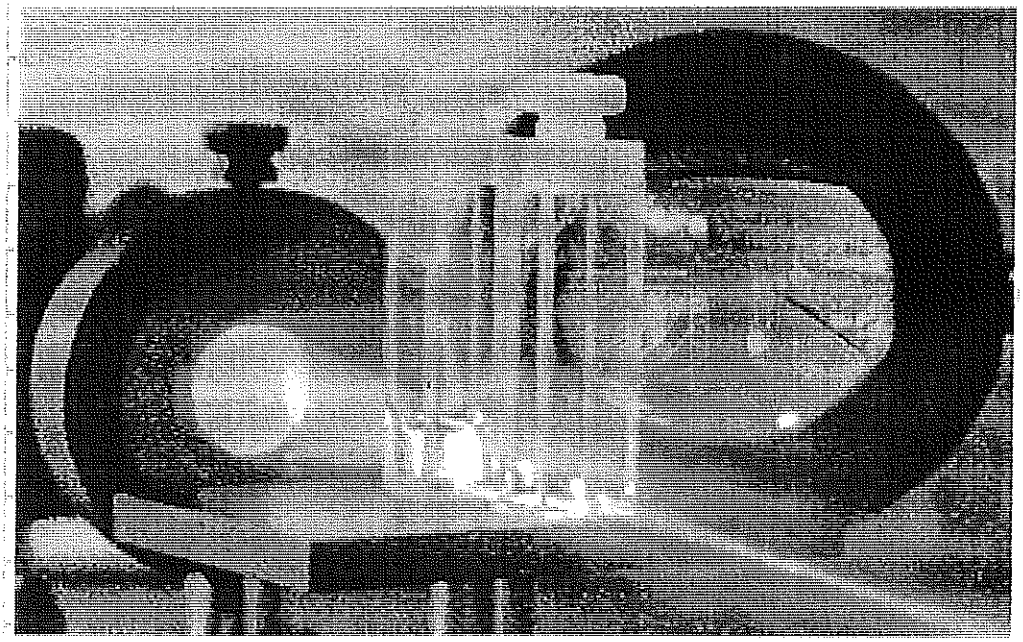
Critical Technology Assessment of the U.S. Optoelectronics Industry



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Critical Technology Assessment of the U.S. Optoelectronics Industry

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EXECUTIVE SUMMARY

- The purpose of this critical technology assessment is to provide policy makers in Congress and the Executive branch with information and analysis on the current technology status, economic performance and global competitiveness of firms in the optoelectronics sector. The majority of information for this report was obtained from a written survey of 368 U.S. companies involved in various optoelectronic activities. The survey was conducted by the Department of Commerce, Bureau of Export Administration (BXA) between October 1997 and April 1998.

- This study is a follow up to BXA's previous February, 1994 Critical Technology Assessment of the U.S. Optoelectronics Industry. Similar questions were asked in both industry surveys, enabling BXA to obtain data showing long term changes in the industry.

- Optoelectronics, for the purposes of this assessment, was broadly defined as systems, equipment, and/or devices which emit, modulate, transmit, and/or sense light or are dependent on the combination of optical and electronic devices. In the current technology-driven markets, optoelectronics are fairly ubiquitous; numerous products appear in communication, computer, business equipment, industrial, medical, transportation, military and consumer categories.

Optoelectronics Technology

- Many consider optoelectronics as today's enabling technology, especially considering this decade's explosive growth in information exchange and the plethora of data that quickly threatens to overwhelm available storage technologies. Electronics, once the future of every new improvement, is starting to take a back seat as the photonics part of optoelectronic technology surges steadily forward, revealing its vast potential.

- One opto-technology driver is the Internet, which has spawned many new trends, including increased use of electronic banking and on-line shopping. The escalating volume in phone and Internet traffic has pushed telecommunications networks into the realm that only optical fiber, with its much wider bandwidth, can satisfy. For audio and video, with increasing public demand for enhanced storage capability and increasingly graphics-laden products, again the solution is optical technology, with the prevalent media items like compact discs and the newer DVDs.

- Great strides are being made in a number of areas. For example, refinements in manufacturing and design have made flat panel displays better and cheaper. Once used only in military and high-cost business equipment, high resolution displays are now turning up on a number of consumer goods, like personal digital assistants, cell phones and pagers. There is a new market in digital cameras, and lightweight, consumer-friendly

video cameras are becoming the norm for many vacationers. In medicine, various types of lasers are being used in new applications in corneal reshaping, dentistry, dermatology, urology and cardiology. Even the ubiquitous light bulb is a target for change, with manufacturers of new high brightness light emitting diodes, which use less power and last longer, trying to steal that market.

U.S. Optoelectronic Industry

- The largest end market for optoelectronic products by far was in the computer and business equipment sector, with nearly 46 percent of the sales ($4.65 billion in 1996). The second largest sector was communications, with 20 percent of the total sales. The military market came in third at nearly 15 percent of sales, down from its position as the second largest category as determined in BXA's 1994 optoelectronics industry survey. These figures tend to confirm the expanding market seen in communications and the declining budgets devoted toward military spending. While three-quarters of the companies in the 1994 survey participated in the defense market, now only one-third of the current respondents manufacture products for the defense sector.

- Device sales showed generally positive growth trends, with the respondents predicting annual overall growth of around 10 percent. The U.S. was the largest market by far, at 71 percent, with an expected growth of 9 percent between 1996 and 1997. While exports accounted for only 29 percent of the sales, their growth rate is faster than the domestic market, with the best growth region expected in China. The expectations for equipment sales were mixed, with a dip in sales for 1996 anticipated at 0.3 percent followed by a 4.8 percent sales increase for 1997. The U.S. was again the prominent market, accounting for 54 percent of annual sales. Domestic sales were expected to dip slightly then increase by 5 percent in 1997. For international sales, China was once again the leader in expected growth. While the Japanese market is expected to drop dramatically with the current financial crisis, one bright spot is the other Pacific Rim nations, where sales in 1998 are expected to grow by 27 percent for devices and 20 percent for equipment. Note that this data has not been adjusted for the current 1998 Asian financial crisis.

- The average facility production capacity utilization for components was 70 percent of capability. This lower average utilization value than is often expected of major companies can most likely be attributed to the larger percent of smaller companies in the data group, which often run at lower capacities. Of all components, edge laser production utilization was the highest, at 82 percent, and solar cell production ran the lowest, at 20 percent. For equipment, the overall capacity utilization values are higher, with many companies maintaining a production capacity utilization of nearly 80 percent. Optical I/O equipment ranked the highest, at a near maximum production capacity of 98 percent, and the lowest product line production value was in image processing, at nearly 58 percent.

- Employment in the optoelectronics sector was expected to grow by at least three percent, which matched the 1994 BXA survey's growth trends in 1990 and 1991. Many of the respondents indicated that the decrease in the U.S. labor force growth, currently 1.3 percent a year versus 2.5 percent a decade ago, has put extreme pressure on employers who need a steady supply of trained workers in this highly technical field. The shortage of skilled labor is a constant problem, and companies find themselves having to pay large amounts of money to attract engineering staff.

- In 1996, technical staff constituted 10.5 percent of the respondent's work force, compared to 1992 figures where they were 17.3 percent of the total. Interestingly, the percentage of manufacturing employees has also dropped, from 56.1 percent in 1992 to only 28.8 percent in 1996 (per Census data, the percentage of manufacturing employees for many industry sectors generally runs about 50 percent). The real increase has been in the marketing/sales/administration/other category, which grew from 26.5 percent in 1992 to 60.8 percent in the 1996 data. This could be explained by the participation of resellers/distributors in the recent survey; they were not included in the earlier survey.

- Company investment in facilities and new equipment has maintained its upward growth trend, shown in the 1994 survey, with a much stronger growth in new plant purchases and expansions over new equipment. New plant expenditures increased by 44 percent from 1996 to 1997, then again by 83 percent for the 1997-1998 time frame. With regard to equipment, purchases for the 1996-1997 period were expected to grow by 10 percent, and again by 5 percent for the following year. With an array of new products becoming marketable, this was expected, as manufacturers will need to expand facilities and update production lines to build the new products.

Research and Development

- In 1996, the surveyed firms spent over $1.9 billion on optoelectronics-related R&D. The data shows a continuing slight upward growth trend in research investment, similar to the trends in the 1994 BXA Survey. However, whereas the earlier report noted internal funding in 1991 as 74 percent of the total, in 1996, internal funding accounted for 90 percent of the available investment. Government spending, which was 23 percent of the total in 1991, has shrunk to 10 percent. This is most likely attributable to cutbacks in defense spending.

- Interestingly, while the Department of Defense agencies were still responsible for about 66 percent of the 1996 government funding, in 1991 they accounted for nearly 90 percent. Thus, there has been a stronger shift toward funding from various non-defense government organizations, such as the National Aeronautics and Space Administration, the National Institutes of Health, and the National Science Foundation. With more emphasis on dual-use technologies, we expect an increasing percentage of R&D funding opportunities to come from the non-defense government sector.

- Average R&D spending by the surveyed companies as a percentage of total sales was 8.1 percent, a decrease from the 1994 assessment average of 11 percent. This decrease can probably be attributed in large part to the across-the-board cutbacks in military spending, which funded many research projects. However, this is still significantly higher than the average investment in R&D for all industries, which was a mere 2.9 percent in 1995.

Competitive Prospects

- Overall, companies responding to the BXA survey were optimistic about their future competitiveness. Of the 401 responses (368 company surveys, some with multiple divisions) to the competitive outlook query, about one-third of the companies reported that their outlook will improve greatly. An additional forty-five percent expected their outlook to improve somewhat. About twenty percent of the respondents indicated that their competitiveness was anticipated to stay the same; only 25 firms (6.2 percent) believe that their business will decline somewhat or greatly in the near future. Overall, many manufacturers believe that they are standing strong in their market sectors. While individual companies may wax and wane, the U.S. optoelectronic industry appears to be quite optimistic that it is maintaining its technological leadership and will continue to do so in the years ahead.

- Regarding business obstacles hindering their competitiveness, delays in product development was the item of most concern to the survey respondents. The second highest concern was high labor costs, followed by a lack of low cost capital. Foreign government support of foreign firms ranked fourth, and the lack of investment/R&D credit came in fifth. Of the top ten concerns, four centered around financial issues, and two focused on the poor quality of the workforce and the current educational system.

Import Dependency

- Some 63.3 percent of the companies surveyed rely on at least one foreign-made component or piece of equipment to manufacture their end product. Clearly, if there is no available domestic product, companies must source offshore, and both lack of a domestic source and inadequate domestic source came up as leading reasons for importing. Lower cost was the second leading reason, driving home the need for improved manufacturing efficiency in order to remain competitive. Better quality, ranked number four, was also a strong area of concern.

- The diverse group of survey respondents listed dependencies on a wide variety of foreign sources for materials, components and equipment used in the manufacturing process. Some trends are apparent from a review of these data. Numerous survey respondents indicated dependency on foreign sources of optical grade glass because there was "no known domestic source." Sources of such glass were identified in Germany, Japan, and

the United Kingdom. Another frequently mentioned dependency was ceramic packages/ferrules/substrates (most often from Japan). EG&G in Canada was often mentioned as a sole source for various photo diodes. Interestingly, several survey respondents indicated a dependency on "nonlinear crystals" from China (no known domestic source).

- Of the firms responding, 43.2 percent indicated that they need foreign sources to maintain their current levels of quality and/or price. And, 54 percent said that they will continue to be dependent on foreign sources, as use of domestic suppliers will not allow them to remain competitive. When asked if they had a contingency plan if their particular foreign supplies were cut off, 18.2 percent of the responses were negative, indicating that they would have to end production of a particular product and in some cases the company would be forced to go out of business.

Defense/Non-Defense Markets and Effect of Budget Cuts

- Some 208 of the 368 companies surveyed, or 56.5 percent, have been or will be affected by budget cuts of one kind or another. Defense budget cuts were noted by 133 of the companies surveyed. Of these, 46 of the firms were directly affected by defense budget cuts that seriously impacted their R&D funding, while 87 of the companies experienced budget decreases through canceled or reduced defense contracts. Understandably, the effect of these budget cuts varied from company to company. Recognizing the continual countdown in defense budgets, some companies have wisely diversified their markets to survive the decrease in the government business. Others have had to cut staff, close production lines, and initiate cost-cutting measures.

