developments and this area is one of the priorities for the government.

Other few associations related to life sciences are Ophthalmic Instruments Association (JOIA) with 130 members and Medical Optical Equipment Manufacturers Association (JMOIA) with 26 members. JOIA members are companies making laser equipment for eye treatment and various diagnostic and measurement devices. JOIA also organizes event³⁴ with the sponsorship opportunities. As for JMOIA, it covers three topics – endoscope, medical equipment and eyewear. Majority of the 26 members are big corporations like Olympus, Hoya, Nikon, Canon, etc.

2.6.6. DISTRIBUTOR ASSOCIATION

One more interesting association, not mentioned above, is the laser and optics related equipment distributors' association – Japan Importers Association of Lasers and ElectroOptics (JIAL). Some information about the association can be found on their website³⁵. There is also a relevant list of companies – 26 distributors. The founding company is Japan Laser and the best way to get information is to go through them.

2.6.7. SOCIETIES

Relevant to photonics, 16 societies were identified for this report and the majority of them are funded by companies. This list of sponsors is a great source to look for companies related to the appropriate sectors. Companies are more actively engaged with societies than associations and also, sometimes joining the society can be the way to get the opportunity to sell to some laboratories.

Photonics societies	
 LASER SOCIETY OF JAPAN	 THIN FILM SOCIETY
 特定非営利活動法人 日本フォトリクス協議会	JAPAN PHOTONICS COUNCIL
 OPTICAL SOCIETY OF JAPAN	
Laser processing societies	
	 LASER TECHNOLOGY SOCIETY
Life science and medical societies	
 JLSM Japan Society for Laser Surgery and Medicine	 日本レーザー歯学会 <small>Japanese Society for Laser Dentistry Secretariat Address : Kouku heken kyosukai 1-43-9 Komagome, Tachimi, Tokyo, JAPAN Inquiries : gakkai1@tokuhoken.or.jp TEL : +81-3-3947-8891 FAX : +81-3-3947-8341</small>

Table 22 – Photonics societies in Japan.

The biggest societies are The Japan Society for Precision Engineering (220 companies) and The Japan Society of Industrial Machinery Manufacturers (174 companies). Only part of the members of these societies are related to photonics.

Almost all the societies are based in Tokyo and just the laser related ones are from Osaka. Osaka University has strong research groups and companies related to laser research.

The Laser Society of Japan (LSJ) is one of the main societies related to laser research and companies involved with lasers. Society is also heavily involved in OPIC conference organization. There are around 90 sponsoring companies – local manufacturers, distributors and overseas companies. However, their website is only in Japanese and contacting without any Japanese knowledge will be challenging.

The Optical Thin-Film Science and Engineering Group (TFSE) located at Tokai University, Faculty of Engineering, Department of Optics and Image Engineering,

Muroya Laboratory has an impressive number of supporting members – 145. TFSE organises Optical Thin Film Fair during the Science Photonics Fair.

The Optical Society of Japan (OSJ) is very active and collaborates with other societies worldwide – OSA, SPIE, etc. It has several research groups³⁶ at different universities in Japan and organizes events³⁶. Society is supported by 34 companies.

Japan Photonics Council (JPC) since 2009 organizes monthly events and during them members do technical presentations relevant to their industry. Society has 38 corporate members.

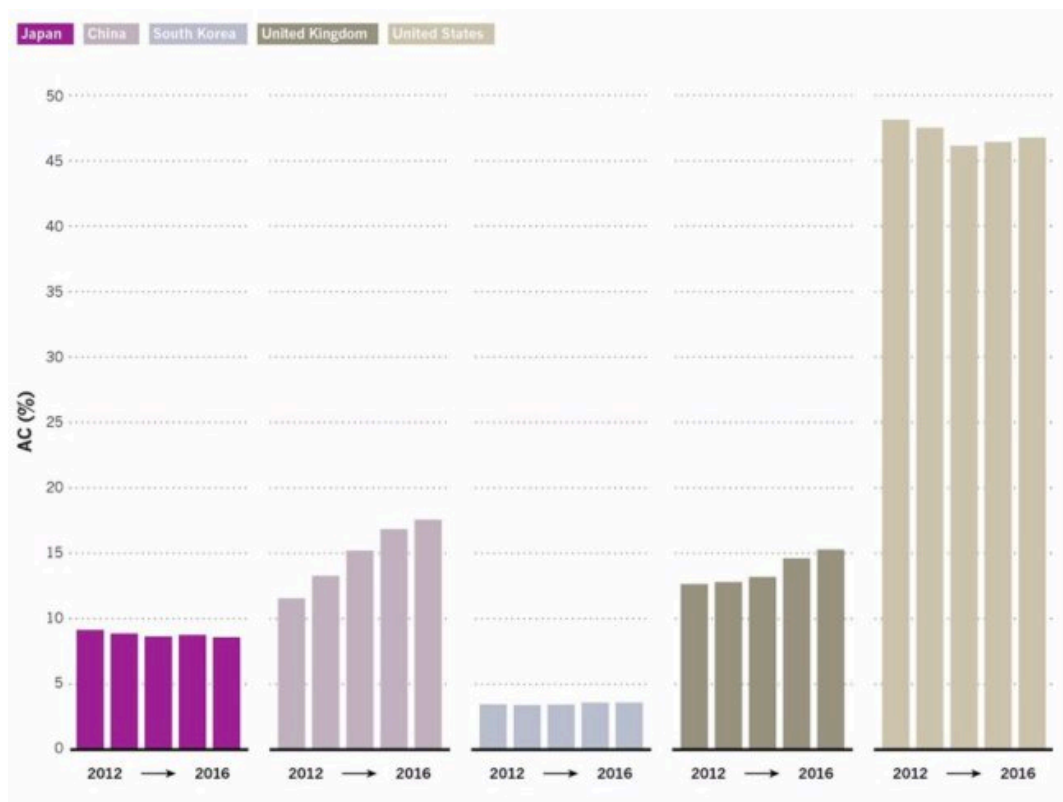
Japan Laser Processing Society (JLPS) is a good place to look for companies related to laser processing in Japan. There is information about 120 supporting members in English. The society is also an organizer of Laser Precision Microfabrication and Laser Advanced Materials Processing conferences³⁷ for when they happen in Japan. JLPS is headquartered in the Joining and Welding Research Institute at Osaka University.

Societies related to life science applications are laser surgery (JLSM) and laser dentistry (JSLD) (there are more associations in the file - "Photonics_Companies_&_Organizations_in_Japan.xlsx"). In Japan, there are only a few companies that are making laser surgery equipment. In this report, one company making lasers for dental treatment is Yoshida Dental.

The summary of the discussed organisations can be found in table 43 (chapter 6.2) and the extended list with additional information about all the 39 associations and societies in Japan, identified for this report, is in the file – "Photonics_Companies_&_Organizations_in_Japan.xlsx". The recommendation is to use the list of members to identify relevant companies. Another idea worth considering can be about becoming a member of the association or society. By being a member, the company could gain the possibility to learn about the industry and network with the potential partners. However, in the majority of cases, knowledge of Japanese language and an affiliate company in Japan is needed.

3. R&D AND UNIVERSITIES IN JAPAN

Even though Japan has many Nobel prize winners in physics and other sciences, according to Nature Index³⁹, a database that tracks the output of high quality research publications, Japan is falling behind every year⁴⁰. Some of the reasons are the declining number of young researchers and the funding, that since 2001 was dialled down, while elsewhere in the world budgets were growing steeply. Now the government tries to increase the funding and support for the top performing research groups, but for that to take effect some time will have to pass.

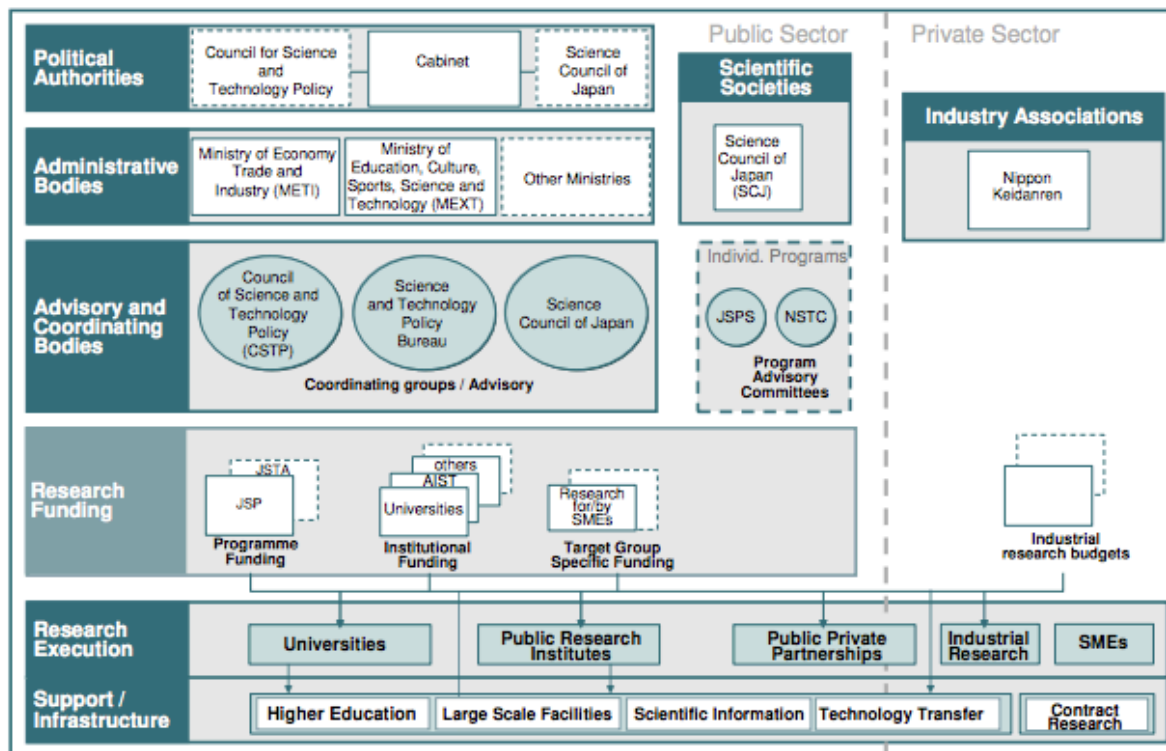


Graph 23 – Japan's share of high quality papers (AC) over the years, taken from the Nature index^{43, 153}.

According to MEXT analysis on Japan's R&D spending⁴¹, Japan is in the fourth place in 2014 by the amount spent on research, just behind US, EU and China. While EU, US and China spending are increasing, Japan's was not.

National Japanese R&D spending in 2015 amounts to 139 billion EURO (3.25% GDP) and private sector takes care of 70% of that amount. The private sector is the most important performer of research, significantly above EU and OECD averages. As a consequence, according to the 2015 research performance analysis⁴² by MEXT, Japan is surely in the second tier according to published papers but is on top of the game regarding the patents.

The top ten leading Japanese institutions⁴³ for high-quality science start from the University of Tokyo – the biggest university in Japan. Kyoto, Osaka and Tohoku Universities are in the second, third and fourth place respectively. RIKEN, Japan's leading research institute, is fifth, then follows Tokyo Institute of Technology (sixth), Nagoya University (seventh), Kyushu University (eight) and Hokkaido University (ninth). The National Institute for Materials Science is tenth.