- Non-defense budget cuts have affected or will affect 75 of the companies surveyed. Fifteen of these companies have already been affected and the remaining 60 stated that they could be distinctly affected by budget cuts. The government organizations that were mentioned the most were NASA, NIH and NSF.

CHAPTER I

INTRODUCTION

Background

The objective of this optoelectronics critical technology assessment is to ascertain the status of and changes in the optoelectronics industry, valuable information needed by policy makers in Congress and the Executive branch. Industry strategists, as well, expressed the need for this type of information. Working with the Optoelectronic Industry Development Association (OIDA) and the U.S. Department of Defense, the U.S. Department of Commerce's Bureau of Export Administration (BXA) sought to evaluate the long-term health and competitiveness of the industry; to determine the growth trends and emerging markets in this field; and to develop recommendations to ensure the continued ability of the industry to support defense-related missions and programs.

The assessment was conducted pursuant to the Defense Production Act (DPA) of 1950, as amended (50 U.S.C.A. app. sections 2061 and 2171 (1991 and supp. 1998)) and as delegated to the Secretary of Commerce in section 401 (4) of Executive Order 12656 (3 C.F.R. 1988 comp., 585 (1989)). In developing the survey form and this report, Commerce consulted with private sector trade associations and firms in order to include information that would be useful to them and would not be obtainable from other Government or industry sources. In addition, guidance was taken from the February 1994 *Critical Technology Assessment of the U.S. Optoelectronics Industry*, also published by Commerce, so that comparisons could be made regarding the evolution of the industry. A format similar to that used in BXA's earlier study was utilized where possible to allow for ready comparison to that earlier data.

Scope and Methodology

For the purposes of the assessment, optoelectronics was broadly defined as systems, equipment, and/or devices which emit, modulate, transmit, and/or sense light or are dependent on the combination of optical and electronic devices. This definition is very encompassing; indeed one critic remarked that a flashlight would apply. However, it was necessary that the baseline definition be broad as there are many industry interpretations of the word "optoelectronics" and Commerce wished to be as comprehensive as possible in its evaluation. The use of optoelectronics is fairly ubiquitous; various products appear in communications, computers and business equipment, industrial/medical, transportation, military, and consumer categories. The trade industry associations were especially interested in this study as entirely new optoelectronic sectors have arisen since the last assessment, such as digital cameras, and little data were available on new markets.

The primary source of information for this report was a direct survey of U.S. companies conducted by Commerce between October, 1997 and April, 1998. A copy of the survey form is

provided in Appendix A. Commerce developed a comprehensive mailing list using association membership listings and addresses from various optoelectronic-related directories. As a result, the survey pool included a wide range of companies, both large and small; many are directly involved in optoelectronics, while some are on the periphery. Foreign-owned firms were included in the survey if they had any U.S.-based facilities. Completed surveys were received from 368 companies, a strong representation of the industry and a larger group of companies than were included in the previous study.

Comparative information to enhance the survey data was found in various published and online sources, such as industry trade periodicals, U.S. and foreign government statistics, and government or non-government studies on optoelectronics. Additional insight was provided by experts in various aspects of optoelectronics in the Department of Commerce, the Department of Defense, universities, and the private sector.

The first section of this report provides an overview of the growth in the optoelectronics field and a sampling of the recent developments and trends. Then, a profile of the survey respondents is given, outlining markets addressed, product categories, and the geographic distribution of the industry. This is followed by an outline of the industry performance and a breakdown of the economic factors, such as sales, product distribution and company sizes. Finally, respondents' perspectives on their competitive prospects in various markets are presented.

CHAPTER II

OPTOELECTRONICS PRODUCTS OVERVIEW

Optoelectronics, the marriage of optical technologies with electronics, is an ever increasing market of applications. Indeed, many consider optoelectronics today's enabling technology. This is especially true in regard to the growth of the information age in this decade which has resulted in a plethora of data that quickly threatens to overwhelm storage technologies, a situation which is only now being addressed by increasing use of optical media. Electronics, once the future of every new improvement, is starting to take a back seat as the photonics part of optoelectronic technology surges steadily forward. For increased processing speed, the photon is the answer; as stated by one reviewer of future trends, "At a time when nanoseconds are the bread-and-butter of digital electronics, photonics is exploring femtoseconds (a million times faster)."* Optical solutions are increasingly the only way to go, and this chapter provides a snapshot of some of the newest market trends.[1]

Indeed, the future potential for optoelectronics seems limitless. "Progress [in optoelectronics] is faster even than microchips were at the equivalent point in their development," says Gerry Butters, President of Lucent Technologies for the North American region.[1] Electronicast, a San Mateo, California market research firm, estimates that sales of opto-electronic equipment hit $4.5 billion in 1996 and will grow to $34 billion by 2006.[2] While research firms may use varying definitions for equipment compared to this report, Electronicast's figure demonstrates the growth potential for optoelectronic products in the coming years.

One opto-technology driver is the Internet, which has spawned many new trends, with increasing use of electronic banking and on-line shopping. In 1996 the Internet created an estimated 1.1 million jobs, and 30 million people were actively using it worldwide. By 2002, according to Forrester Research, the Internet will generate $344 billion in U.S. revenue.[3] And the growth in data flow seems to show no signs of stopping. "Data traffic in the public network is outpacing the familiar Moore's Law [for computers] by doubling about every 12 months ... Thanks to new technologies such as optical amplifiers and dense wavelength division multiplexing (DWDM), the network infrastructure's cost is dramatically cheaper then in the past."[4] When the cost goes down, naturally people tend to use it even more. It has been predicted that the volume of data traffic will overtake traditional voice traffic no later than 1999, and perhaps before the end of 1998.[5] As a further example of its growth, the number of Internet host sites has grown from 4 in 1969 to 29,670,000 in January, 1998.[6] The business is here to stay – and flourish.

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* A complete listing of all the optoelectronic devices and equipment included in this report is found on page 5 of Appendix A.

Fiber Optics and Enhanced Telecommunications

Fiber optics is one of the most obvious and visible parts of the optoelectronics market, thanks largely to the increasing use of fiber optic cable by phone companies promoting the excellent quality of their optical cable connections. The unprecedented growth in Internet traffic (burgeoning with larger and larger audio and video files), along with escalating interest in video conferencing and high-definition television, have pushed telecommunications networks into the realm that only optical fiber, with its much wider bandwidth capacity, can satisfy. Already well established in the business community, the potential for fiber to the home (FTTH) draws closer and closer as the electronic traffic increases and the work environment evolves with more telecommuting. On the business environment end, the burgeoning user demand and innovations in fiber-optic technology are creating a favorable market opportunity for suppliers of components and products supporting fiber-to-the-desktop (FTTD). Copper wiring, once the workhorse of network cabling, is definitely reaching its limits, and companies involved in information intensive applications need the features that only fiber can provide, like no susceptibility to electrical/radio interference, which is an inherent problem with copper wire[7]

Fiber provides an assortment of benefits: greater speed and bandwidth, immunity to electromagnetic and radio frequency interference, and crosstalk, greater reliability and security, and reduced attenuation. With all these refinements, one might question why every computer on every desktop in this country is not connected this way. The reason is that copper wiring is still perceived by many to be more durable, less expensive and easier to install than optical fiber. While once true, improvements in cabling technology and the fiber optic cable itself have made installation a much easier task than it once was. Glass optical fiber is very strong, with an extremely high tensile strength that exceeds all other media. The fiber cable is smaller and lighter than copper, so it is easier to handle and requires less space in floors and ceilings. The vast improvements in splicing and connectors and the testing of fiber optic cables have really eliminated copper's traditional installation advantage.[8] With the every increasing needs of data transmission by the demanding public, FTTD becomes increasingly attractive.

Bandwidth is the available carrying capacity of a communication line, whether it is a telephone line or a coaxial cable. Fiber optics may be the only means available to keep up with the phenomenal growth in desired data throughput. Experimenters at Lucent Technologies' Bell Labs have increased the speed of transmission by a factor of nearly ten in the past two years, to 3 trillion bits, or 3 terabits per second.. That transmission rate is enough to support 100 million simultaneous Internet connections. Others have also made progress on this front, as well, in an attempt to keep up with consumer demand for enhanced media choices, such as video on Web sites and movies on demand. [9]

Terabit networking does look to be the way to go, and has been successfully applied in new optoelectronic hardware advancements. The Army's Aviation and Missile Command is applying a three-dimensional compression technology to develop new components that will incorporate all the switching electronics and optical interconnects required to distribute fiber optic data to

electronic local networks. This has allowed engineers to shrink the current foot-locker-sized switching equipment that performs the function down to the size of a pager.[10]

A significant research goal is the refinement of optical switching. Data transmission, whether by phone or computer, starts as electrical impulses. Before it can travel on high capacity optical fiber lines, it must be converted to an optical output. Currently, that task is done by the local phone company, using a switch that modulates a laser so that variations in the light carry the signal. An optical switch would make the transfer much more reliable and cheaper. Such an optical switching system, based on research financed by DARPA (the Defense Advanced Research Projects Agency), will be implemented by the end of 1999 in the Dallas area.[11]

Optical Devices

Optocouplers are devices that can convert an electrical input to a light emission or reconvert such to an electrical signal. There is a booming market for these. Such optoelectronic devices, which are being used in a number of the latest digital products, include charge-coupled devices (CCDs) for digital cameras, laser diodes for DVD disks, and portable electronic devices, including laptops, cell phones and PDAs with IR capacity.[12] Mike Bottini of Siemens Microelectronics Inc. of Cupertino, California, expects the optocoupler market to grow at about a 6 percent annual rate through 2001, a position supported by Dataquest Inc. Optocouplers are widely used in telecommunications, power supplies for PCs, and industrial-control applications, as well as in larger consumer appliances such as washing machines and air conditioners and mobile communication products.[13]

Another group of optical devices are lasers. In the past, lasers were more of an exotic contrivance in science fiction, but today, lasers have gained use in a wide range applications. Currently they are common in a number of professions, including medicine, where they are used for corneal reshaping, in dermatology (cosmetic and plastic surgery), urology, cardiology (surgery, blood analysis), dentistry, and photodynamic therapy (skin cancer treatment). There are many diseases and conditions where therapy involving lasers has distinct advantages over alternative treatments. In manufacturing, lasers are increasingly used in noncontact, nondestructive inspection and testing, detection of trace compounds, and component recognition.

Additionally, semiconductor laser diodes have attained only a small fraction of the success and widespread applications of the silicon-based transistor in the past 20 years, despite impressive modulation speeds, low power consumption and long lifetimes. Some believe that the "transistor" of the photonics world is the vertical cavity surface emitting laser (VCSEL), the key enabler for very large scale integration photonics. The ease of integration of these devices using standard semiconductor processing techniques and testing opens up the potential for a wide range of applications (photoelectronic sensors, laser pointers, terabit data communication transceivers). One current application is in laser printers, which use one or two of the established edge-emitting laser diodes with data speeds up to ~100 million bits/sec to scan printed information onto a photoreceptor.[14]

With the development of high brightness light emitting diodes (LEDs), lighting, considered a rather immutable technology by many, is stirring up excitement. High brightness LEDs are preferable to ordinary incandescent light bulbs because of their low power consumption, superior longevity, high reliability, and brightness. LEDs are especially attractive for municipal applications because of their lower power consumption and extended lifetime (as long as seven years versus annually for current traffic lights).[15] The promise of light-emitting plastics for displays that are simultaneously lightweight, low profile, low-power and low-cost are another promising development.[16] One company researching the topic, Dow Chemical, reported that their light emitting plastic – a conjugated polymer made with fluorine – produces the brightness of ordinary fluorescent lighting with just five volts of power. [17]

Data Storage

Data storage is one of the most interesting challenges facing the optoelectronic industry. Many current software programs would quickly overwhelm the PC storage standards of a few years back. One example of this are the increasingly graphics-laden video games of today, which clamor for space. To address that problem, the removable data storage industry, now with CD-ROMs (Compact Disc, Read Only Memory), CD-RW (Rewritable), DVD-based (Digital Versatile Disc) DVD+RW and DVD-RAM (Random Access Memory), seems to offer an ever growing, bewildering array of products for the consumer.