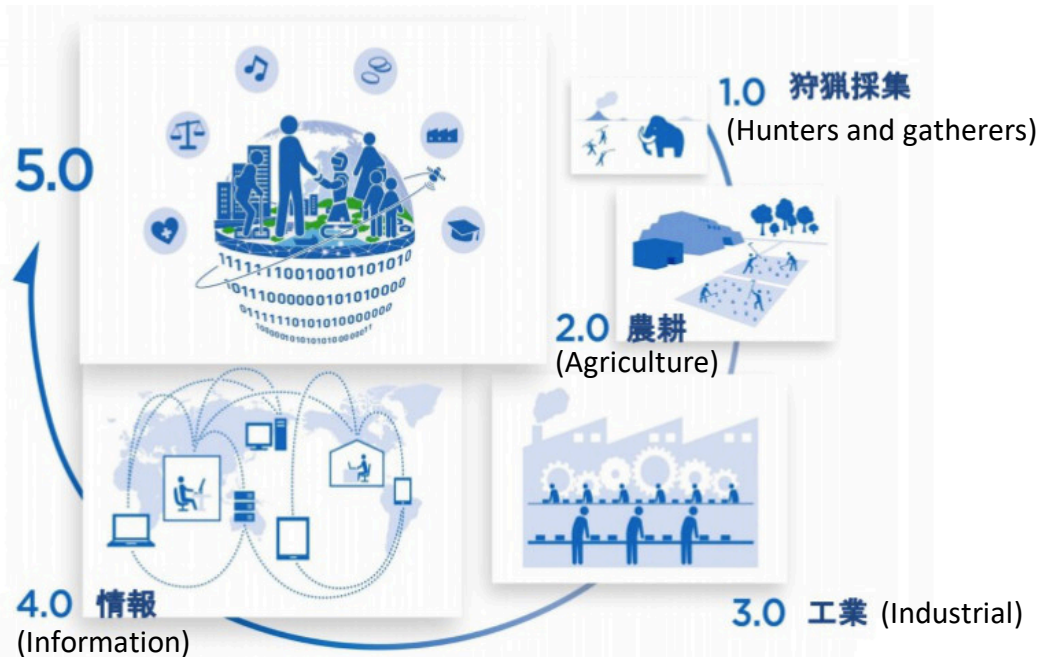


Picture 24 - Relevant decision structures of Japanese National Innovation System.

The structure of the innovation system in Japan can be seen in the picture above. It was covered in detail in the country profile report⁴⁴ from the ec.europa.eu. That report describes relevant decision makers in the Japanese innovation system – main ministries, research agencies and research institutions. Further on, in this chapter, organisations, institutes and universities, that are the most relevant to photonics for industrial manufacturing or life sciences will be introduced.

3.1. RESEARCH DIRECTION SETTING ORGANISATIONS

The first, at the top of the list, is the Cabinet Office⁴⁵, headed by the prime minister. They set the general R&D strategy. Description of Strategy on Science, Technology and Innovation for 2017⁴⁶ is a very general direction, emphasising society 5.0. Complementing it, there is a fifth science and technology basic plan⁴⁷ (2016 – 2020). The plan is prepared by the Japanese government in order to promote science and technology in Japan over a five-year term, based on a 10-year forward outlook.



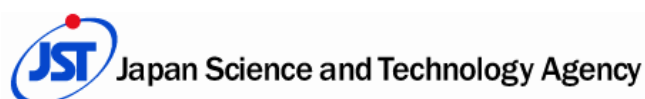
Picture 25 – Illustration of society 5.0, taken from the Cabinet Office homepage.

One of the main ministries further carrying out this plan⁴⁸ is the Ministry of Education, Culture, Sports, Science and Technology (MEXT) with the following research priorities:

- Aerospace
- Nuclear Energy
- Environment and Energy
- Ocean and Earth Science
- Earthquakes and Disasters Reduction
- Life Sciences
- Information and Communications
- Nanotechnology

3.2. RESEARCH FUNDING ORGANISATIONS

The direction that is set by the Cabinet and the ministries MEXT and METI is carried out through the research funding organisations.



Japan Science and Technology Agency (JST)⁴⁹, one of the main research funding agencies, is focused on the commercialisation of basic research results and research funding. The complete list of the projects can be found in the searchable database⁶² on JST website.

The research is divided into eight research programs⁵⁰: CREST, PRESTO, ACT-I, ERATO, ACT-C, ACCEL, ALCA and RISTEX. None of these research programs are directly related to photonics, however, some projects⁵¹ in 2017 under these programs were photonics related, for example:

CREST – team-based research program for a wide range of topics.

- “Advanced core technology for creation and practical utilization of innovative properties and functions based upon optics and photonics” by Ken-ichi Kitayama Professor, The Graduate School for the Creation of New Photonics Industries.

PRESTO – Precursory Research for Embryonic Science and Technology.

- “Optical control of biological functions for the elucidation of biological systems” by Yoshinori Shichida Visiting professor, Research Organization of Science and Technology, Ritsumeikan University⁵² / Professor Emeritus, Kyoto University.

ERATO – The Exploratory Research for Advanced Technology.

- “MINOSHIMA Intelligent Optical Synthesizer” by Kaoru Minoshima Professor, Graduate School of Informatics and Engineering, The University of Electro-Communications.

ACCEL research program aims to set a path to the next phase, such as company R&D, venture start-up and other public funding, based on the outputs of the Basic Research Programs (CREST, PRESTO, ERATO, etc.) that have the potential to be world-leading.

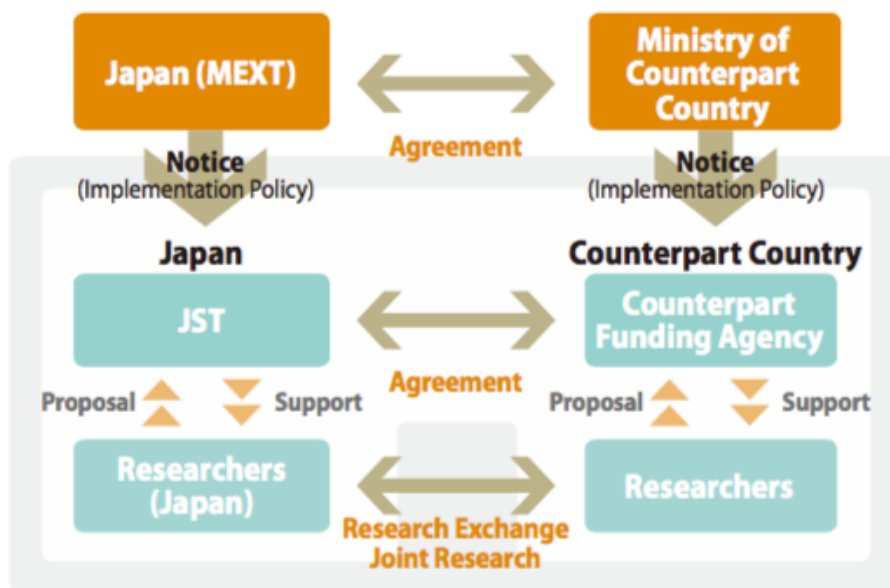
- “Development of High-Resolution LIDAR System based on Slow-Light Structures” by Toshihiko Baba Professor, Graduate School of Engineering, Yokohama National University⁵³.
- “Photonic Crystal Surface-Emitting Semiconductor Laser - Towards Realization of High Power and High Brightness Operation” by Susumu Noda Professor, Graduate School of Engineering, Kyoto University.

ALCA - Advanced Low Carbon Technology Research and Development Program.

- “Photon Management and Optical Engineering” by Kenji TANIGUCHI Specially appointed professor, Osaka University

JST Europe office in France⁵⁴ provides information about the international research programs, where joint Europe and Japanese teams can work together. There is one joint research area with Germany in optics and photonics⁵⁶ for 2018. Funding agency from the Germany side is Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research).

Regarding the joint project with EU, the funding is focused on power electronics and with different European countries, there are different agreements. For example, projects were with France for 2018 on Molecular Technology and in 2017 Finland just finished on Medical Science. You can browse these research programs^{56, 58} on the JST website.



Picture 26 - Jointly Europe and Japan funded research structure, taken from JST brochure⁵⁵.

JST also provides some useful resources. J-STAGE⁵⁹ is an electronic journal platform for science and technology information in Japan. It is basically a database of Japanese published scientific articles. JST has published there more than 2000 journals, conference proceedings and other academic publications.

Another useful tool from the JST is the Research map⁶⁰. It is a database of researchers in Japan. Interesting data there – the top five most popular areas for research are Informatics (4,3 %), Clinical medicine (4 %), Basic medicine (3,8 %), Literature (3,7 %) and Electrical engineering (3,1 %).

If a researcher is looking for a job or a project, there is a jREC-IN portal⁶¹ to look for the open positions at the Japanese research institutions. At the moment of writing, there were 260 open positions.



New Energy and Industrial Technology Development Organization⁶³ (NEDO) was established as a governmental organization in 1980 to promote the development of new energy technologies. Research and development of industrial technology were later added, and today NEDO is active in a wide variety of areas as one of the largest public research and development management organizations in Japan. For project activities, NEDO has a budget of just over 1 billion €.

The list of funded projects and technology description⁶⁴ is published in the website⁶⁵. The first five technology fields are related to energy and the last four to industrial technology. From the industrial technology group, three projects stand out:

- Development of next-generation laser technology with high brightness and high efficiency by Yohira Kobayashi (Associate Professor, The University of Tokyo)⁶⁶.
- Development and practical application of moulding technology for next-generation industrial 3D printers by Hideki Kyogoku (Professor, Kinki University Faculty of Engineering, Department of Robotics)⁶⁷.
- Development of ultra-low power optoelectronic mounting system by Yasuhiko Arakawa (Professor, The University of Tokyo)⁶⁸.

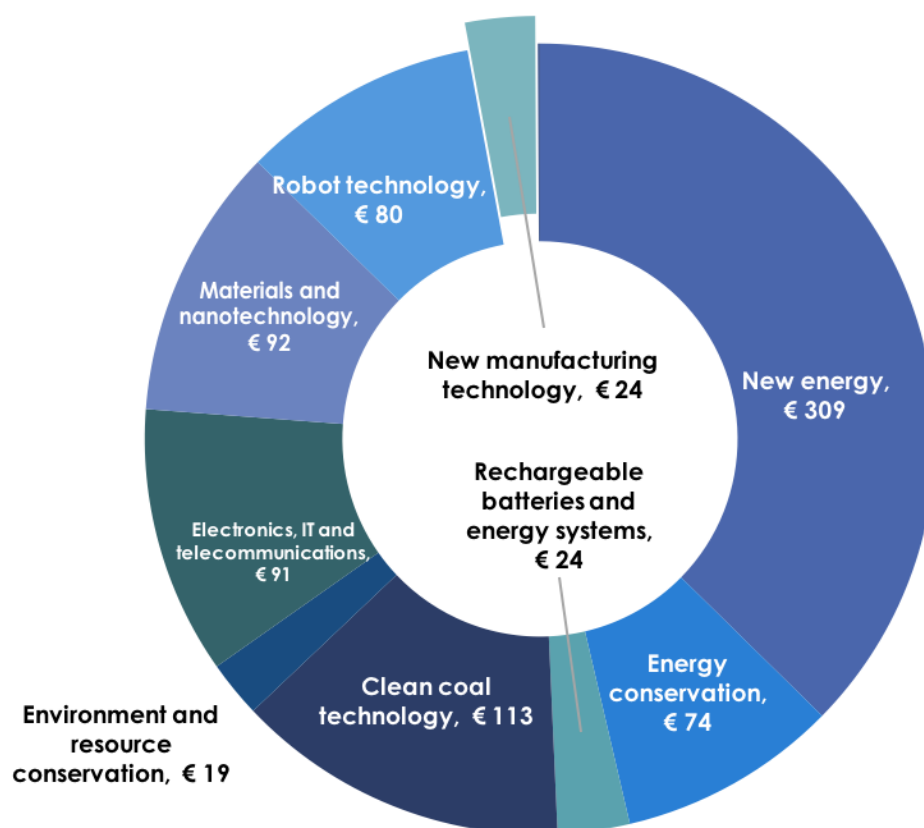


Chart 27 – Funds distribution at NEDO according to research area in millions.