The biggest issue remains that of intercompatibility. While CDs have for the most part been the exception, as the storage needs call for higher and higher densities, establishing a standard has been a problem. For example, believing DVD to be the next successor to the large CD market, there have been no fewer than four emerging technologies put forth by companies eager to capture the market – that all promise to offer additional playback platforms for DVD, as well as other CD-based formats, while simultaneously offering the capacity of recording and rewriting high volumes of all types of data.[18]

The rewritable storage media industry isn't used for just data storage anymore. For example, Sony's Minidisc was introduced in 1992 for recording and distributing consumer audio. And, DVD enthusiasts are eager to overtake the current VCR market. Before that happens, many factors need to be considered, including cost and consumer interest. The VCR format is firmly entrenched, and many consumers may ignore the new formats despite greater storage capacity and better picture/sound quality. One important factor that U.S. companies must face is competition; since the 1980s, Japanese companies have steadily increased their investments in research and development in optical storage technologies. Japan's optoelectronic business is worth $40 billion in annual sales, compared to total annual U.S. optoelectronic sales of $6 billion. At the same time, however, many of the major users of optical storage technology are located in the United States.[19]

In optical data storage, lasers are a critical component. Storage capacity continually improves with refinements on the available laser wavelengths and will increase further with innovations

such as digital holographic data storage systems. For example, researchers are making significant strides toward the development of the long-sought blue diode laser. Its small wavelength will allow remarkable increases in optical storage capacity. Scientists at Boston University are using sapphires to develop a new blue laser that may lead to a new generation of optical storage disks as well as video screens and computer displays. Sapphire is the substrate material that holds in place gallium nitride wafers which emit blue wavelengths, the shortest of the light spectrum. It is hoped that blue lasers can lead to new display technologies and optical storage disks that hold four times the amount of information found on today's digital video disks.[20]

The future of enhanced storage capacity may include organic materials. Work at NASA's Ames Research Center is underway on the potential applications of an organic material, bacteriorhodopsin. Thin films made from that material promise a powerful, durable storage material for optical computer systems. The material has high memory-density and readily supports millions of write/erase cycles without degradation.[21]

Displays

Refinements in manufacturing and advancements in display technology are bringing better, cheaper displays into exciting and new markets. Displays for smaller electronic devices such as personal digital assistants, cell phones and pagers continue to evolve. Once rather simplistic, newer displays are much cheaper to produce, use much less power, and with the enhancements in screen resolution, can even receive a fax on a pager.

Although it may be a few years before they are widely used in products, the market for small display technologies could grow from zero to $1 billion over the next five years.[22] Another forecaster predicted that potentially 15 percent of the 230 million cell phones to be built in the year 2000 will need the high-information-content [miniature] displays, based on current consumer demand. As these displays are expected to sell for $50 to $60, this could be as much as a $2 billion market in two years.[23]

The market for flat panel displays (FPDs) is another high-growth area. The U.S. military demand for FPDs reached $415 million in 1996, making up only a fraction of the consumer market. By the year 2005, the total market for FPDs for defense- and avionics-related applications is expected to be over $4 billion. While Active Matrix Liquid Crystal Displays (AMLCDs) make up the majority of current military FPDs, electroluminescent, plasma and Field Emission Displays (FEDs) are entering this market as competitive alternatives.

The biggest challenge that flat panel display manufacturers face is producing FPDs at a much lower cost. The Pentagon still demands a ready supply of top quality FPDs that provide high-resolution screens for several new platforms, but at less expense. This market is expected to grow drastically as older displays are upgraded or replaced and as new platforms such as the

Joint Strike Fighter (JSF) are developed. Although U.S. companies currently dominate the market in advanced electronic displays, they face stiff competition from abroad.[24]

Refined Sensors

Optoelectronics can play a significant part in enhancing sensing capabilities. For example, the Federal Aviation Administration is having an explosives-detection portal designed by Sandia National Laboratories. Its intended purpose is to prevent airline bombings and hijackings by detecting any explosive chemical residues present on passengers entering the gate. People would pass through a portal, similar in appearance to a metal detector. A puff of air would pass over them, and the collected air sample would immediately be tested using a commercially available spectrometer. According to lead project researcher Kevin Linker, "it is capable of detecting very small concentrations of all substances of interest to the FAA."[25]

Researchers at Rensselaer Polytechnic Institute in Troy, New York, are developing an imaging system that may be used in detecting items such as plastic explosives hidden in suitcases. This system, called real-time electro-optics terahertz sensing, is similar to X-ray and radar technologies. However, the frequency of the electromagnetic radiation used is more than 1 trillion cycles per second.[26] Only recently has the technology advanced enough to allow real-time imaging to be performed at that speed.

Criminal investigation units have difficulty in discovering incriminating organic evidence, such as fingerprints on textured surfaces. This has prompted research into better investigative tools. A new portable evidence finder, developed at the request of the National Institute of Justice, senses the weak fluorescent emissions given off by all organic substances, which are normally invisible to the naked eye. The user wears special shuttered glasses whose net effect is that the fluorescing materials appear to flash brightly at a rate that is distinctly noticeable to the human eye. The researchers will be testing the prototype this year and hope to have it available for licensing and manufacture by early 1999.[27]

All in all, the field of optoelectronics is an exciting place to be. It's progressive, it's growing, and just when it seems to hit a plateau, innovators stumble across a new mountain to climb that leads to a new range of better, faster products for the consumer.

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26. Greg Paula, "Crime-fighting Sensors," *Mechanical Engineering*, January 1998, 66-68.

27. Greg Paula, "Crime-fighting Sensors," *Mechanical Engineering*, January 1998, 68.

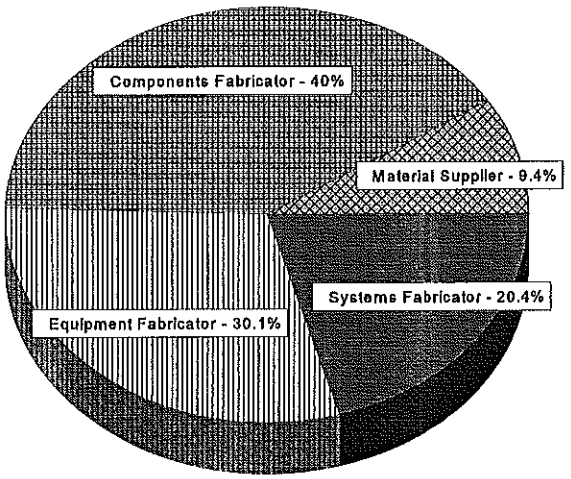
CHAPTER III

PROFILE OF SURVEY RESPONDENTS

The primary source of information for this report was a detailed questionnaire conducted by BXA between October, 1997 and April, 1998. A total of 368 completed surveys (out of 764 mailed) were obtained from companies active in various optoelectronic fields. Although the survey fell short of capturing all U.S. firms involved in optoelectronics, we believe that the companies responding are representative of the entire sector. They manufacture a broad range of optoelectronic materials, components, equipment and systems; non-manufacturing companies (R&D, distributors, etc.) are represented as well. Figure 1 shows a breakdown of the respondents involved in manufacturing as their primary business. Note that survey respondents could indicate multiple primary and secondary businesses.

Figure 1

Primary Manufacturing Business (382 Responses)

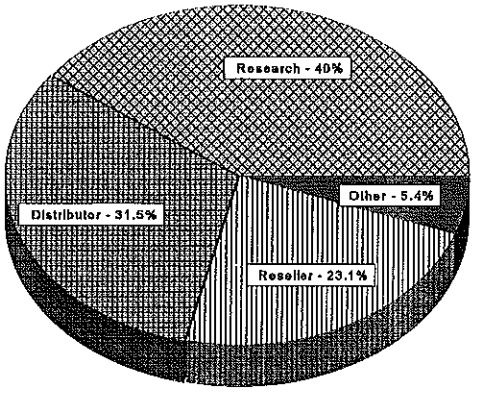


Source: BXA Optoelectronics Survey

Of the categories defined in the figure, only 36 of the respondents were primarily material suppliers, while 153 were component manufacturers, 115 produce equipment, and 78 were systems fabricators. With regard to non-manufacturing firms, Figure 2 shows the breakdown of their primary business.

For the companies that were not primarily manufacturers, there were 52 research-oriented firms, 41 involved as distributors, 30 were resellers, and 7 fell into the "other" category. Many firms were involved in multiple lines of business.

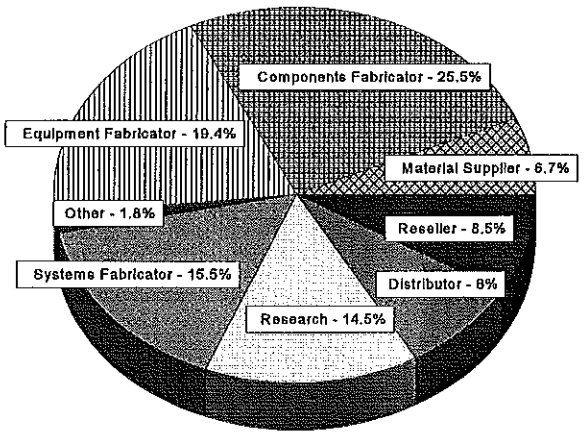
Figure 2
Primary Non-Manufacturing Business (130 Responses)



Source: BXA Optoelectronics Survey

A better perspective can be gained on the survey respondents by combining these primary and secondary business responses. This overall "big picture" is illustrated in Figure 3. Overall, 48 respondents were material suppliers, 181 components fabricators, 138 equipment fabricators, 110 system fabricators, 103 involved directly in research, 57 were distributors, 60 were resellers, and 13 involved in other related optoelectronic business.

Figure 3
Overall Business Profile Of Respondents (710 Responses)



Source: BXA Optoelectronics Survey

Product Categories

The following tables outline the number of companies responding to the BXA survey marketing each optoelectronic device and optoelectronic equipment product category. As with the line of business data above, respondents could indicate more than one response.

Table 1
Device Categories/Survey Respondents

DEVICES PRODUCT CATEGORY	NUMBER OF RESPONDENTS
Semiconductor Lasers	37
Non-Semiconductor Lasers	57
Light Emitting Diodes (LEDs)	36
Detectors	49
Sensors	20
Imaging Arrays	35
Hybrid Optical Devices	38
Edge Laser-Based T/R Modules	15
LED or VCSEL Optical Links	12
Optical Amplifier Modules	19
Flat Panel Display Modules/Devices	18
Solar Cells	7
Optical Fibers	64
Optical Connectors	42
Passive Optical Devices	113
Optical Control Devices	35
Optical Storage Media (excluding content)	7
Optical Materials	43
Other Components/Devices	74

Source: BXA Optoelectronics Survey

Table 2
Equipment Categories/Survey Respondents

EQUIPMENT PRODUCT CATEGORY	NUMBER OF RESPONDENTS
Optical Measurement & Test	91
Commercial Communications	35
Other Optical Communications	9
Optical Imaging	63
Sensing	40
Optical Disk	9
Optical Image Processing	9
Optical I/O	18
Display	9
Optical Medical	17
High Power Laser	36
Photoprinting & Testing	2
Other Optoelectronics Equipment	33

Source: BXA Optoelectronics Survey

Geographical Distribution

Survey recipients were asked to identify the location of their optoelectronic manufacturing and research establishments in the United States and abroad. They were also asked to indicate the category of optoelectronic production and research that was currently being conducted at each of their sites. In general, the geographic distribution of optoelectronic facilities throughout the United States tends to focus on two areas, California and the Northeast. This pattern does not seem to deviate too much from the previous 1994 survey, but due to a larger pool of information accumulated, these lines are now more clearly defined.