In general, “New energy” has funds for photovoltaic projects. “Electronics, information and telecommunications” encompass optoelectronics and photonic integrated circuits research. “New manufacturing technologies” focuses on laser processing and 3D printing. The smallest, “Crossover fields”, is for sensor technologies.

From the international standpoint, NEDO has offices worldwide and runs projects⁷⁰ that bring Japanese technology to Europe, US and Asia, however, mainly in energy and robotics. The office in Paris⁷¹ is monitoring technology developments in Europe and representing Japan. NEDO is also active in Germany and in 2017 signed a

statement of intent⁷² with the German government to develop research funding programs to increase industrial competitiveness, especially relating to concepts of Industry 4.0 and Internet of Things.



Japan Society for Promotion of Science (JSPS) has the extensive list of funded programs and activities on their website⁷³. This society is not focused on natural sciences and engineering but has funds for international researchers wanting to do research in Japan in any area.

3.3. UNIVERSITIES AND INSTITUTES

There are a lot of research carrying out institutions – universities, institutes and research centers in Japan and they are spread throughout the country. However, there is the accumulation of them in Tokyo, Osaka, Ibaraki, Kyoto, Shizuoka and Saitama.

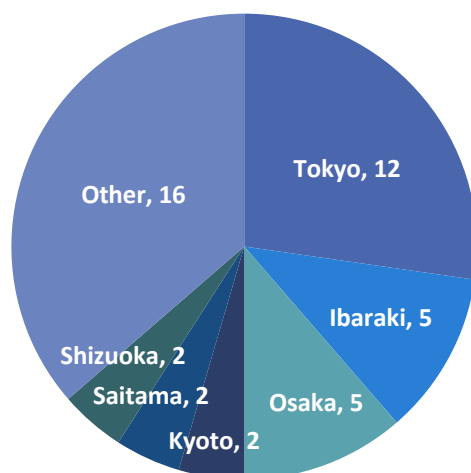


Chart 28 – Photonics related research institutions' distribution according to location.

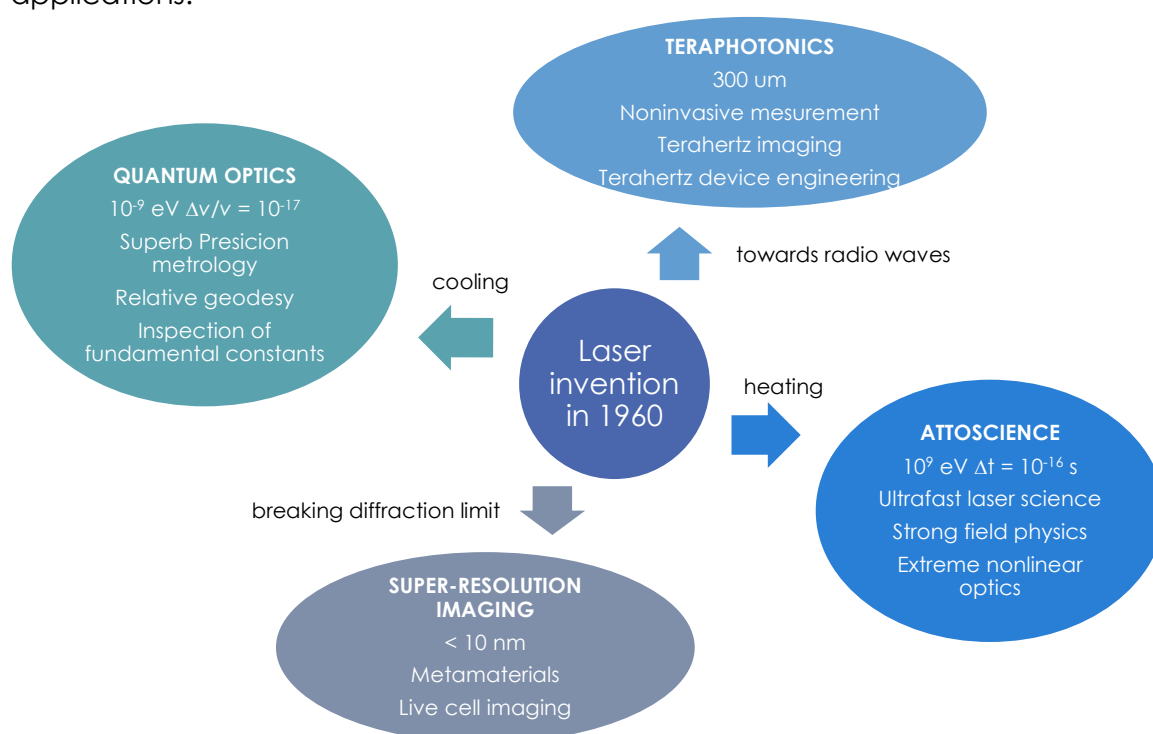
According to the research topic, they are also widespread, but from the conversations with the companies, the general description was that Osaka area (including Kyoto) is the centre for laser processing, Kyushu and south of Japan for medical applications. Shizuoka is tightly connected to Hamamatsu Photonics and that means various applications, mainly related to detection of photons. Ibaraki has AIST and Saitama – RIKEN. RIKEN is more related to attosecond lasers, THz and near field-optics while AIST to photonic sensing and communication. The summary of some university research can be found in table 44 (chapter 6.2).

3.3.1. RESEARCH INSTITUTES



RIKEN is Japan's largest research institution renowned for high-quality research in a diverse range of scientific disciplines. Founded in 1917 as a private research foundation in Tokyo, RIKEN has grown rapidly to a network of world-class research centers and institutes across Japan.

One of the main centers related to photonics is RIKEN Center for Advanced Photonics⁷⁴ (RAP). RAP focus areas are attosecond lasers, near-field optics, metamaterials and terahertz light. The work of the RAP focuses on practical applications.



Scheme 29 – Description of RAP research, from RAP brochure⁷⁷.

Center related to life sciences is RIKEN Center for Life Science Technologies⁷⁵ (CLST). CLST aims to promote research on biomolecules and life science technologies, focusing on 3 areas of research: designing molecular structures at the atomic level, manipulating molecular function at the cellular level and tracing molecular dynamics at the whole-body level. CLST comprises the Division of Structural and Synthetic Biology, the Division of Genomic Technologies, and the Division of Bio-function Dynamics Imaging.

RIKEN also has Chief Scientist Laboratories⁷⁶. These scientists form the core of RIKEN's interdisciplinary research system. They are appointed on a long-term basis to bridge gaps between disciplines and ensure that RIKEN positions itself as a pioneer in new

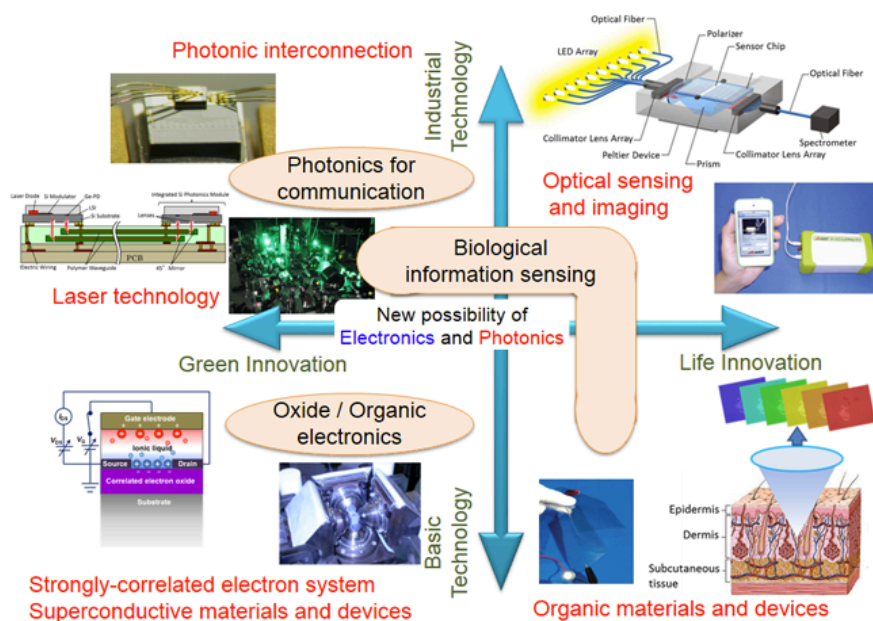
emerging fields. Out of 35 laboratories, 7 are related to photonics in the fields of atomic and molecular physics, quantum devices, nano-medical engineering, thin-films, spectroscopy and materials fabrication.

And then, higher up, there is Distinguished Senior Scientist Laboratories⁷⁸. They are set up and managed by particularly distinguished researchers with outstanding records and leadership ability. One of those laboratories is Structural Biology Laboratory lead by Shigeyuki Yokoyama.

For the research requiring global expertise, there is the Global Research Cluster⁷⁹.



The National Institute of Advanced Industrial Science and Technology (AIST) is one of the largest public research organizations in Japan. As per AIST description, it focuses on the creation of technologies useful to Japanese industry and society, and on bringing innovative technological seeds to commercialization. AIST is organized into 5 departments and 2 centers and has about 2000 researchers doing research and development at 10 research bases⁸⁰ across the country.



Picture 30 – Key research areas of AIST ESPRIT institute, taken from the ESPRIT website.

One center related directly to photonics is Electronics and Photonics Research Institute⁸¹ (ESPRIT). It consists of 140 researchers from a wide range of research fields. ESPRIT collaborates with industry and does research and development on optical information technology, applied photonics and future electronics.

Key research groups at the institute are Optical Information and Communication Technology⁸², Photoinduced Process and Optical Sensing⁸³ and Emerging Electronics⁸⁴.

AIST is also actively developing international relationships and has already signed⁸⁵ about 14 MOUs with different European research institutions.



Japan Atomic Energy Agency (JEA) with the Applied Laser Technology Institute is developing laser-based techniques in the field of nuclear engineering and various techniques for advanced industrial technology⁸⁶. The primary research topics are related to laser processing and processing modelling, sensing through optical fibres, medical laser applications and LIBS.



In laser processing field, in Osaka, apart from the university, worth the mention is Institute for Laser Technology. It is a private institute doing research and services for business. Established by professors from Osaka University. LIDT and laser micromachining process development are some of the services for the industry. Some of the research activities are fs micromachining, white light LIDAR and laser biotechnology. This institute has a strong industry support⁸⁷.

3.3.2. UNIVERSITIES



The University of Tokyo established in 1877 as the first national university is one of the biggest and the leading research institutions in Japan. There are many laboratories at different institutes and centers working with photonics in this university. It is also the university with the greatest number of start-ups coming out of it, including technical ones. The University of Tokyo also has a venture capital fund.

Institute for Photon Science and Technology⁸⁸ and Photon Science Center⁸⁹ are initiatives supported by MEXT to promote collaboration and photonics research at the University of Tokyo. The research is in atomic and molecular physics, lasers and interferometry, quantum computing and attosecond science.

School of Engineering⁹⁰ has groups working with physics and technology of nanostructures, quantum computing and laser spectroscopy. While Research Center for Advanced Science and Technology⁹¹ has laboratories related to nanofabrication, measurement methods⁹² and biophysics⁹³.

Innovation based on coherent photon technology (ICCPT)⁹⁴ is a joint initiative by the University of Tokyo, Mitsubishi Electric and Toray. The focus is on novel laser processing technologies.

The University of Tokyo Graduate School of Science and Technology has a Center for Ultrafast Intense Laser Science⁹⁵ to promote photonics related research. One⁹⁶ of the laboratories at the center is doing research on molecular imaging and spectroscopy for life science.