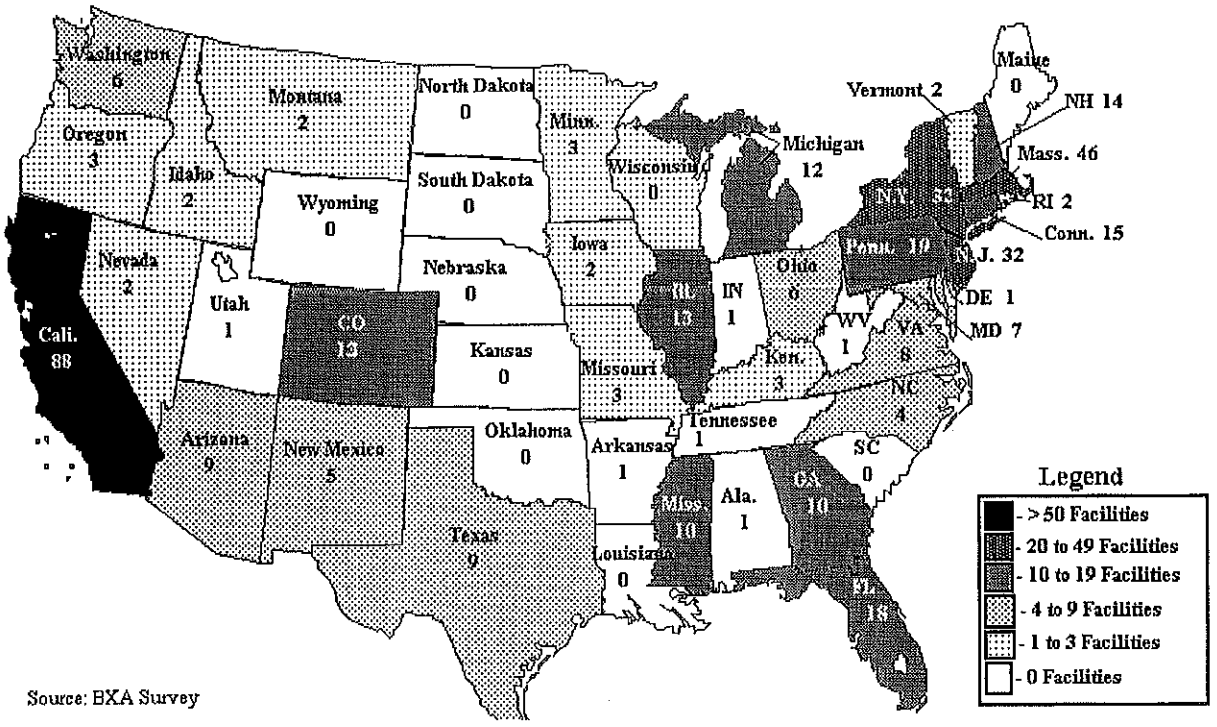
Manufacturing Establishments

The 1994 optoelectronics survey received responses from ninety-five manufacturing companies. That number was greatly exceeded by this year's survey which encompassed 368 companies from 40 states and 9 foreign countries. Out of these 368 companies, a total of 403 domestic and

19 foreign optoelectronic manufacturing facilities were identified. The state with the greatest number of facilities is California, with 88 facilities, followed by Massachusetts (46). Production facilities for optoelectronic components in particular are concentrated in these regions. The majority of foreign optoelectronic facilities owned by U.S. companies could be found in Mexico (4), Canada (4) and the United Kingdom (3).

Both California and the Northeast have a large, established high-tech work force, which makes these areas more attractive for the companies. With the increasing industrial trend toward just-in-time manufacturing, many of the vendors have also concentrated themselves in the same areas as the optoelectronic manufacturers, allowing for shorter and more frequent shipments. It would appear that these two factors have had the strongest contribution to the current localization of the optoelectronic industry.

Figure 4 Company Geographical Distribution



Source: BXA Survey

Note: Alaska and Hawaii have 0 facilities

Although the majority of the optoelectronic facilities are located in the Northeast and California, a fair number of facilities are also in other parts of the country. As seen in Figure 4, certain states in the central (Colorado and Illinois) and the southeastern (Florida, Mississippi and Georgia) United States have ten or more optoelectronic facilities. These states have consciously attracted high-tech industries, although not specifically targeting the optoelectronic industry. As is true with many industries, the optoelectronics industry encourages the growth of a large number of small vendors (twenty or fewer employees), that often produce niche-market devices and materials. Some states, like Colorado, provide better incentives for small businesses, and as a result, have a higher percentage of small, high-tech industries, including optoelectronic suppliers. Many considerations affect where companies and industries locate, but these seem to be the main contributing factors.

Research Establishments

Out of the 368 companies that responded, fifty-one reported research as one of their primary activities, although in most cases, it was not their only focus. Many of the companies that focused on research were also manufacturers. Of the companies that reported their main focus as research, all operate from only one facility. None of these establishments are research-only facilities.

Once again, California has the most optoelectronic research facilities, with fourteen. Massachusetts came in second place with eight, followed by New Jersey with five research firms. Approximately fifty-seven percent of the research facilities are in the top four optoelectronics manufacturing states. Besides California, there seems to be a trend of research facilities on the East Coast of the United States, which mimics the manufacturing facilities.

Company Ownership

The 368 companies responding to BXA's survey were involved in a wide variety of domestic and international business relationships. Fifty-five of the firms were part of (owned by) larger, domestic parent firms. Twenty-eight were wholly-owned by foreign firms, and 33 were involved in joint ventures; 21 of them with U.S. companies, and 12 with international companies.

The majority of the foreign-owned companies were owned by Japanese firms (10). Others, in a descending order of ownership were German, English, Chinese, Israeli, Swiss, Swedish and Canadian. The majority of foreign joint ventures again originated from Japan (8), with a descending number of ventures by Germany, Switzerland, Israel and Russia.

CHAPTER IV

INDUSTRY PERFORMANCE

This section presents the various measures of economic performance of the U.S. optoelectronics companies that responded to the BXA survey. Data on research and development, shipments, employment changes, and financial measures are all presented. In most instances, the information pertains to the 1996-1997 period. Some forecasts were obtained for the 1998 through 2000 timetable.

Research & Development

Companies were asked to report on their annual expenditures on optoelectronics research and development for 1996, and provide estimated costs for 1997-1998. The results are presented in the following table. R&D spending was highly concentrated in the BXA survey sample; five large companies accounted for over three-quarters of the total.

Table 3
Annual R&D Expenditures
[In thousands of dollars]

	1996 (n=289) *	**1997** (est.,n=302)	**1998** (est., n=294)
TOTAL	$ 1,858,461	$ 1,982,581	$ 2,069,553
Internally Funded	1,662,499	1,785,181	1,874,457
Defense (DARPA, etc.)	115,989	111,934	121,057
Non-Defense Government (NIST, NASA, etc.)	60,238	66,731	44,567
Foreign Government	1,374	662	0
Non-Government Domestic	14,290	12,305	24,283
Non-Government Foreign	4,071	5,768	5,189

Source: BXA Optoelectronics Survey

Figure 5 displays the R&D expenditure data graphically. It indicates a slight upward growth in research investment, similar to the trends in the 1994 BXA *Critical Technology Assessment of*

* For clarity, the number of responses, n, has been included in the published data. The minor variances that occur are due to the startup and closures of various companies or divisions and/or due to some firms not providing data for all three years.

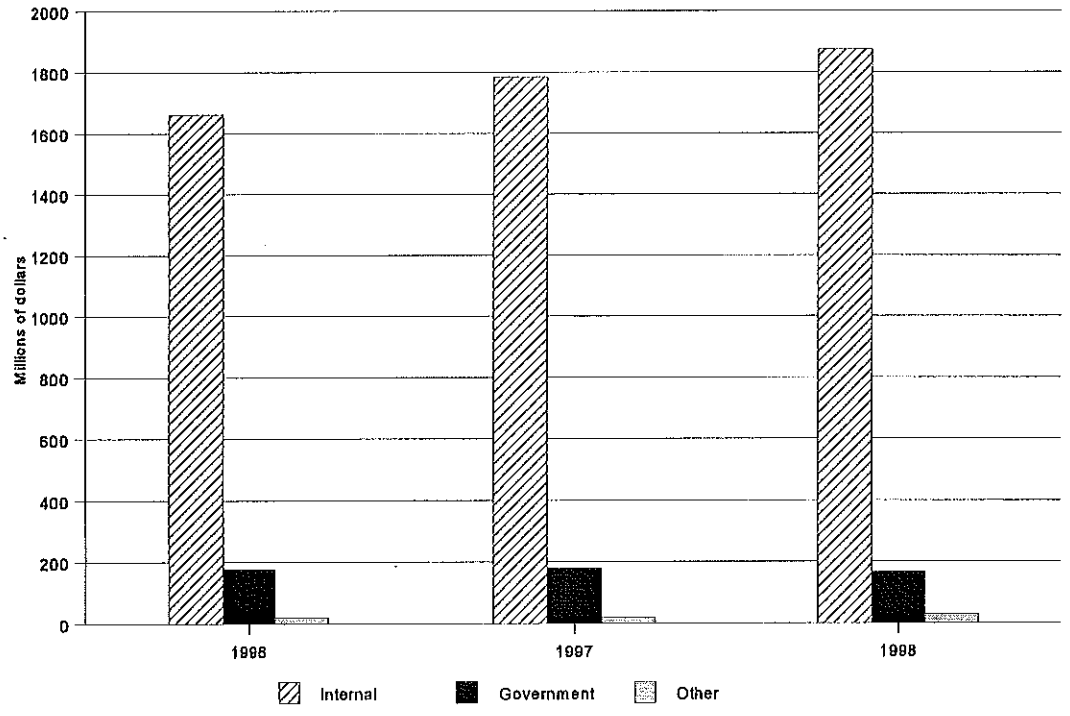
the U.S. Optoelectronics Industry. However, whereas internal funding in 1991 in the earlier report was noted as 74% of the total, in 1996, internal funding accounted for 90% of the available investment. Government spending has shrunk from 23% of the total in 1991 to 10% in 1996. This is most likely attributable to cutbacks in defense spending.

Between 1996 and 1998, a total of 65 establishments received funding from Department of Defense (DOD) agencies, and 41 received funding from other non-defense government sources. Twenty-eight companies received funding from both DOD and non-defense government sources. Only 4 had foreign government support, and 42 obtained funding from other domestic sources. Twenty-one of the companies received outside support from non-government foreign sources.

Interestingly, R&D funding by DOD dropped from 90% in 1991 to 66% in 1996 of the total current government segment, indicating R&D has shifted somewhat toward funding from various non-defense government organizations, such as the National Aeronautics and Space Administration, the National Institutes of Health, and the National Science Foundation, and the National Institute of Standards and Technology. With more emphasis on dual-use technologies, we expect an increasing percentage of R&D funding opportunities to come from the non-defense government sector, although Defense will also remain a very important source.

Figure 5

R&D Expenditures, 1996-1998



Source: BXA Optoelectronics Survey

Average R&D spending by the surveyed companies as a percentage of total sales was 8.1%, a decrease from the 1994 assessment average of 11%. A significant percentage of this decrease can probably be attributed to the across-the-board cutbacks in military spending, which funded many research projects. This is still significantly higher than the average U.S. industrial investment in R&D, which was 2.9% in 1995. However, other high-tech industry segments, such as communication equipment, electronic components, and optical/surgical/photographic instrumentation devoted a comparable level of funding to R&D, around 8%.[1] With regard to other government programs, the National Institute of Standards and Technology's (NIST) Advanced Technology Program (ATP), launched in 1990, is now committed to applying the bulk of its funding to focused program areas. One of those is photonics manufacturing.

As outlined in the NIST *1998 White Paper: Photonics Manufacturing*, the U.S. has a very strong base of fundamental research and basic technology in photonics. Indeed, many times U.S. technology is equal to or better than that available in the rest of the world. U.S. companies compete well in areas where performance is critical but the needed volume is low, such as in military products. Where U.S. firms fall short is competing in markets where the product volumes are high and efficient manufacturing is a must, such as in consumer products. The focus of the ATP's photonics manufacturing program is to improve the photonics manufacturing infrastructure and thereby increase the competitiveness of U.S. manufacturers of high-volume photonic products. Funding for the program moved upward from 1993-1995, but fell under serious political attack in 1996. Funding was cut off. However, it has since rebounded, and will show a small increase over 1995 levels for fiscal 1999.

At the national level, the United States leads the world in R&D spending, however, both Japan and Germany devote a higher fraction of Gross Domestic Product to non-defense related R&D.[2] According to data collected by the Science Coalition, in 1995, the federal government provided 36% of the national total of all R&D funding (this includes everything, not just optoelectronics-related), while industry itself funded 59% of the national total. Overall, the federal share of the national R&D total eroded from 46% in 1987 to 36% in 1995. Industry investments in R&D have generally been flat in real terms since 1988.

Capital Expenditures

In optoelectronics, investment has been driven by the rapid introduction of new or improved products and expanded market opportunities. As was seen in the 1994 assessment, company investment in facilities and new equipment maintained its upward growth trend, with a much stronger growth in new or expanded plant expenditures over new equipment. As calculated from the data in Table 4, estimated plant expenditures from 1996 to 1997 increased by 44%, then again by 83% for the 1997-1998 timeframe. With regard to equipment, purchases for the 1996-1997 period were expected to grow by 10%, and again by 5% for the following year. With an array of new products becoming marketable (as described in Chapter II), this was expected, as manufacturers will need to expand facilities and revise production lines to build the new products.

Table 4
Annual Plant & Equipment Expenditures
[Values in thousands of dollars]

	1996 (n=300)	**1997** (est., n=311)	**1998** (est., n=308)
Plant Expenditures	$ 59,767	$ 85,938	$ 157,122
Equipment Expenditures	876,268	962,794	1,004,812
TOTAL	936,590	1,048,701	1,160,995
Internally Funded	933,715	1,037,508	1,154,301
Externally Funded:			
Defense (DARPA, etc.)	1,913	927	534
Non-Defense Gov. (NIST, NASA, etc.)	91	243	979
Foreign Government	230	300	0
Non-Government Domestic	591	9,673	5,056
Non-Government Foreign	50	50	125

Source: BXA Optoelectronics Survey

Note that the breakdown of external funding sources again illustrates the downward spiral of available defense money and the shift toward increased funding by the more commercial-oriented, non-defense government sources.

Sales

Survey respondents were asked to provide a variety of information on their sales of optoelectronic devices and equipment. These data include projections made by the respondents from 1996, which were made in 1997. With the Asian, and now an apparent global financial crisis, these projections are probably overstated. We do not know to what extent, except to say that new technology, as a rule, suffers more in economic slowdowns as R&D budgets are slashed and consumers postpone discretionary spending. The sales data are presented by region, individual types of devices and equipment, and by application.

Sales by Region

With regard to devices, the growth trends seen in Table 5 were generally positive, with the respondents predicting annual growth of around 10 percent. The United States was the largest market by far (71%), with an expected positive growth of 9% between 1996 and 1997 and 7.8% between 1997 and 1998. Exports accounted for only 29% of sales, however, the growth rate reported is faster than the domestic market. Some markets were definitely stronger; China shows better than forty percent increases in sales for both years (albeit from a small base). The growth rate in sales to Japan was projected to decline over the period, from 47% between 1996 and 1997 to only 12% between 1997 and 1998. Considering the current financial crisis that Japan is facing, the market for U.S. products there could drop dramatically. Sales to other Pacific Rim nations were expected to dip in 1997 but then rebound some 27% in 1998, which is very similar to the anticipated performance of the Canada/Mexico market.

Table 5
Regional Device Sales
[Values in thousands of dollars]

Sales To:	1996 (n=242)	1997 (est., n=250)	1998 (est., n=236)
United States	$ 3,323,545	$ 3,622,396	$ 3,903,920
Canada/Mexico	138,720	131,857	160,309
Europe	622,612	610,207	691,987
Japan	290,316	426,208	476,399
China (PRC)	27,996	39,362	56,706
Other Pacific Rim	160,412	152,000	193,117
Other	88,525	160,467	174,582
Total Sales	4,652,126	5,142,497	5,657,020

Source: BXA Optoelectronics Survey

Expectations on equipment sales (Table 6) were mixed, with a dip in sales for 1997 anticipated at 0.3% followed by an increase in sales of 4.8% for 1998. The U.S. was again the prominent market, accounting for 54% of annual sales. U.S. sales were expected to dip slightly then increase by 5% in 1997. For international sales, China was once again the leader in expected growth, with 6.5% in 1996, then up by a remarkable 78% the next year. Japan showed a slight decrease in sales for both years, although again that prediction could vary widely depending

upon the current financial crisis facing that country. The Canada/Mexico markets reportedly will show modest increases of around 2.8% annually, while the European market fluctuated back and forth, negating any real growth trend. The other Pacific Rim countries remained one bright spot, with sales increases of 12% anticipated in 1997 followed by a another 20% surge in 1998.

Table 6
Regional Equipment Sales
[Values in thousands of dollars]

Sales To:	1996 (n=173)	1997 (est., n=181)	1998 (est., n=175)
United States	10,044,972	9,989,190	10,501,017
Canada/Mexico	2,151,733	2,213,683	2,274,300
Europe	5,409,876	5,242,030	5,454,131
Japan	273,000	263,717	262,451
China (PRC)	25,711	24,029	42,898
Other Pacific Rim	648,010	729,485	873,241
Other	213,990	242,552	207,297
Total Sales	18,767,292	18,704,686	19,615,335

Source: BXA Optoelectronics Survey

Sales By Component

Respondents were also asked to break down their sales by component. However, the data obtained from the surveys are very incomplete for this section, as many survey respondents found it difficult to provide their sales figures by component.

The data in Table 7 show that the expectations on the individual component markets are generally upbeat, with solid increases in sales anticipated for most of the products. The predictions given by the respondents for the growth in 1998-2000 is even more favorable, with all marketers giving positive trends. While many manufacturers expected growth of 20-30%, optical amplifier module data projected a growth of 386%. Even more remarkable, hybrid optical sales were expected to grow by 666%, and the market for optical connectors by 779.5% (probably not unrealistic considering the escalating demand for data pathways). All in all, from this data, component sales look promising.

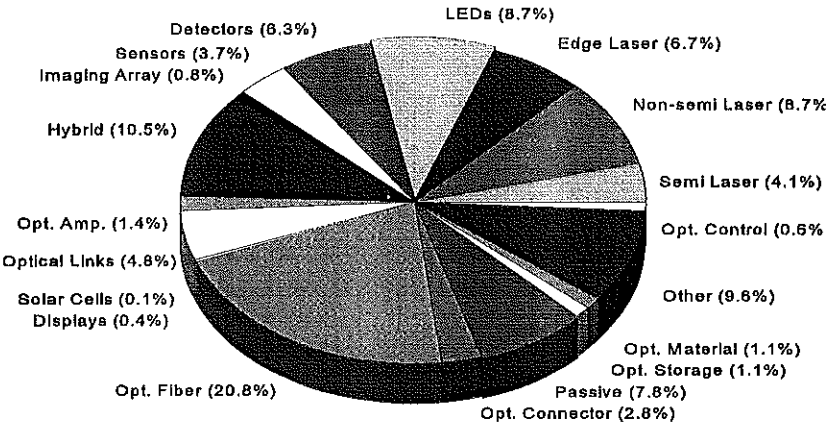
Table 7
Individual Component Sales
[Values in thousands of dollars]

	1996	1997(est.)	1998-2000 Avg. Growth (%)	# of Responses
Semiconductor Lasers	$ 172,792	$ 328,638	39.2	31
Non-Semiconductor Lasers	368,835	396,246	70.0	29
Light Emitting Diodes (LEDs)	368,254	376,586	24.9	14
Detectors	266,739	265,746	31.2	34
Sensors	157,818	180,902	12.6	13
Imaging Arrays	36,354	32,528	26.3	11
Hybrid Optical	446,365	461,491	666.0	19
Edge Laser T/R Modules	283,734	91,890	30.5	4
Optical Links	203,816	234,372	30.2	9
Optical Amplifier Modules	60,428	56,597	386.0	5
Flat Panel Displays	14,738	17,091	42.3	6
Solar Cells	6,002	6,804	445.0	3
Optical Fiber	879,193	965,013	32.4	38
Optical Connectors	119,456	138,011	779.5	17
Passive Optical	330,414	375,217	34.3	63
Optical Control	24,069	21,247	56.2	10
Optical Storage	46,067	26,319	11.8	4
Optical Materials	44,787	55,555	25.7	23
Other Components	405,919	465,848	42.0	61
TOTAL	$4,235,780	$4,496,101		

Source: BXA Optoelectronic Survey

A visual perspective on the relative size of each component sector can be seen in Figure 6. Clearly, the largest individual sales are in optical fiber, followed by hybrid optical components. However, grouped together, the laser components (semi, non-semi, and edge-based laser) also compose a sizeable share of the market.

Figure 6
Market Share Of Component Sales - 1996



Source: BXA Optoelectronics Survey

Sales By Equipment Type

As with component sales figures, the data on the breakdown on types of equipment sold are somewhat fragmented (due to some company limitations on providing sales data by equipment type), and the sum *does not match* the previous regional aggregate equipment sales figures. However, while limited, the information may help provide some perspective on the growth in individual equipment areas.

Table 8
Equipment Sales By Type
[Values in thousands of dollars]

	1996	1997(est.)	1998-2000 Avg. Growth (%)	# of Responses
Optical Measurement & Test	$ 460,209	$ 438,320	26.0	68
Commercial Communications	734,320	763,065	24.2	22
Other Opt. Communications	11,930	17,223	143.9	10

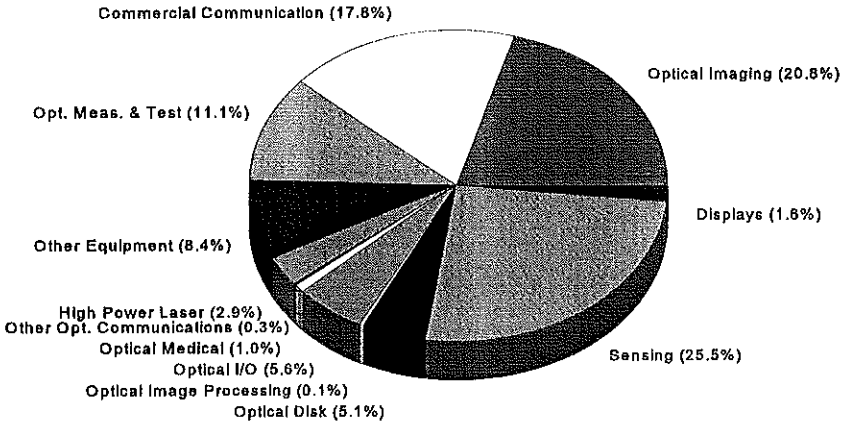
	1996	1997(est.)	1998-200 Avg. Growth (%)	# of Responses
Optical Imaging	860,272	833,020	40.8	35
Sensing	1,052,837	982,531	41.6	18
Optical Disk	210,563	266,924	18.5	2
Optical Image Processing	4,325	2,155	59.6	6
Optical I/O	231,036	278,121	8.3	6
Displays	64,980	171,301	184.7	9
Optical Medical	39,362	50,791	44.9	16
High Power Laser	119,306	117,152	210.3	26
Other Equipment	345,704	334,676	60.6	37
TOTAL	$4,134,844	$4,255,279		

Source: BXA Optoelectronics Survey

The following figure presents a better overall visual perspective of the available equipment sales. Clearly, sensing equipment led the group, followed by optical imaging, commercial communications and optical measurement & testing.

Figure 7

Market Share Of Equipment Sales - 1996



Source: BXA Optoelectronics Survey

Sales by Application

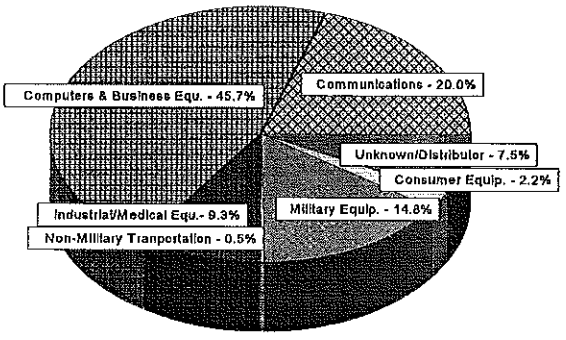
The sales data can also be broken down by application as shown in Table 9 and Figure 8. Aggregate sales figures for both devices and equipment are provided by particular application category. Please note that these figures may differ from summing the previous two tables, as some respondents only gave overall category totals in their data.