At the Institute of Industrial Science of the University of Tokyo⁹⁷, there is a Center for Photonics Electronics Convergence. One of the highlights is Professor Arakawa⁹⁸. He is doing research on quantum dots and quantum dot lasers – more energy efficient, compact and less temperature dependent lasers. After joining forces with Fujitsu in 2004 they developed the laser and in 2006 set up a company – QD Laser, that is one of the few laser makers in Japan. Other laboratories also work on nanostructures, THz photodynamics, photochemistry, holographic memory and spin manipulation.

The Institute for Solid State Physics has a Laser and Synchrotron Research Center⁹⁹ with 12 laboratories. Research is on physical properties using photoemission spectroscopy, surface & nanometre-scale physics, quantum wire lasers, electronic structure, spin characteristics, ultrafast optical sciences, synchrotron enabled research, terahertz science and cryogenic ultra-high energy resolution laser angular resolved photoemission.



Osaka University is another university that has a strong foothold in the photonics science in Japan. Being around the industry, it is one of the strong centers for laser research for material processing and high energy lasers.

First of all, the university has the Photon Science and Technology Division joining various laboratories at the university and outside. The list¹⁰⁰ of partners in this division include 15 departments and organisations from wide ranging fields – from laser development, THz to various medical and biological applications.

Photonics center¹⁰¹ at the Osaka University has more than twenty research laboratories and numerous businesses conducting research¹⁰¹ on photonics. Center is also organising the photonics days¹⁰² to promote new developments and start-ups in the area.

Institute of laser engineering at Osaka University in 2015 got into news¹⁰³ when they have fired 2 petawatt laser pulse – the world's most powerful laser pulse at LFEX facility in the institute. The institute has over 12 laboratories¹⁰⁴ doing research in diverse fields.

One famous research facility of this institute is developing laser nuclear fusion reactor and technologies.

From the aspect of laser technologies for industrial manufacturing applications, the Joining and welding research institute is one of the leaders in the country. The central part is the department of laser materials processing¹⁰⁵. This institute is doing research in laser processing from the mid 1960 and is one of the pioneers in Japan¹⁰⁶.

For the medical research, the university has Graduate school of frontier biosciences, Graduate school of medicine and Graduate school of dentistry. Also, to help and promote the collaborations, Osaka University has an affiliate¹⁰⁷ in Groningen, Netherlands.

The University of Electro-Communications

The University of Electro-Communications is a 100 years old technical university in Tokyo with the centers for laser, life sciences, communication, energy and space research.

Institute for Laser Science¹⁰⁸ is developing a wide variety of light sources, including ceramic lasers. Also, carries out a wide-ranging fundamental and applied research including atomic optics and research of extreme physical properties using high-output lasers.

Advanced Ultrafast Laser Research Center¹⁰⁹ pursues optical cellular imaging using high-performance lasers with groups from the University of Tokyo Graduate School of Medicine and the Hiroshima University Graduate School of Science.

Center for Photonic Innovation¹¹⁰ is bridging the gap between the basic research results and the practical technology.



Kyoto University does not have a separate laser or photonics research institute, but at the Graduate school of engineering, there is a Photonics and Electronics Science and Engineering Center¹¹¹ and at the Graduate School of Science, research¹¹³ topics are on quantum optics, nanophotonics, spectroscopy and laser-matter interaction¹¹³.

Worth the mention is that Kyoto is also home to Shimadzu, Horiba and some other big companies. And for international researchers' university has the Hakubi Project¹¹⁴ where it supports the research activities of top level researchers from around the world.



KYUSHU
UNIVERSITY

At the Kyushu University, relating to photonics is the Faculty of Science with the Laboratory for Optical Condensed Matter Physics¹¹⁵ that studies the interaction of light with magnetic materials by using a femtosecond laser.

And at the Center for Organic Photonics and Electronics Research is the famous laboratory of Chihaya Adachi & Hajime Nakanotani¹¹⁶ very well known for its research on OLED technology.



OIST

The Okinawa Institute of Science and Technology Graduate University has four research groups working in the field of photonics and is a very international university with over half of the faculty and students recruited from outside Japan, and all education and research are conducted entirely in English.

The research¹¹⁷ is on quantum systems, femtosecond spectroscopy, optical neuroimaging and light matter interaction. In Okinawa, there is also small photonics industry with Shibuya corporation's laser processing¹¹⁸ equipment factory.



光産業創成大学院大学

The Graduate School for the Creation of New Photonics Industries

The Graduate School for the Creation of New Photonics Industries¹¹⁹ is the new university in Japan related to photonics. It has been founded by Hamamatsu Photonics with Shizuoka University and Hamamatsu University School of Medicine. It is the initiative from the Hamamatsu Photonics to strengthen the photonics industry in Japan and especially around the Shizuoka area where Hamamatsu Photonics originated. The research is conducted in the fields of laser processing, optical communication, energy, biotechnology and medical. Also, Shizuoka University has an exchange agreement with the University of Applied Sciences in Jena, Germany in the optics related fields.

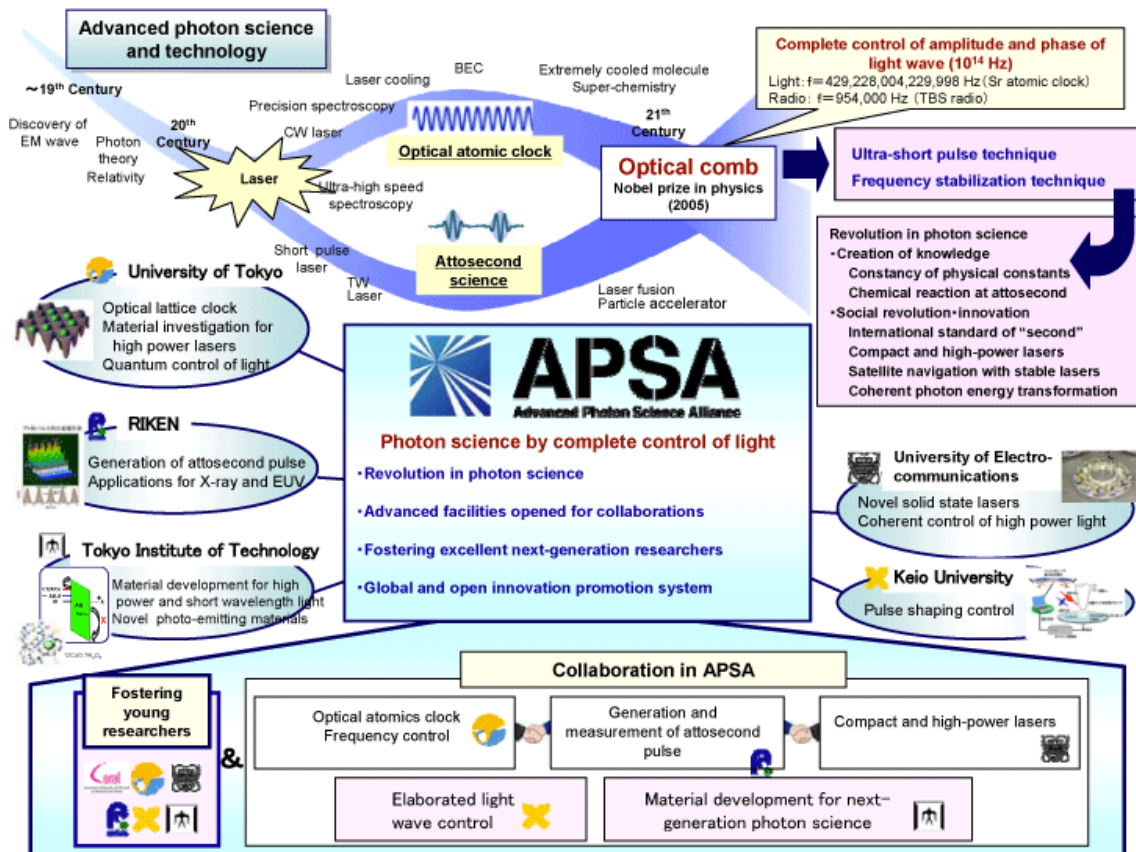
3.3.3. GOVERNMENT INITIATIVES

In Japan, photonics is not one of the top focus areas for the government and there are not many government funded projects compared to Europe, where photonics is one of the key enabling technologies. However, the government still tries to develop photonics technologies and the research around it.



Recognising the importance of photonics, MEXT has created the Photon Frontier Network¹²⁰ and says – “Photon science and technology is the platform upon which so

much of our society is built: matter and materials, biotechnology, information-communication, manufacturing, and more. This makes it a key technology, crucial to future innovation and enhanced industrial competitiveness. Japan recognizes the vital importance of research and development in the photon science and technology field and is dedicated to its strategic and constructive promotion.”



Picture 31 – Description of APSA activities, from APSA homepage.

Photon Frontier Network program has two specific objectives: to progress development of advanced light sources and measurement methods and to improve the quality of education and research in photon science and technology. There are two consortiums that are executing this program – Advanced Photon Science Alliance¹²¹ (APSA) that includes Riken, The University of Electro-Communications, Keio University and Tokyo Institute of Technology.



Another center is Consortium for Photon Science and Technology¹²² (C-PhoST) with Osaka University, Kyoto University and Institute for Molecular Science (National Institutes of Natural Sciences). The research focus of C-PhoST is in the four following areas – terahertz, high power lasers, infrared light sources and device development.

3.3.4. CLUSTERS AND SCIENCE PARKS

Since 2000 Japanese government has been encouraging cluster development in Japan to increase international competitiveness and strengthen regional industries. As a result, there are many clusters and science parks. EU-Japan Centre for Industrial Cooperation has done a detailed analysis¹²³ of it and this information is available at www.eubusinessinjapan.eu. Currently, there are no photonics clusters in Japan, but many related to medical applications. The one initiative worth the mention is Photonics World Consortium¹²⁴. It is an organisation promoting research in several areas including biophotonics, fibre lasers for sensing and medical applications. Clusters can be useful if thinking about setting up operations in Japan, they provide infrastructure and usually have incentives.

3.4. R&D PUBLIC PROCUREMENT ANALYSIS

Japan has a very big network of research institutions and aiming to be at the forefront, many of them are purchasing photonics products. This chapter presents analysis on recent public procurements organised by Japan's public research institutions. The information can be useful to understand what kind of equipment organisations are buying, who are the main suppliers and amounts involved.

The data was gathered using a quick scan service¹²⁵ by the EU-Japan Centre's for Industrial Cooperation Tax and Public Procurement Helpdesk. This service allows scanning recent public procurements with up to 10 keywords. The scan is done on the titles of the calls only and the following keywords were used.

Japanese	English
分光器	spectroscope
分光計	spectrometer
フェムト秒	femtosecond
テラヘルツ検出器	THz detector
パルスレーザー	pulse laser
レーザーシステム	laser systems
レーザー加工機	laser processing machine
光学素子	optical elements
光学系	optical system

Table 32 – Keywords used for the quick scan.

Results do not include repair (修理), maintenance (保守) and lease (賃貸借). The analysis found the total of 7389 calls over the available period. The details of the procurements were available only from the top 20 most recent calls of each keyword and the amount for these calls was 1,9 billion JPY (about 16 million EUR). The majority of the procurements were for the spectrometers and lasers.

Over seven thousand calls were found for all available period and 931 calls for the year 2017. For 2017, the distribution is very similar to the total calls and the demand looks to be relatively stable.