Table 9
Sales By Application
[In thousands of dollars]

Category	1996 Sales	% Total	# of Respondents
Computers & Business Equipment	$ 6,568,106	45.7	60
Communications	2,889,751	20.0	100
Military Equipment	2,123,202	14.8	101
Industrial/Medical Equipment	1,337,467	9.3	199
Unknown/Distributor	1,073,621	7.5	134
Consumer Equipment	317,845	2.2	57
Non-Military Transportation	76,265	0.5	21
TOTAL	$14,386,257		

Source: BXA Optoelectronics Survey

Figure 8
Sales By Survey Category - 1996



Source: BXA Optoelectronics Survey

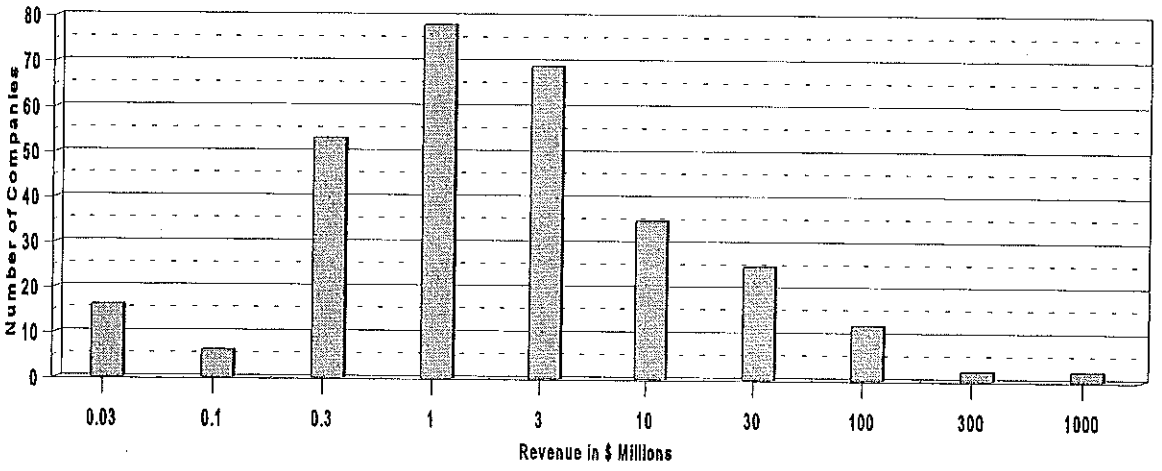
The categories listed are similar to the ones used in the 1994 BXA Optoelectronics Industry Survey, which allows for some comparison. As in 1994, the largest market was in computer/ business equipment, at 45.7% of the respondents. However, whereas the military market was the second largest category in 1994, the current data shows the communications market pulling ahead, putting military sales in third place. These polling results tend to confirm the expanding market seen in communications (driven by the consumer needs of increased electronic media flow, cell phones, etc.) and the declining budgets devoted toward military spending. While three quarters of the companies in the previous survey (71 out of 102) participated in the defense market, less than one third (101 out of 368) of the current respondents manufacture products for the defense sector.

Companies by Revenue

Figure 9 shows the number of companies for each indicated range of optoelectronics revenue. The data used were for 1997, which includes fifteen start-up companies recently established by the survey respondents. Clearly, our survey covers a wide spectrum of the companies in the industry, especially smaller companies which make up the essential industry infrastructure.

Figure 9

Distribution Of Survey Respondents By Optoelectronics Revenue - 1997



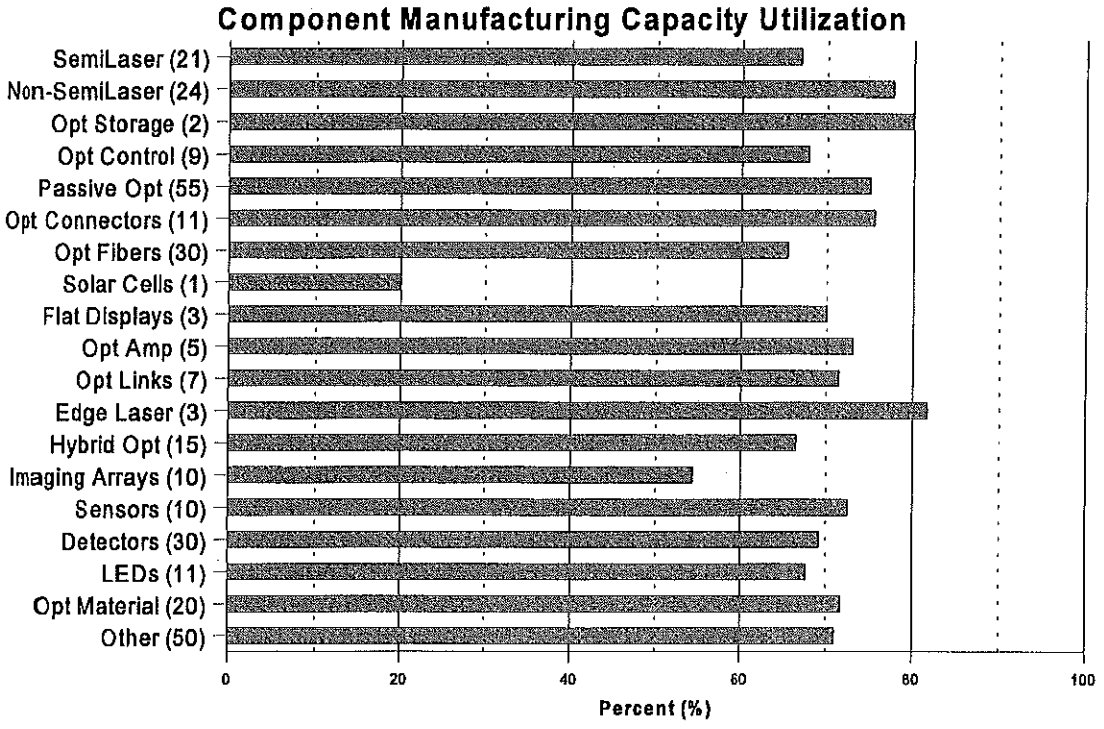
Source: BXA Optoelectronics Survey

Capacity Utilization

The following figure illustrates the average facility production capacity utilization for the manufacture of the listed components (with the number of companies responding in parentheses). For several components, the averages fall in the low 80s; however, most of the component

facilities appear to be running at a moderate 70% of production capability. This lower average utilization value than is often expected of major companies can most likely be attributed to the larger percentage of smaller companies in the data group, which often run at lower capacities. Among all components, solar cell production capacity is the most underutilized, at only 20%; however, only one company responded.

Figure 10

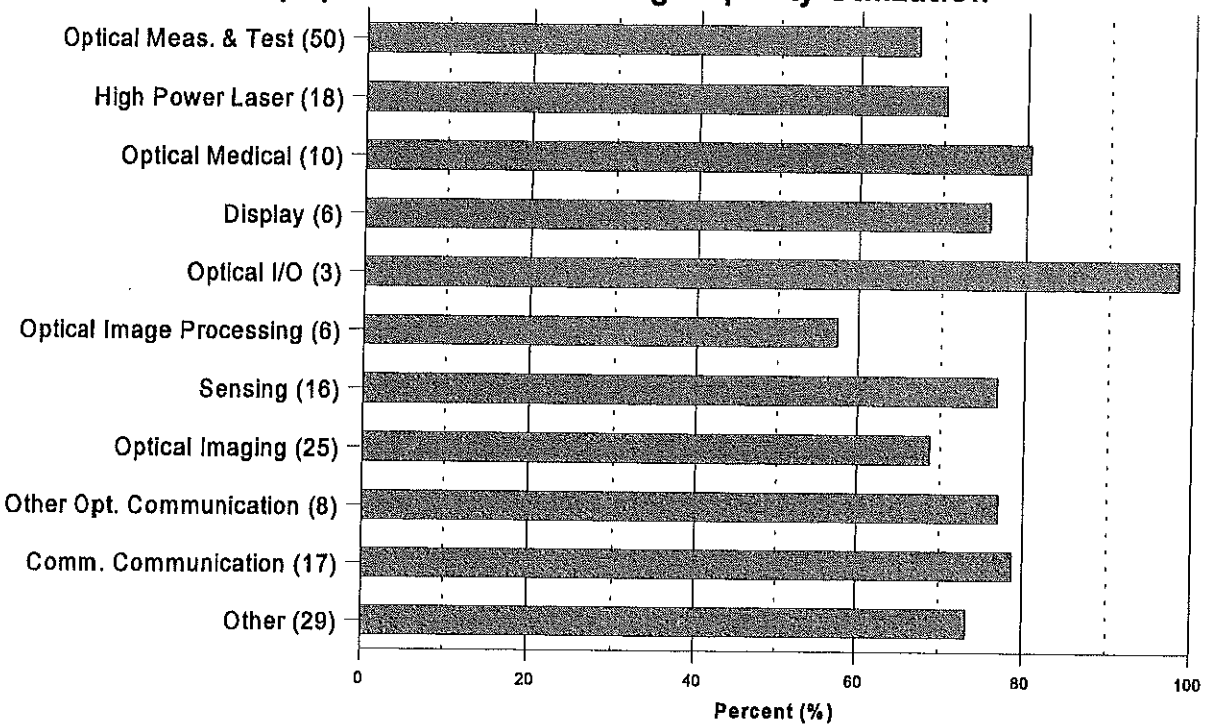


Source: BXA Optoelectronics Survey

For equipment manufacture, the overall capacity utilization values are somewhat higher, as seen in Figure 11. From the equipment listings (with the number of companies in parentheses), it's clear that on average, many of the companies are maintaining a production capacity in the high 70th percentile. Note again that these averages, lower than would be expected for major production facilities, reflect the large proportion of small companies in the survey data, which, while profitable, often are not running full time or at full capacity. One category average, optical I/O equipment, closely approached maximum capacity, and even the equipment item with lowest utilized production capability, image processing, reached an average of 57.5%.

Figure 11

Equipment Manufacturing Capacity Utilization



Source: BXA Optoelectronics Survey

Employment

Table below presents the employment data for the survey respondents broken down by job category.

Table 10
Employment Profile *

Job Category	1996	1997(est.)	1998(est.)
Marketing/Sales/General & Administrative	47,316	48,626	49,602
Scientists, Engineers and Technicians	14,752	16,068	17,393
Manufacturing	40,545	42,478	44,365
Other	38,306	38,435	38,562
TOTAL	140,919	145,607	149,922

Source: BXA Optoelectronics Survey

*** Includes employees of one very large company that accounts for over 50% of total employment and an even higher percentage of Market/Sales/General/Administrative and Other categories**

Employment is expected to grow by at least three percent, a promising sign; this also matched the 1994 BXA Survey's growth trends for 1990 and 1991. According to many of the survey respondents, the optoelectronics industry faces a trend also being noticed among other U.S. high-tech industries. U.S. labor force growth has slowed drastically – from 2.5 percent a year two decades ago to 1.3 percent today. As a result, unemployment has reached record-low levels, putting extreme pressure on employers who need a steady supply of trained workers.[3]

In 1996, the percentage of technical staff constituted 10.5% of the respondent's work force. The percentage of manufacturing employees was 28.8%. The marketing/sales/general/administrative was 60.8% for the 1996 data (some of this could be explained by the participation of resellers/distributors in the recent survey; they were not involved in the earlier survey), and the number for other employees is 27.2%. However, these percentages are highly dependent on the reported employment pattern of one large company; when this firm is excluded, the percentage of technical staff for 1996 becomes 24%, the manufacturing employees are 49%, the marketing staff is 19%, and the figure for other staff is 8%. These figures are roughly comparable to the 1992 values from the earlier BXA Survey, which are 17% for technical staff, 56% for manufacturing, 12% for marketing and 15% for other employees.

Labor Concerns

Like every other industry, a strong labor force is an integral facet of the optoelectronics industry. So it would seem only natural that many of the companies would have concerns, either major or minor, about their labor force. Out of the 368 companies surveyed, 114 (31%) directly expressed having such concerns.

Fourteen percent of those companies commenting complained about a lack of basic skills in their labor force. They said that the workers do not have a sufficient education or work ethic. "Most applicants do not have enough knowledge even though they seem to have enough schooling. They cannot add or subtract or know where places are in the world," was a statement included in the survey of one company. Six companies specifically stated that the lack of skills of the labor force have driven them to hire foreign nationals.

A small percentage of companies (5.3%) complained that they cannot afford the growing costs of the skilled labor force. Most of the increase in the cost of skilled labor is due to a decrease in the available number of skilled workers. As one company reported, "Shortage of skilled labor is a constant problem. Experience and talented engineers are in short supply and [a] large amount of money must be paid to attract new engineers."

The majority of the companies that had a complaint about their labor force were clearly searching for workers with specific skills. Optoelectronic specialists were the most highly sought after by the optoelectronic companies with 24 comments. Software engineers were also in high demand

with 14 comments by the companies. The firms are also seeking the valuable skills of analog designers, mechanical engineers and machinists.