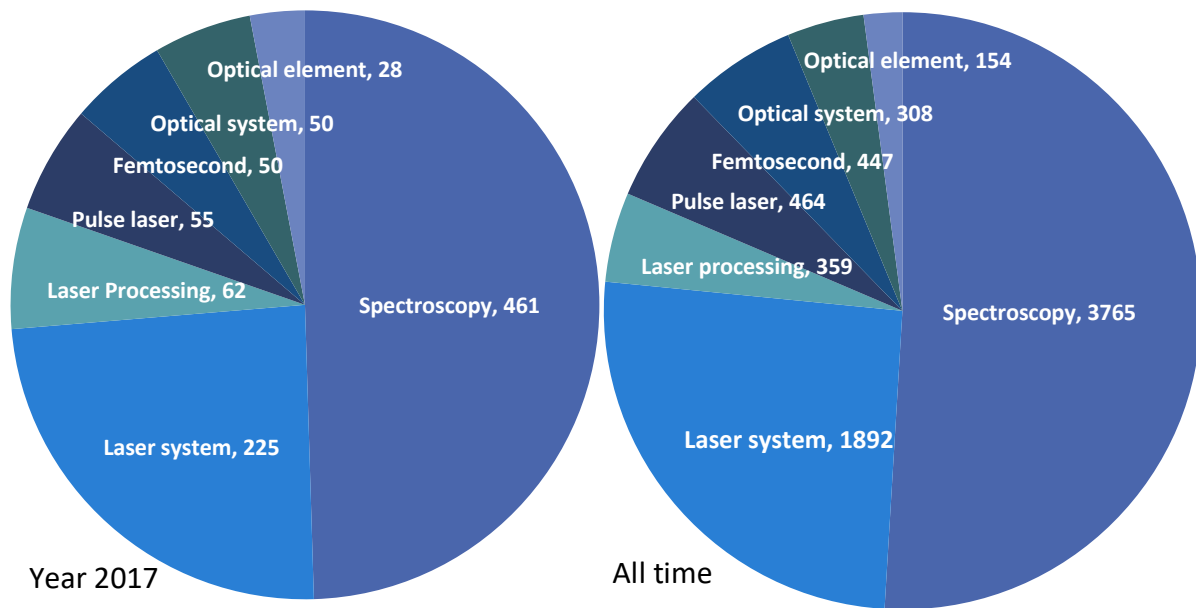


Chart 33 – Distribution of the number of procurements for each keyword.

Prefecture	Calls	Prefecture	Calls
Tokyo	26	Fukuoka	12
Hyogo	24	Aichi	9
Ibaraki	23	Osaka	8
Kyoto	14	Saitama	6

Table 34 – Highest number of calls by prefecture.

The best performing prefecture by the number of calls is unsurprisingly Tokyo, but almost the same amount of calls is also in Hyogo and Ibaraki. In Hyogo, there is a Riken Harima Institute and in Ibaraki - National Institute of Advanced Industrial Science and Technology (AIST). These are the two biggest institutes in Japan.

Institution & calls		mln. JPY	Institution & calls		mln. JPY
University of Tokyo	7	233	Kyushu University	8	38
RIKEN	23	210	Tokyo Institute of Technology	5	33
AIST	21	183	JAEA	4	9
Kyoto University	7	181	JAXA	2	9
Osaka University	4	87			

Table 35 – Organisations that spent the most on procurements.

There were 63 unique organisations that have purchased photonics related products. From those, 9 organisations take almost 50% of the amount of all the calls – 967 million JPY (about 8 million EUR if 120 JPY is 1 EUR).

For the “femtosecond” group the top buyers were RIKEN Harima and AIST institutes. In the “pulse laser” group, top buyers were AIST and Kyoto University. In the “optical

element" group top buyers were again RIKEN Harima, JAEA and also AIST. For the "spectroscopy", most calls were announced by Kyushu University and Tokyo Institute of Technology.

If looking at the biggest purchases by the amount of JPY, there are several leaders and, in the top, are the following:

- Femtosecond OPCPA system suite (68 990 400 JPY) for University of Tsukuba sold by Luxree Corporation.
- Integrated femtosecond titanium sapphire regenerative amplifier (58 479 408 JPY) for National Institute of Advanced Industrial Science and Technology (AIST) sold by Spectra Physics Corporation.
- Ultra-short pulse wavelength tunable laser system set (47 492 892 JPY) for Kyoto University sold by Spectra Physics Corporation.

Spectra Physics is quite often among other big purchases. If looking at the companies that won the most calls, in the top five, that all won more than 100 calls this year, the first is JASCO Corporation – the spectrometer manufacturer. The second is Coherent Japan – an affiliate of Coherent from the US. And the third place is for Spectra Physics Japan. Then, Nikon INSTEC – one of the biggest distributor of optics, laser and scientific equipment. And Rika Ikeda rounds up the top five, this company is another trading company with 365 employees and 41,8 billion JPY annual sales. The top 50 company list can be seen in the table below.

Name and calls won		Name and calls won	
JASCO Corporation	175	KS OLYMPUS CORPORATION	26
Coherent Japan KK	139	Shinko Seiki Co.	26
Spectra Physics Corporation	136	Kozu Seiki Co.	26
Nikon INSTEC Co.	114	Advantech Toyo Corporation	24
Rika Ikeda Co.	103	Southern Medical Science Co.	24
Tokyo Instruments Inc.	83	Kawasaki Heavy Industries	23
Riken Corporation	77	Spectroscopic Instrument Co.	23
JUSCO Support Co.	60	Ikeda Science Co.	23
Japan Laser Co.	59	Rika Yoshiya Co.	22
Indeco Co.	53	Ocean Photonics Corporation	22
Shimadzu Science West Japan	51	Towa Science Co.	22
Hamamatsu Photonics Corporation	46	Hitachi High-Technologies	20
Kanto Bussan	43	Kirk Co.	20
JEOL	43	Nisshin Machinery Corporation	19
Olympus Medical Science Sales Co.	42	Eta Shokai Co.	19
Masaki Corporation	39	Hitachi Capital Corporation	19
AOBA SCIENCE INCORPORATED	38	Japan Roper Corporation	19
PhotoTechnica Co.	38	Chiyoda Science Co.	19
Takeda Rika Kogyo Co.	37	Art Science Co.	18

Pune Corporation	35	Yamato Science Corporation	18
Tohoku Electronics Industry Co.	35	Yushu Scientific Instruments Co.	18
Toyama Corporation	33	Riho Pharmaceutical Co.	17
Raycher Systems Co.	32	Sun Instruments Co.	17
Miyano Medical Treatment Co.	32	Shimadzu Corporation	17
Wako Pub	28	Los Angeles Corporation	17

Table 36 - Top call winners by selected keywords.

Participating in the public procurement in Japan without the help of the local company is very difficult, though not impossible. The process of public procurement is well described by Lyckle Griek, who runs the Japan Tax and Public Procurement Helpdesk¹²⁶. Since, for most companies the best way would be to use the help of some local partner, below is the list of top distributors.

Name	Calls won
Nikon INSTEC CO., LTD.	114
Rika Ikeda Co., Ltd.	103
Tokyo Instruments Inc.	83
Japan Laser Co., Ltd.	59
Indeco Co., Ltd.	53
Kanto Bussan Ltd.	43
Masaki Corporation	39
AOBA SCIENCE INCORPORATED	38
PhotoTechnica Co., Ltd.	38
Takeda Rika Kogyo Co., Ltd.	37
Pune Corporation	35

Table 37 – List of top distributors according to the won tenders.

The majority of the trading companies at the top are big ones with a wide product portfolio. Some exceptions are – Tokyo Instruments, Japan Laser and Phototechnica. As it appears, in Japan there is little local competition for the items related to the keywords used for this research – lasers, optics. And the opportunities are open for the overseas companies, the important points are to build good relationships with the local partners, choose them wisely and work with them closely.

4. EXHIBITIONS, CONFERENCES AND EVENTS

Japan is a country where building a trusting relationship, before doing a business, is very important. To initiate those relationships, Japan has to offer many industry events – exhibitions and conferences, not to mention small society and association meetings that are happening all around the country.

During the research, 36 various exhibitions and over 20 conferences were identified in Japan that are related to photonics for industrial manufacturing and life science applications. In addition, some of the organizations do matchmaking and company visit events that can be another good opportunity to meet potential partners and learn about the industry. The visitor count is approximate – just for the event size description.

From the graph below it is clearly visible that manufacturing applications are dominating the space – though the range for manufacturing is wide, from automotive to batteries, precision manufacturing and 3D printing. Exhibitions included in each sector can be found in the file – “Photonics_Events_in_Japan.xlsx” with the complete list of events.

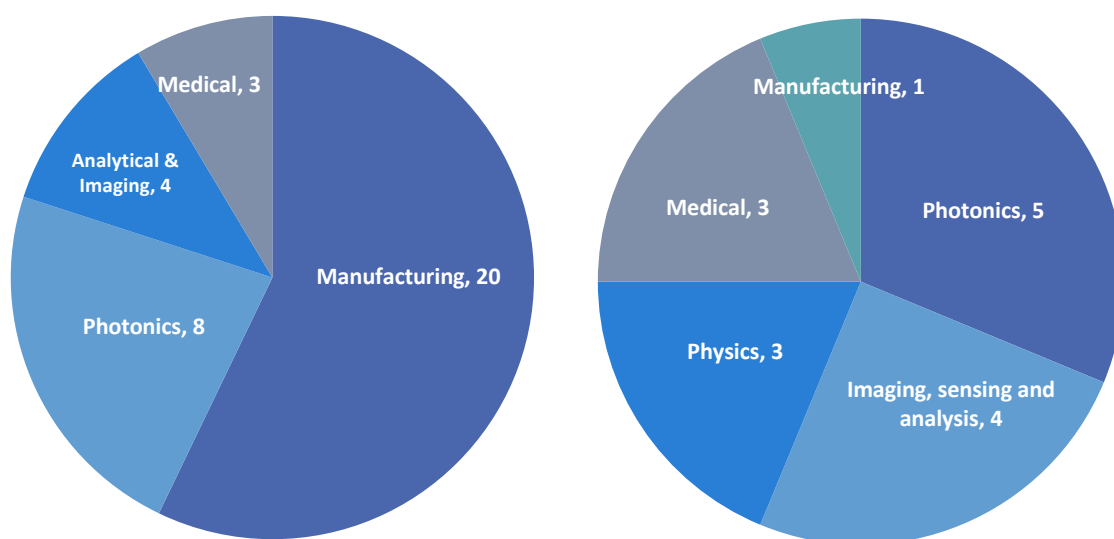


Chart 38 – Exhibition (left) and conferences (right) distribution according to the topic.

With the conferences, the picture is very different. The dominating topics are related to photonics, imaging, sensing & analysis, physics and medical. These clearly are not all the conferences, but the ones that were either recommended by companies who participate there as a sponsor, through associations or that were visible from international organizations like OSA and alike. There are a number of conferences that are local and only in Japanese, most of these are not included in the list.

Another interesting aspect looking at the events was the location. In both, conferences and exhibitions, Tokyo was dominating. For the conferences, locations are very spread out, it is either Tokyo or all around the country. For the exhibitions, it is

also spread out, but some centers can be distinguished. Tokyo, Yokohama and Chiba are big exhibition centers in the Kanto area. Other local centers are Osaka and Nagoya a bit south from Tokyo and Fukuoka in the southern island of Kyushu. These areas are also relevant to photonics, as industries are also noticeably concentrated there.

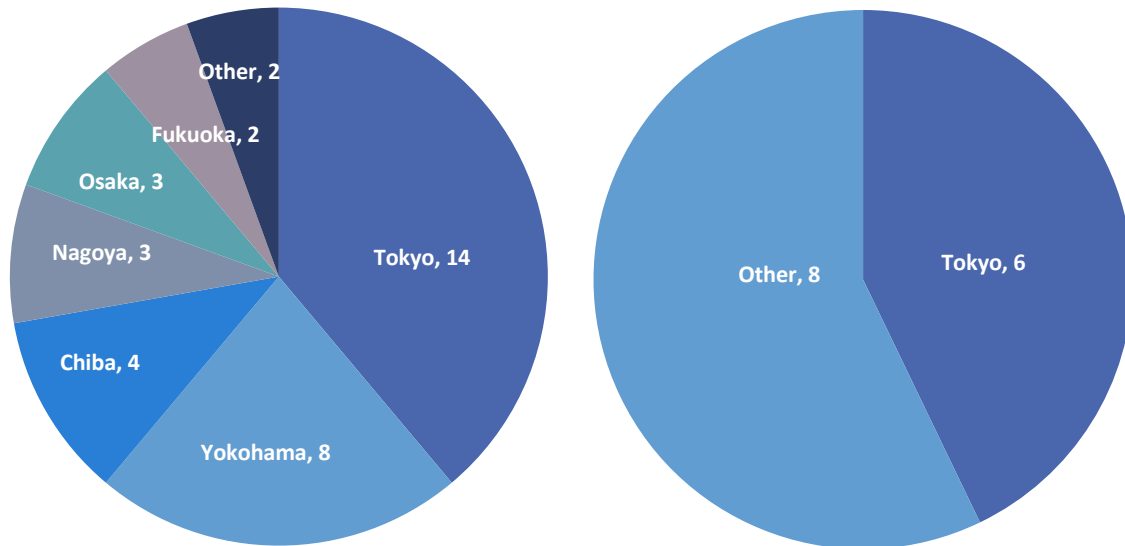


Chart 39 – Exhibitions (left) and conferences (right) according to location.

4.1. EXHIBITIONS

Looking at the exhibitions, the biggest ones are related to manufacturing and are general, meaning that many different technologies are displayed, and a wide range of companies participate. But because Japan is a country with a lot of manufacturing, it is a good place to learn about this wide industry. The biggest exhibitions for manufacturing attract 90 to 150 thousand visitors and are located around Tokyo or Nagoya.

The biggest, by the official number of visitors – 67 thousand, from the photonics exhibitions is the Fiber Optics Expo. This exhibition is concurrent with three other Expos and the visitors interested in fibre optics part are less. Fibre optics is a big industry in Japan¹²⁷, for example, of Japan's 38,7 million fixed broadband subscriptions, 75% were fibre. This is one of the highest percentages in the world. And there are many big companies involved with fibre optics like NTT, NEC, Fujitsu and Sumitomo, most of them are the exhibitors.

Another big exhibition is LED Next Stage – dedicated to LED technology, big industry in Japan. According to the OITDA yearly market reports, the display and solid-state lighting field was the biggest industry in the optoelectronics field, even though it declined by more than 12% in 2016. This exhibition attracts about 60 thousand people in Tokyo. However, the exhibition is completely focused on the end products and not the development or manufacturing and is concurrent with other events.

Then follows Photonix – this exhibition consists of 3 different parts, specializing in laser processing, optics and optical measuring/analytical technology. The total number of visitors is usually around 59 thousand. However, it is also a concurrent event with LCD/OLED/Sensor Technology Expo, Highly-functional Film Expo, Highly-functional Plastic Expo, Highly-functional Metal Expo, Highly-functional Ceramics Expo, Adhesion & Joining Expo, Highly-functional Paint & Coatings Expo. Photonix visitor's count is joint for all the exhibitions, so almost 60 thousand people came to the venue, but it's unknown how many came intentionally to Photonix. A look at the exhibitors' list can help to decide if it is worth to participate, but the majority of people at this exhibition will not be there for Photonix.

In all industry related events, mentioned in this report, technologies related to photonics were exhibited. For Semicon, technologies for inspection, wafer dicing and processing were from companies like Lasertec, Mitsubishi, Accretech and Disco. At Nepcon, companies like Amada Myachi, DMG Mori, Mitsubishi and other manufacturers of laser processing equipment were exhibiting. There were also some distributors and laser manufacturers like Japan Laser and Coherent. At the Jewellery exhibition, only a small area was dedicated to the manufacturing technologies where a laser is also an important tool. Top laser tool producers commented that for them it was a rather important industry because, for expensive pieces of jewellery, manufacturers like to use the reliable equipment.

Battery Japan is also the event that is focused mainly on the end product and not the manufacturing or development. However, major Japanese battery manufacturers do exhibit there, and it can be useful to talk to them. The Nanotech Japan was a good place for the certain type of photonics products. From the photonics, there were companies related to imaging, precise laser processing and polymerization. Many companies from Europe participated either in the country, EU or individual booths.

After seeing those big industry events and discussing it with the companies, the general advice is to visit these industry events with the goal to learn about the industry and not to sell. It is really interesting to see what the application market looks like, but participants at the exhibitions are dominatingly from sales and there is very rarely someone from engineering or development at the booth. The entry to almost all the exhibitions is free and if you are in Japan, this is a cost effective and good way to see the industry and get some contacts.

Below, in more detail, are the five exhibitions related only to photonics, but for a wide range of applications, including medical and industrial manufacturing. The participants and visitors are interested in the displayed technology for their applications and it is worth to exhibit at these shows. The favourite show for most of the companies was Optics and Photonics International Exhibition (OPIE) concurrent with 14 scientific sub-conferences in diverse photonics areas.



Picture 40 – Top photonics exhibitions in Japan.

OPIE and OPIC conference are in April every year. The location is usually Pacifico Yokohama with about 15 thousand expected visitors. The exhibition consists of Laser Expo, Lens Expo, IR+UV Expo, Industrial Camera Expo, Medical & Imaging Expo, Space & Astronomical Expo and Positioning Expo. Concurrently Optics and Photonics International Congress with 14 sub-conferences will happen and this combination usually attracts many of photonics companies from Japan and overseas^{128,129}.

Photonix – International Laser and Photonics Expo, if looking only at the number of visitors, this is the biggest photonics exhibition in Japan with almost 60 thousand participants. However, as indicated previously, the visitor count is collective for 8 Expos. Looking at last year's exhibition it can be seen that many of the main companies, active in photonics area, were present – overseas companies, distributors, local components and systems manufacturers. This event in December takes place at the Makuhari Messe conference center in Chiba.

All about Photonics (InterOpto, LED Japan, Imaging Japan) is another exhibition dedicated to photonics in October. It is expected to have 4600 visitors and the venue is Makuhari Messe. This exhibition is organized by OITDA – an optoelectronics association of Japan. One feature of this exhibition is that it is concurrent with the CEATEC Japan – a 150 thousand visitors' technology and IOT exhibition. That should attract some additional participants and at CEATEC it is definitely possible to find device producers that are dependent on photonics. Another concurrent show with this is MEMS Sensing and Network systems. Even though All about Photonics is

concurrent to some of the biggest exhibitions in Japan, it is clearly not a very big photonics exhibition.

The Science Photonics Fair is an exhibition at the Science Museum in Tokyo in November. It is a small exhibition (4400 visitors) organized by the company Optronics. There are 6 parts to this exhibition, namely – Infrared, Optical thin films, Spectroscopy, UV, Laser science and technology, Optics and Laser lighting. This exhibition is small but specialized with distributors and local manufacturers in each of those categories participating. It is not very international, but a good place to meet smaller local manufacturers. Some of the distributors bet big on this exhibition.

4.2. CONFERENCES

Out of 17 conferences related to photonics, with 7 of them, there is a sponsoring opportunity and the small exhibition. In Japan, there are many conferences happening each year and 17 is definitely not the total number of conferences that will happen in 2018, but the selected ones represent the situation well. Japan is also a place for some bigger international photonics conferences, in 2017 Japan held the following events – OSA Laser Congress, The 24th Congress of the International Commission for Optics and the 18th International Symposium on Laser Precision Microfabrication.

With the sponsoring opportunity in 2018, there are:

- JSAP Spring Meeting (by Society of Applied Physics) – March, Tokyo
- CSJ Annual Meeting (by Chemical Society) – March, Tokyo
- Annual meeting of The Pharmaceutical Society of Japan – March, Kanazawa
- The 43rd Optical Symposium – June, Tokyo
- The 57th Annual Conference of Japanese Society for Medical and Biological Engineering – June, Sapporo
- The 41st Annual Meeting of the Japan Neuroscience Society – July, Kobe

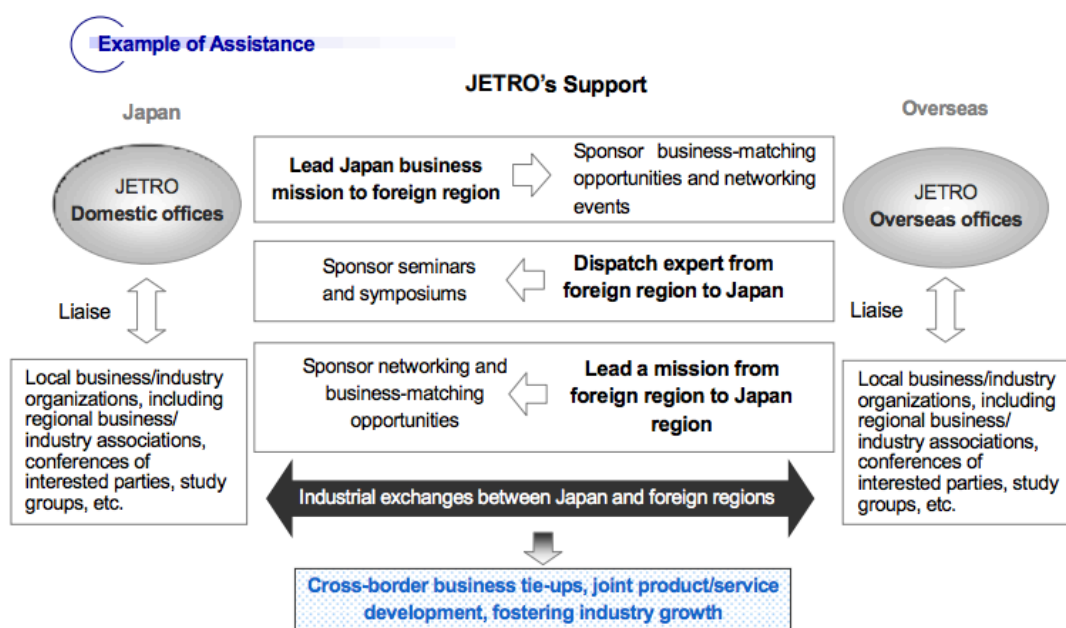
At the exhibition part of these conferences, SMEs can meet many companies related to photonics – JASCO, Shimadzu, Hamamatsu, Hitachi, Spectra Physics and Coherent. For example, during the JSAP spring meeting, there were over 100 participants at the exhibition, including many of the distributors and overseas companies related to photonics. The exhibition is not at all busy but is well targeted towards academia customer.

4.3. BUSINESS EVENTS

Another kind of events happening in Japan is the match-making and company visits organized by JETRO, SME Support Japan and the EU-Japan Centre for Industrial Cooperation. These organizations help SMEs find partners in Japan.



JETRO has a Regional Industry Tie-up (RIT) program¹³¹. In the framework of it, JETRO organises business delegations to and from Japan as well as networking events. Since JETRO has offices worldwide, they can gather businesses from abroad to visit local businesses in Japan. The activity is represented in the scheme below.



Picture 41 – Description of JETRO Regional Industry Tie-up (RIT) program.

This activity of JETRO has some success stories¹³² and if the reader would like to participate, the best approach would be to contact the local JETRO office¹³³.



SME Support, Japan has a similar program and also a database of companies in Japan that are interested in international collaborations.