Optoelectronics is not the only industry with worker skills shortages. American industry as a whole is increasingly complaining that the quality of the labor force is their most pressing challenge. The United States just is not training sufficient skilled workers to support its various high-tech manufacturing industries. Even for some of the more popular industries, such as software and entertainment, many technical positions remain unfilled. The number of U.S. computer science graduates has fallen from a high of 50,000 in 1986 to 36,000 in 1994. The National Science Foundation reported that, in 1995, 30 percent of all R&D workers with science and engineering doctorates were foreign-born. One-fifth of all undergraduates in computer-related fields – and half of all doctoral candidates – are citizens of foreign countries.[4]

"These trends are most pronounced in the high-technology hotbeds of California. Today, one-third of the engineers in Silicon Valley and Orange County are from other countries."[5] Some might see this as a most disturbing but seemingly unavoidable trend in the United States. Indeed, as the same article expresses, "Skilled immigrants have become a kind of secret weapon for U.S. technology firms unable to find the workers they need. But mounting anti-immigrant sentiment and new immigration laws have reduced the number of highly skilled newcomers coming to America. Between 1992 and 1995, the influx of skilled immigrants dropped by 32 percent – nearly 75 percent in California's Silicon Valley. The Information Technology Association of America estimates there are now 190,000 vacancies for high-tech workers, and the industry could create a million more new jobs over the coming decade." This trend is one that is expressed repeatedly by concerned companies in the optoelectronics field, and one that is probably being most ineffectively addressed.

Seven percent of the surveyed companies also commented on the high turnover rates of some of the skilled workers. One company, when posed with the question of whether they had any current or projected labor concerns, stated, "Yes, we are very concerned about excessive labor turnover, liability claims and labor union activities effecting our production output."

END NOTES

1. National Science Foundation Website, Science and Engineering Indicators, 1998.

2. *The Science Coalition*, "Trends in R&D - US Public Science, A Report to Congress," April 1997, 3.

3. Joel Kotkin and David Friedman, "Put a Cork in It," *Washington Post*, 24 June 1998, Outlook section, page C4, col. 1-3.

4. Joel Kotkin and David Friedman, "Put a Cork in It," *Washington Post*, 24 June 1998, Outlook section, page C4, col. 1-3.

5. Joel Kotkin and David Friedman, "Put a Cork in It," *Washington Post*, 24 June 1998, Outlook section, page C4, col. 1-3.

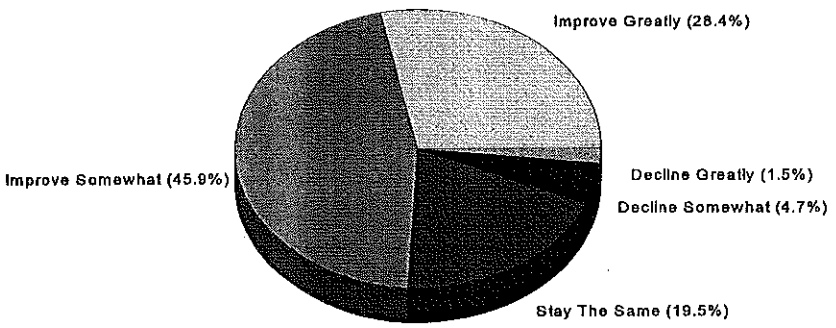
CHAPTER V

COMPETITIVENESS FACTORS

Competitive Prospects

Overall, companies responding to the BXA survey were optimistic about their future competitiveness. Of the 401 responses to the competitive outlook query, about 1/3 of the companies reported that their outlook will improve greatly, as seen in Figure 12. Further, over forty-five percent expected their outlook to improve somewhat. About twenty percent of the respondents indicated that their competitiveness was anticipated to stay the same. Fortunately, only 25 firms (6.2%) believe that their business will decline somewhat or greatly in the near future.

Figure 12
Overall Competitive Outlook For Next Five Years (401 Responses)



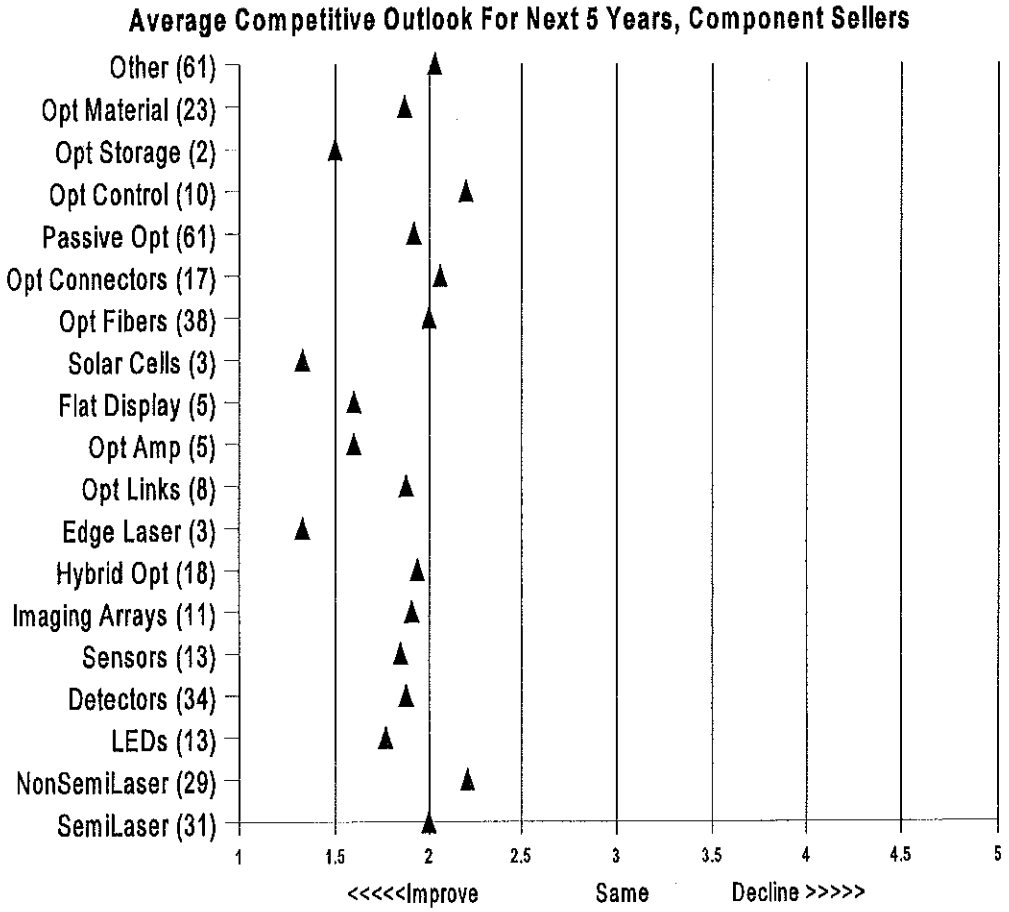
Source: BXA Optoelectronics Survey

Six companies expected sales to decline sharply. In one company, the owner was about to retire and had let people go; two firms noted that the big drops in government military spending had forced them to seek out new lines of business, leading one to close one particular component line completely. A fourth company was an intermittent job shop; their optoelectronic business is now much less regular, with a decrease in non-defense government sales. The final two companies gave no reason.

For analytical purposes, optoelectronic companies were divided into smaller groups to determine if competitive outlook varied by product type. For components, on a scale from 1 (will improve greatly) to 5 (will decline greatly), the overall average figure was 2.05, which shows a strong belief by many companies in the strength of their markets. A more exacting breakdown among the various optoelectronic components along with the number of companies responding is

illustrated in Figure 13. While all of the component prospect averages are positive, producers of solar cells and edge lasers indicated the most favorable growth (but also had fewest respondents).

Figure 13

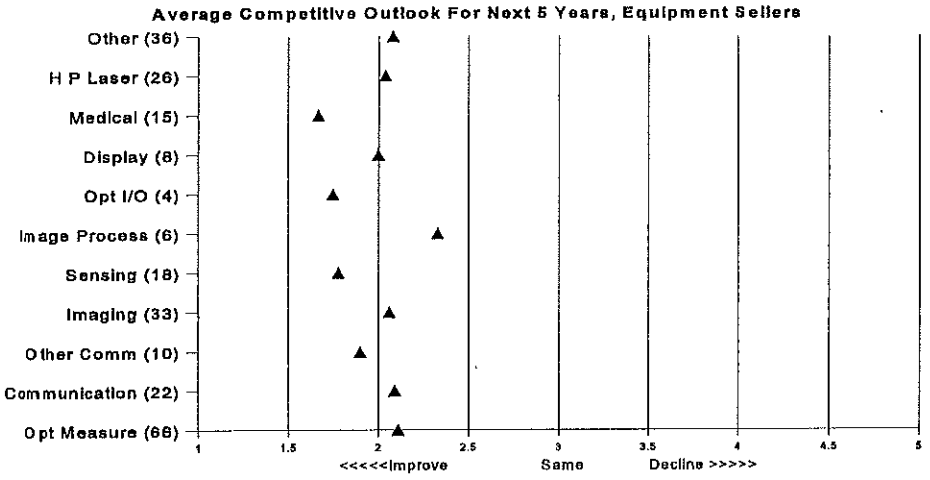


Source: BXA Optoelectronics Survey

Across the board, the respondents feel that they have technologically competitive products that are helping them to maintain or improve upon their status in their particular markets.

For optoelectronic equipment categories, competitive prospects also appear favorable. The competitive averages for the entire range of equipment were strongly positive (overall average of 1.98), with optical medical equipment, optical I/O, and sensing equipment producers indicating the best growth prospects. These averages are illustrated in the following Figure 14.

Figure 14



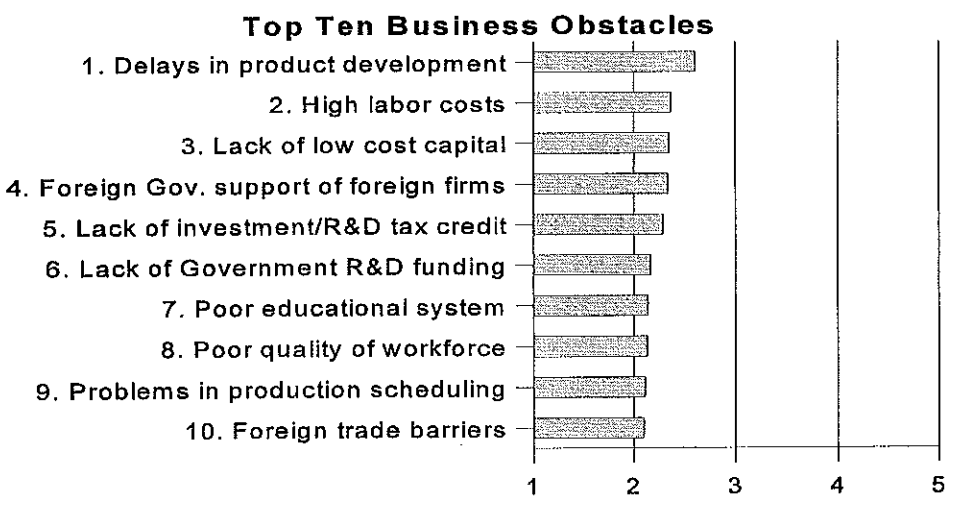
Source: BXA Optoelectronics Survey

Overall, many of the particular equipment and device manufacturers believe that they are standing strong in their market areas. While individual companies may wax and wane, the U.S. optoelectronic industry appears to be quite optimistic that it is maintaining its technological leadership and will continue to do so in the years ahead.

Potential Business Obstacles

Respondents provided feedback to a variety of business competitiveness concerns, rating the issues from 1-5, with 5 being a major obstacle and 1 being no obstacle. The top ten results are:

Figure 15



Source: BXA Optoelectronics Survey

Clearly, companies do have concerns, but with the averages for the top ten barely exceeding the halfway mark on the scale, firms do not consider the obstacles to be as major as was originally expected. Note that four of the ten concerns centered around financial issues, either a lack of available funding through various means or foreign assistance to the foreign competition. Other obstacles not ranking in the top ten, such as U.S. export controls, foreign product dumping, limited U.S. sources for critical manufacturing equipment and the reliance on foreign parts averaged even lower.

Import Dependency

Some 63.3% of the companies surveyed rely on at least one foreign-made component or piece of equipment critical to the manufacture of their end product. The companies were asked as to why they selected imported products rather than use domestic products. The results are given, by order of popularity, in the following table:

Table 11
Reasons For Sourcing From Overseas

	Primary Reason	Secondary Reason
1. No Known Domestic Source	24.9%	5.6%
2. Lower Cost	22.0%	23.2%
3. Domestic Source Inadequate	20.6%	16.2%
4. Better Quality	17.1%	27.9%
5. Other	6.9%	7.6%
6. Supplement to Domestic Source	5.8%	8.0%
7. Faster Delivery	1.3%	8.7%

Source: BXA Optoelectronics Survey

If there is no available domestic product, companies must source offshore, and both lack of a domestic source and inadequate domestic source came up as leading reasons for importing. Lower cost was the second leading reason, driving home the need for improved manufacturing efficiency in order to remain competitive. Better quality, ranked number four, was also a strong area of concern.