The match-making part is CEO Network Enhancing Project¹³⁴. SME Support, Japan organises events in major cities throughout Japan for SMEs seeking overseas expansion and CEOs from abroad seeking partnerships with Japanese companies. This project focuses on building relationships between Japanese SMEs and overseas companies through company visits, 1 on 1 business meetings, lectures and networking events.

The database of businesses is called J-Good Tech¹³⁵. It is an online business matching platform (available in English) with Japanese SMEs. After identifying a potential partner SME Support can assist with the match-making process. The quick search in the database for various laser and optics keywords gave relevant results.



The EU-Japan Centre for Industrial Cooperation also offers business missions to Japan for EU SMEs wanting to exhibit at the conference and have meetings with the companies or organizations in the industry. This support with meetings, interpreters and participation at the exhibitions is very helpful. At the moment, there are missions related to ICT, Nanotechnologies, Biotechnologies and Food & Drinks.

Currently, the most relevant to photonics is the Cluster Support Mission on Nanotechnologies, but just for a specific type of applications. However, since photonics is one of the key enabling technologies in Europe and Japan imports a lot of its photonics technologies, especially components like lasers and optics, it can be worth to organize a mission around photonics too. The information about the many of EU-Japan Centre services to business can be found on the Centre's website¹³⁶.

4.4. RECOMMENDATIONS

From the conversations with the companies and personal experience, the advice is to take big industry events like Semicon or Nepcon as a good place to learn about the industry that is applying photonics for their products, but the exhibitors are rarely interested in another kind of partnerships than a sale. And the visitors to these shows are usually from the industries that use the exhibited tools. Often it is not useful to participate with the booth without the solutions directly for the target industry.

Clearly, the best place to exhibit in Japan is photonics exhibitions. The industry favourite is OPIE in April in Yokohama with concurrent conferences on a wide range of photonics related topics.

Regarding conferences, in this report, you will find a list of 7 conferences for 2018 that allow sponsorship with the exhibition. The biggest one from the conferences is JSAP Spring Meeting in March in Tokyo with around 100 exhibitors. Conferences with sponsorship opportunities are a good place to reach a specific academic audience.

As for government supported company visits and partnership building events, JETRO and SME Support do not seem to organise industry specific events, however, it might be possible to organise them with the help from a big and relevant overseas industry organisation. As mentioned above, the EU-Japan Centre for Industrial Cooperation organises industry specific events and participation at the industry exhibitions, but for now, there is no event related to photonics. The most relevant for photonics technologies is the Cluster Support Mission on Nanotechnologies. It is well worth the

consideration for the photonics companies with technologies applicable to nanotech, as for example 3D polymerisation, very precise laser patterning or imaging.

It would also be very useful to have an EU supported photonics mission to the exhibition like OPIE, where most of the Japanese industry professionals gather. This exhibition is concurrent with several quality conferences and the audience is high quality.

Lastly, it is very important to have the information about the industry before going to an event to build partnerships. Japan is a big market, but it is a must to know where the offered solution fits in and what unique value brings to the table to find Japanese counterparts interested in the offer.

5. CHALLENGES AND OPPORTUNITIES

5.1. WHY GO TO JAPAN?

Overall, Japan is an attractive market. It still holds big global share in photonics and is becoming more open for collaborations. Big corporations want to stay on top and are looking for investments to fuel the growth. The market size, emerging openness and dynamic photonics industry can surely benefit innovative EU companies in Japan.

If taking into account the production done overseas, the Japanese global market share in 2015 is over 30%. A big part of a production by Japanese companies is done in China and other countries. However, even though the production value related to photonics in Japan is already not among the top biggest markets, Japan is important because apparently, the decision makers with the R&D centers are still in Japan. Successful projects in Japan could guarantee the choice of supplier in the countries where the actual manufacturing is being done.

At the first glance¹³⁹, the Japanese market usually appears to be difficult to understand. The language barrier is challenging to overcome, people do things “the Japanese way,” and regulations create a labyrinth designed to protect domestic companies. However, Japan offers great opportunities for the companies with attractive and competitive products and starting a company can be no more difficult than anywhere else.

In Japan, Trumpf, the largest industrial laser systems manufacturer, is growing for more than 50 years already (since 1977) and when the company's president, Hartmut Pannen was asked by Yokohama government about the business in Japan, the answer¹⁴⁰ was straight - “Except risk of exchange rate fluctuations and earthquakes, everything in Japan is OK”. For Trumpf, in the beginning, Japanese market size was more attractive than anything else. Also, Japanese staff proved to be superb. Since 2008 Trumpf also opened a production facility in Fukushima.

Another example is from Toptica, that in 2016 also have opened an office in Japan. Thomas Renner, executive VP sales and marketing of Toptica Photonics said¹⁴¹: “Japan has always had strategic importance for us because of the density of high tech industries and academic research centers. We purchase many of our strategic components in Japan and also have close contacts with Japan's world-leading scientific and technology experts.”

Edmund Optics in Japan also has¹⁴² a production facility and office for many years now. It is one of the important markets and Japan accounts for a big part of the revenue in Asia and is growing in double digits still.

Worth remembering is that there is a big number of photonics distributors and overseas companies' subsidiaries in Japan – many photonics technologies are imported from overseas. For example, top laser manufacturers are Trumpf, Coherent, IPG Photonics and Spectra Physics – not the Japanese companies.

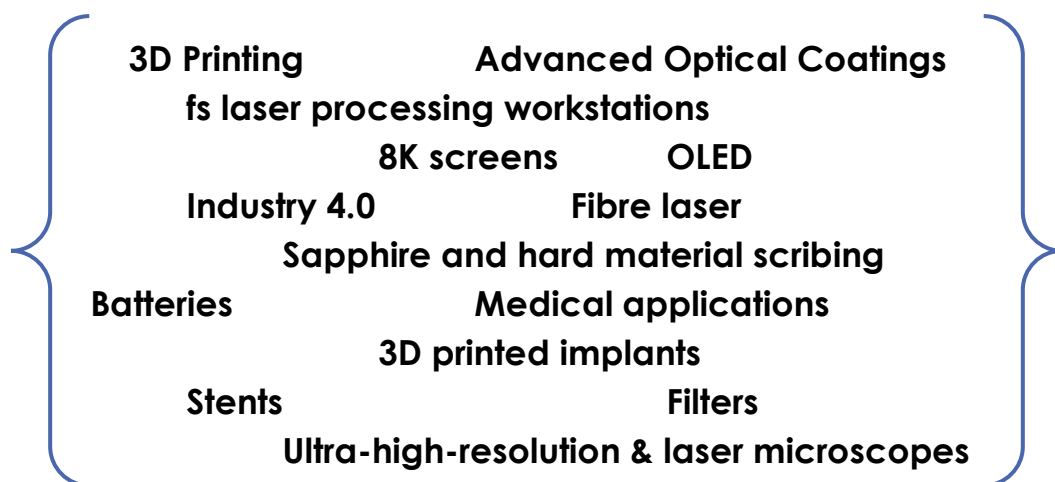
5.2. THE BIG CHALLENGE

The keyword related to doing business in Japan is patience¹⁴³. SMEs have to be patient, have time and resources available. Most probably, the entrance to the market will not be fast nor cheap and will require effort. Generally, it is usually best to grow enough at home market before getting to Japan.

The first thing to overcome in Japan is a different culture. There are a lot of studies and reports on that already. The EU-Japan Centre for Industrial Cooperation also provides training¹⁴⁴ for executives. The very last report¹⁴⁵ on this topic by the EU-Japan Centre "From Understanding to Navigating Japanese Business Culture" can be found on the Centre's website. The American Chamber of Commerce in Japan also confirms¹³⁹ that with proper research and knowledge Japan is a great market to go after. The key to being successful in Japan, many experts insist, is accepting that it takes meticulous preparation and hard work. While this is definitely true anywhere, the difference in Japan is the price for mistakes.

5.3. THERE ARE OPPORTUNITIES

Both material processing and life science & medical related photonics markets have opportunities in Japan. Life science & medical industry is a big priority set by the government and industrial manufacturing is historically a huge industry, that is on the wave of converting to use a laser as a tool for traditional and novel applications.



Picture 42 – Some of the industry trends in Japan.

Since Japan has a small amount of local laser and other photonics technology producers, this market is mainly served by overseas suppliers or big Japanese companies developing technologies in-house, but then it is hard to be competitive

and they are realising that. According to some local fibre laser producers, IPG Photonics in Japan has around 70% of the fibre laser market.

The bigger challenge is to work with the Japanese partner to do product or technology developments and not just sell the ready product. This was reported to be a much more difficult task. Generally, Japanese companies are more willing to get the full solution.

As was found during the research, in Japan the biggest concentration of photonics companies is in the Kanto area, around Tokyo. Other centers are the Kansai area (around Osaka), Shizuoka with Hamamatsu and up north – Aichi. The main sector according to the applications is related to laser processing equipment, then optics and general laser products and equipment. From the life science area, the biggest groups are related to spectroscopy solutions and imaging. Also, many more companies are related to industrial manufacturing versus medical applications. In this report, the ratio is 152:29. However, the novel medical applications are noticeably increasing.

5.4. R&D IS THE ENTRANCE

There is a big number of universities and institutes in Japan related to photonics. For most distributors, academia is usually as important a customer as the industry. According to the public procurement analysis in this report, top purchasing institutions were the University of Tokyo, RIKEN, AIST, Kyoto University, Osaka University, Kyushu University, Tokyo Institute of Technology, JAEA and JAXA. In the recent years the funding was dialled down but the dropping R&D quality in Japan recently made the government pour more into the research, it is still slow, but the effect is already visible.

Also, for 2018 JST has a joint research funding program with the German counterpart for optics and photonics⁵⁶. Other opportunities for joint research might also open up.

As for private R&Ds, there are many research centers in Japan active in photonics. Many of the Japanese companies that do the manufacturing overseas, keep their research activities in Japan. R&D stage is one of the best ways to enter the company with the proposal. When the product is "on the shelf" companies are very reluctant to change anything even though the price or specs are much better. From the R&D to "the shelf" in Japan on average takes no less than 2 years, so the patience is required. Japanese companies are still investing a lot in R&D and the focus on quality is still prevalent.

The person to approach in the company is usually the engineer as they are the decision makers and carry the responsibility. Therefore, it is a mistake to focus on the management only, with the approval from the engineer, the management will usually go along. And being clear about why the Japanese company has to choose the solution is important, as R&D in Japan is often at the forefront. To be sure that the

Japanese company is not just interested in benchmarking, an offer to sign an NDA is a good test.

The one widely heard optimistic confirmation was that Japanese companies are getting more and more open to collaborations. For many of the industries, to be competitive now it is not enough to do everything in-house and an increasing number of Japanese companies are realising that.

As for start-ups, the scene in Japan is growing too. The majority of technology start-ups in Japan come from universities and the University of Tokyo is by far the biggest producer of start-ups. Some of the start-ups are interested in partnerships and knowledge from overseas.

The associations and societies are a good place to identify target companies. Later maybe joining a society could be a way to build new relationships.

5.5. START WITH DISTRIBUTORS

One of the easiest ways to get started in Japan is to work with a distributor. In the file – "Photonics_Companies_&_Organizations_in_Japan.xlsx", there are over 50 to choose from and chapters about distributors and public procurement analysis can help to make the choice. There are many success stories with distributors^{141, 154, 155} and they can do a really good job. However, it is very important to work closely with the partner to support the customer. It is also expected to visit customers a few times per year, attend the exhibitions with the distributor and be effective with the support.

Big subsidiaries tend to focus on big accounts and many suppliers treat Japan as any other market, so there is still a niche where good and fast support with the quality product can go a long way. If it is possible to service products at the customer site, without shipping them overseas, by having trained engineers at the distributor, it is an advantage. Products that are easy to service, like being modular, can also make it easier.

One way to provide a better support is to agree with the distributor to employ one of the supplier's engineers in Japan, that he could be on site to help the customers anytime. This is a great opportunity for distributors and suppliers, as distributors have an advantage in front of the customer and supplier's engineer can learn about the industry from the front seat. Moreover, this will check the distributor's commitment.

5.6. ENTER JAPAN

If having the distributor is not enough anymore, it is a time to set up an office. Japan is encouraging foreign investments and there are resources that can help. JETRO and EU-Japan Centre for Industrial Cooperation both have services^{147, 148} for foreign SMEs to help set up¹⁴⁹ operations in Japan and navigate the legal labyrinth or get the benefits of incentives. EU-Japan Centre even offers¹⁵⁰ free office space for the first few

weeks. These organisations also organise missions to visit enterprises and events in Japan, this can be a great first step.

As for exhibitions, there are a lot of them in Japan. Big industry exhibitions like Nepcon, Semicon or Nanotech are a good place to learn about the end product industry, but not for selling. Except for Nanotech, where photonics companies could offer, for example, precise 3D polymerisation or laser patterning solutions. The best exhibition to go with photonics is OPIE and hopefully the EU may be able to offer support here in the future with a separate mission to Japan.

The big challenge of setting up in Japan will be to hire competent employees, so the best is to stick with the distributor and make them the partner. Jenoptik Japan did this with their distributor Kantum Electronics. It is important to be creative.

5.7. M&A IS OFTEN THE WAY

If looking at the deeper partnerships, Japan seems to prefer the way of acquiring the partner and then figuring out the way of working together, especially if the company size difference is big. This is especially true when Japanese companies go overseas. It is rare for them to set up operations themselves, Japanese companies usually acquire operations overseas and start from that.

Big companies like Sony or Panasonic have centers overseas from where they look for technologies that could complement the portfolio. Sony in Stuttgart has a Technology Partnership Europe group that does just that. Smaller companies like Hamamatsu, also have partners, such as universities²² or venture firms. Or they use their subsidiaries to find interesting technologies that could be useful.

In general, it is advisable to start the approach to Japanese company through the subsidiary in Europe, from the research of this report, 40% of Japanese companies have some kind of presence in EU.

5.8. WORK IN JAPAN?

Finally, many of the smaller Japanese companies confirmed that there is a shortage of good photonics specialists in Japan, especially for the smaller companies, as big corporations take the majority of the graduates. And as it is known well, the population in Japan is not in the growth stage. Many of these companies now would consider foreign professional employees.

6. USEFUL INFORMATION

6.1 LIST OF SOME ENGLISH – JAPANESE TRANSLATIONS

フォトニクス (photonics)
度光産業 (optoelectronics industry)
技術 (technology)
産業 (industry)
機器 (machinery or tool)

レーザ (laser)
フェムト秒 (femtosecond)
パルスレーザ (pulse laser)
レーザシステム (laser systems)
レーザマーキング (laser marking)
レーザ機器 (laser equipment)
レーザ加工機 (laser processing machine)

分光器 (spectroscope)
分光計 (spectrometer)
テラヘルツ検出器 (THz detector)

オブティクス (optics)
光学 (optics)
光学素子 (optical elements)
光学製品 (optical product)
光学システム (optical system)
光学ミラー (optical mirror)
レーザレンズ (laser lens)
光学薄膜 (optical thin film)
コーティング (coatings)
薄膜製品 (thin film product)
結晶 (crystal)
プリズム (prism)
非球面レンズ類 (aspheric lens)
波長板 (waveplate)

6.2. USEFUL LINKS AND RESOURCES

http://www.laser-concierge.com/category_index.php

Laser concierge website contains information about lasers, instruments, optics, and equipment with information about who are the suppliers in each category in Japan. English version is not complete, so it is suggested to use Japanese version.

<http://www.laser-platform.com/member/>

The LPF association provides a nice list of companies and what type of processing technologies they are using.

<http://www.opt-bg.jp/>

A search portal to find domestic and overseas companies in Japan, done by Optronics. Companies that participated at OPIE are included.

<https://jgoodtech.jp/pub/en/>

It is a service by the SME Support, Japan that lets find companies open for collaboration with overseas. The search for "laser" gave relevant results.

<https://www.eu-japan.eu/>

<https://www.eubusinessinjapan.eu/>

Both of these websites are from the EU-Japan Centre and contains a lot of information about Japan and the services available for the EU SMEs and Japanese companies. You will find information about various industries, information about missions to Japan, other events and much more.

<http://linx.jp/company/partner.html>

Linx is a distributor for imaging systems, like industrial cameras, 3D sensors and other. In their website they provide a big list of integrators that they use throughout Japan.

At least these following companies have offices in Japan and it could be helpful to consult with them before setting up operations in Japan – Coherent, Ophir, Spectra Physics, Edmund Optics, JenOptic, IPG, Trumpf, Precitec, Amplitude Japan G.K., Oxford Instruments, PI, Laserline, Lumentum, Novanta, Thorlabs, CEA Leti, Fraunhofer, Gooch & Housego, Chroma Technology, Toptica and Teraview.

<https://researchmap.jp/search/>

A tool by JST that allows to search a researcher database in Japan.

<https://jrecin.jst.go.jp/seek/SeekTop?ln=1>

Job portal for researchers to find open positions in Japan.

Where to find events:

<https://spie.org/conferences-and-exhibitions?SSO=1>

<https://www.osa.org/en-us/meetings/>

<https://www.jetro.go.jp/en/database/j-messe/>

[http://www.lsj.or.jp/LSJHP/LSJhtml/LSJHP20\(Calendar\).html](http://www.lsj.or.jp/LSJHP/LSJhtml/LSJHP20(Calendar).html)

<http://www.optronics-media.com/event/>

General Electronics Associations		Members
JEITA	https://www.jeita.or.jp/cgi-bin/member/list.cgi?l=en&k=0	379
JPCA	https://jpca.jp/jpca_about/members/	374
Photonics Associations		
OITDA	http://www.oitda.or.jp/main/act/ssupporter.html	76
JOEM	http://www.joem.or.jp/kokai_members.htm	28
PETRA	http://www.petra-jp.org/organization.html	14
Laser Processing Associations		
TRAFAM	https://trafam.or.jp/top/about/member/	37
LPF	http://www.laser-platform.com/member/	21
NGLPTR	http://www.laserprocessing.jp/aboutus	7
Another Photonics Associations		
JOMA	http://www.j-oma.jp/summary/memberlist.html	30
JLEDS	http://www.led.or.jp/jleds/member.htm	50
JOGMA	http://jogma.jp/contents/	11
Distributors	http://www.adcom-media.co.jp/jial/	29
Life Science Related Associations		
MTJAPAN	https://www.mtjapan.or.jp/jp/mtj/en/memberlist.html	76
JIRA	http://www.jira-net.or.jp/e/outline/member.html	192
JOIA	https://www.joia.or.jp/english/members/	130
JMOIA	http://www.jmoia.jp/aboutjmoia/members.html	26
Societies		
LSJ	http://www.lsj.or.jp/LSJHP/LSJhtml/LSJHP24(Sponser).html	90
TFSE	http://www.otfse.org/members.html	145
OSJ	http://myosj.or.jp/en/member/	34
JPC	http://j-photonics.org/aboutjpc/sponsor/	38
JLPS	http://www.jlps.gr.jp/eng/membership/index.html	120
JSLT	http://jslt.jp/link.html	90

Table 43 – List of the described associations and societies with the links of where to find the members' list and how many members each organization have. The complete list of associations is in the file – "Photonics_Companies_&_Organizations_in_Japan.xlsx".

The University of Tokyo
Laser developments, laser processing, laser spectroscopy, nano structures, biophysics, THz and other research areas.
Osaka University
Laser developments, laser processing, biophysics, THz and other research areas.
The University of Electro-Communications
Ceramic, other laser developments and other research areas.
Kyoto University
Laser processing, spectroscopy, nanophotonics and other research areas.
Kyushu University
Material, OLED and other research areas.
Okinawa Institute of Science and Technology
Spectroscopy, neuro-imaging, light-matter interaction and other research areas.
The Graduate School for the Creation of New Photonics Industries
Laser processing, biotechnologies, medical and other research areas.

Table 44 – Summary of research topics at some universities that are relevant to photonics for industrial manufacturing and life science applications.

6.3. LIST OF ABBREVIATIONS

AIST - The National Institute of Advanced Industrial Science and Technology
APSA - Advanced Photon Science Alliance
C-PhoST - Consortium for Photon Science and Technology
CAGR - compound annual growth rate
CEO – Chief executive officer
CLST - RIKEN Center for Life Science Technologies
CMOS - Complementary metal oxide semiconductor
CSJ – Chemical society Japan
CT – computed tomography
EPIC - The European Photonics Industry Consortium
ESPRIT - Electronics and Photonics Research Institute
EU – European Union
EU-Japan Centre – EU-Japan Centre for Industrial Cooperation
GDP – Gross domestic product
ICCPT - Innovation based on coherent photon technology
ICT – Information and communication technologies
IPG – IPG Photonics
IT – information technology
JAXA - Japan Aerospace Exploration Agency
JEA - Japan Atomic Energy Agency
JEITA - Japan Electronics and Information Technology Industries Association
JETRO – Japan external trade organization
JIAL - Japan Importers Association of Lasers and ElectroOptics
JIRA - Japan Medical Imaging and Radiological Systems Industries Association
JLEDS - Japan LED Association
JLPS - Japan Laser Processing Society
JMOIA - Medical Optical Equipment Manufacturers Association
JOEM - Japan Optomechatronics association
JOGMA - Japan Optical Glass Manufacturers' Association
JOIA - Ophthalmic Instruments Association
JOMA - Japan Optical Measuring Instruments Manufacturers Association
JPC - Japan Photonics Council
JPCA - Japan Electronics Packaging and Circuits Association
JSAP – Japans society of applied physics
JSLD – Japan society for laser dentistry
JSLSM – Japan society for laser surgery and medicine
JSPS - Japan Society for Promotion of Science
JST – Japan science and technology agency
LCD – Liquid crystal display
LD – Laser diode
LED – Light emitting diode
LIBS – laser induced breakdown spectroscopy
LIDT - Laser induced damage threshold
LPF - Laser Platform Association
LSJ – Laser society of Japan
M&A – Merger and acquisition
MEXT - Ministry of Education, Culture, Sports, Science and Technology
MITI - Ministry of International Trade and Industry
MOU – Memorandum of Understanding

MRI – Magnetic resonance imaging
 MTJAPAN - Medical Technology Association of Japan
 NDA – non-disclosure agreement
 NEDO - New energy and industrial technology development organization
 NGLPTR - Next-generation laser processing technology research association
 NIR – Near Infrared
 NMR – Nuclear Magnetic Resonance
 OCT – Optical Coherent Tomography
 OECD – Organization for Economic Co-operation and Development
 OITDA - Optoelectronics industry and technology development association
 OLED – Organic LED
 OPIC – OPTICS & PHOTONICS International Congress
 OPIE - Optics and Photonics International Exhibition
 OSA – The optical society
 OSJ - The optical society of Japan
 PET – positron emission tomography
 PETRA - Photonics Electronics Technology Research Association
 PIC – Photonic Integrated Circuits
 R&D – Research and development
 RAP – RIKEN Centre for advanced photonics
 RIT - Regional Industry Tie-up
 SDR – International Monetary Fund special drawing rights
 SME – Small and medium enterprise
 SPM – Scanning probe microscope
 TFSE - The Optical Thin-Film Science and Engineering Group
 TRAFM - Technical Research Association for Future Additive Manufacturing
 US – the United States of America
 UV – ultra violet
 VCSEL - Vertical-cavity surface-emitting laser
 VP – vice president

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