Where are all these products coming from? Japan is the leading source. The top ten import countries indicated by the respondents are:

Table 12
Top Import-Origin Countries

1. Japan	37.4%
2. Germany	18.9%
3. Britain	10.1%
4. China	6.9%
5. Canada	5.0%
6. Taiwan	4.6%
7. Russia	3.6%
8. Switzerland	2.9%
9. France	2.3%
10. Netherlands	1.3%

Source: BXA Optoelectronics Survey

We attempted to discern patterns in the wide variety of foreign sources for materials, components and equipment used in the manufacturing process. A complete listing of foreign-sourced items "most critical" to domestic optoelectronics business is provided in Appendix B. Some trends are apparent from a review of these data. Numerous survey respondents indicated dependency on foreign sources of optical grade glass because there was "no known domestic source". Sources of such glass were identified in Germany (Schott; Heraeus Amersil), Japan (Ohara) as well as the U.K. Another frequently mentioned dependency was ceramic packages/ferrules/substrates (most often from Kyocera of Japan). EG&G in Canada was often mentioned as a sole source for various photo diodes. Interestingly, several survey respondents indicated a dependency on "nonlinear crystals" from China (no known domestic source).

Of the firms responding, 43.2% indicated that they need foreign sources to maintain their current levels of quality and/or price. And, 54% said that they will continue to be dependent on foreign sources, as use of domestic suppliers will not allow them to remain competitive. When asked if they had a contingency plan if their particular foreign supplies were cut off, 18.2% of the responses were negative, indicating that they would have to end production of a particular product and in some cases the company would be forced to go out of business. Those firms that did have contingency plans offered the following courses of action:

Table 13
Contingency Plan Actions

1. Use Domestic Source	33.3%
2. Use Undetermined Source	16.4%
3. Develop In-house	13.2%
4. Use Other Foreign Source	13.2%
5. Redesign Product	8.8%

Source: BXA Optoelectronics Survey

Government Budget Cuts

Many companies in the optoelectronics industry do extensive amounts of business with the federal government, especially the defense sector. When the federal government decides to make budget cuts, this will naturally decrease the profits of the companies that do business with it. Some 208 of the 368 companies surveyed, or 56.5%, have been or will be affected by budget cuts of one kind or another. There are two distinct areas of budget cuts that have been delineated, defense budget cuts and non-defense budget cuts.

Defense budget cuts were strongly noted by 133 of the companies that have been surveyed. Of these, 46 of the firms were directly affected by defense budget cuts that seriously impacted their R&D funding, while 87 of the companies experienced budget decreases through canceled or reduced defense contracts. Understandably, the effect of these budget cuts varied from company to company. Recognizing the continual countdown in defense budgets, some companies have wisely diversified their markets to survive the decrease in the government business. As stated by one firm, "Defense only represents about 10% of our fiber [optics] sales. Defense cuts from [the] early 1990's impacted us then by reducing sales by 20-30%. Since then, we have changed our market direction towards commercial products." Another company had a very different and sobering response, "From the defense spending peak in the 1980's we have had to cut over half our staff, close buildings, and cut costs. We will be merging with [company] within the next six months, and will go through another round of employment reduction, buildings and facilities closures and overall consolidation and cost reductions. We will continue to diversity into foreign sales."

Non-defense budget cuts have significantly affected 75 of the companies surveyed. Fifteen of these companies have already been affected and the remaining 60 stated that they could be distinctly affected by budget cuts. The government organizations that were mentioned the most were NASA, NIH and NSF. Other than that, there was little expressed concern for non-defense budget cuts.

BXA reviewed the data to determine which companies were succeeding in today's market, and visited one to obtain additional information on what criteria help to make a successful optoelectronics company. The results are summarized below.

Adjusting To The Future – One Company's Strategy For Success

- **A well considered focus: Growth projections are established with guidelines on how the firm can maintain/improve the efficiency of production while improving responsiveness to the clients. For example, the firm's in-house testing is specifically suited to the customer needs, and serves to enhance the factory output.**
- **Continued capital investment with a specific annual allotment to enhance/expand production capabilities; testing equipment is built in-house to ensure it meets production precision requirements.**
- **Maintain growth in international markets (Japan, Europe) to stay on top of the areas of interest and to remain fresh and competitive.**
- **Seek and maintain an excellent technical staff in sufficient numbers with the educational caliber to help the company stay on the cutting edge in technology. They have been able to maintain this technical prowess through judicious staff funding support stipulations included in past military contracts, a wise contractual move.**
- **Adjust to declining government military R&D funding through increased use of more commercial-oriented government funding while avoiding over-dependence on federal funds. The current matching fund programs now available drive the effort for additional private funding. While a viable R&D sourcing, companies do have concerns about what constitutes matching funding, what are company R&D deductions - the accounting can get complicated.**
- **Focus on technologies that have the potential for real commercialization. This philosophy of seeking commercial applications for the technologies developed in the government arena has allowed them to diversify their customer base and move away from the dependency on government/military work.**

APPENDIX A

BXA OPTOELECTRONICS SURVEY (THIS COPY IS SMALLER THAN ORIGINAL)

OMB Control 0694-0105 Expires 06-30-98

U.S. Department of Commerce
Bureau of Export Administration

CRITICAL TECHNOLOGY ASSESSMENT: OPTOELECTRONICS

PURPOSE OF THIS ASSESSMENT

The U.S. Department of Commerce/Bureau of Export Administration is working with the Optoelectronics Industry Development Association and in cooperation with the U.S. Department of Defense on a critical technology assessment of the U.S. optoelectronics industry. The goal of this joint assessment is to analyze the long-term health and competitiveness of the optoelectronics industry; to determine the growth trends and emerging markets in this field; and to develop recommendations to ensure the continued ability of the industry to support defense-related missions and programs.

YOUR RESPONSE IS REQUIRED BY LAW

This assessment is conducted pursuant to the Defense Production Act of 1950, as amended (DPA) (50 U.S.C.A. app. section 2061 et. seq. (1993)) and as delegated to the Secretary of Commerce in section 401(4) of Executive Order 12656 (3 C.F.R. 585 (1988)). Your response to this questionnaire is required under section 705 of the DPA (50 U.S.C.A. app. section 2155). Any information submitted in response to this questionnaire will be deemed **BUSINESS CONFIDENTIAL** and treated in accordance with section 705 of the DPA. Information submitted will not be shared with any non-government entity, other than in aggregate form, and the Department will assert the applicable Freedom of Information Act (FOIA) exemption if it is the subject of a FOIA request. Notwithstanding any other provision of law, no person is required to respond to nor shall a person be subject to a penalty for failure to comply with a collection of information subject to the requirements of the Paperwork Reduction Act unless that collection of information displays a currently valid OMB Control Number.

Burden Estimate and Request for Comment: Public reporting burden for this collection of information is estimated to average 4 hours per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to BXA Reports Clearance Officer, Room 4513, Bureau of Export Administration, U.S. Department of Commerce, Washington, DC 20230, and/or to the Office of Management and Budget, Paperwork Reduction Project (OMB Control 0694-0105), Washington, DC 20503.

EXEMPTION

For this report, **optoelectronics** will be defined as systems, equipment, and/or devices which emit, modulate, transmit, and/or sense light or are dependent on the combination of optical and electronic devices. If your firm has not conducted any manufacturing or non-manufacturing activity related to optoelectronics in the United States since January 1, 1995, you are not required to complete this form. If this is the case, please provide the information requested below and return this page to the address on the next page.

Name of Company	**Address (City, State)**
Signature of Authorized Official	**Date**
Name of Official-Please Print	**Phone**

GENERAL INSTRUCTIONS

1. Please complete this questionnaire in its entirety as it applies to the optoelectronic operations of your organization or firm. This questionnaire applies to all of the optoelectronic-related business for your firm, both optoelectronics

components/devices and equipment/systems using optoelectronic technology.

2. The questionnaire has 2 sections as follows:

Section A.	FIRM IDENTIFICATION
Section B.	I. FINANCIAL INFORMATION II. COMPETITIVENESS ISSUES

All of Section B should be copied and sent to each business unit/division for completion.

3. It is not our desire to impose an unreasonable burden on any respondent. IF INFORMATION IS NOT READILY AVAILABLE FROM YOUR RECORDS IN EXACTLY THE FORM REQUESTED, FURNISH ESTIMATES AND DESIGNATE BY THE LETTER "E".

4. **Report all data in either calendar year or fiscal year, and specify which.** Fiscal year values are appropriate if your records are kept that way; if you use fiscal year instead of calendar year values, please indicate the 12 month period:

From _____ to _____

Please make photocopies of forms if additional copies are needed.

5. Questions related to the questionnaire should be directed to Ronald Rolfe, Engineer/Industry Analyst at (202) 482-4563 (e-mail: rrolfe@bxa.doc.gov) or Margaret Cahill, Trade and Industry Analyst at (202) 482-8226 (e-mail: mcahill@bxa.doc.gov). You may also fax your questions to (202) 482-3195.

6. Before returning your completed questionnaire, be sure to sign the certification on the next page and identify the person and phone number to be contacted (if necessary) at your firm. Return questionnaire by **November 21, 1997** to :

Ms. Karen Swasey
Director, Economic Analysis Division, SIES
Room 3876, BXA, re: Optoelectronics
U.S. Department of Commerce
Washington, DC 20230

CERTIFICATION

The undersigned certifies that the information herein supplied in response to this questionnaire is complete and correct to the best of his/her knowledge. The U.S. Code, Title 18 (Crimes and Criminal Procedure), Section 1001, makes it a criminal offense to willfully make a false statement or representation to any department or agency of the United States as to any matter within its jurisdiction.

Company Name _____

Signature of Authorized Official: _____

Title: _____

Phone & Fax Numbers (with area code): Phone:_____Fax:_____

E-Mail address _____

Date: _____

In the event that we have questions regarding your response, please provide below a point of contact with telephone and fax numbers and e-mail address, if different than above.

Point of contact: _____

Title: _____

Phone & Fax Numbers (with area code): Phone:_____Fax:_____

E-Mail address: _____

ADDITIONAL COMMENTS

If you have additional comments after completing the survey, please provide them below.

_____

_____

_____

_____

_____

_____

_____

_____

_____

DEFINITIONS

BUSINESS UNIT/DIVISION - The segment of a corporation consisting of facilities in which discrete groupings of optoelectronic devices or equipment are manufactured and/or related research and development is conducted. Includes auxiliary facilities operated in conjunction with (whether or not physically separate from) such production facilities. Does not include facilities solely involved in distribution.

FACILITY - A site where optoelectronic devices or equipment are manufactured and/or related research and development is conducted.

FIRM - An individual proprietorship, partnership, joint venture, association, corporation (including any subsidiary corporation in which more than 50 percent of the outstanding voting stock is owned), business trust, cooperative, trustees in bankruptcy, or receivers under decree of any court, owning or controlling one or more establishments as defined above.

OPTOELECTRONICS - systems, equipment, and/or devices which emit, modulate, transmit, and/or sense light or are dependent on the combination of optical and electronic devices.

RESEARCH AND DEVELOPMENT - includes basic and applied research and product development in the sciences and in engineering, and design and development of prototype products and processes. For the purposes of this questionnaire, research and development includes activities carried on by persons trained, either formally or by experience, in the physical sciences including related engineering.

UNITED STATES - Includes the fifty States, Puerto Rico, the District of Columbia, the Virgin Islands, American Samoa, and the Trust Territories of the Pacific Islands.

SECTION A

FIRM IDENTIFICATION

(To be completed at the Corporate level)

A1. **Firm Address:** Please provide the name and address of your firm.

Firm Name: _____

Address: _____

City, State, Zip: _____

A2. Parent Firm: If your firm is wholly or partly owned by another firm, indicate the name and address of the parent firm and extent of ownership. For joint ventures, list both firms involved.

Firm Name: _____ _____

Address: _____ _____

City, State, Zip: _____ _____

Country: _____ _____

Ownership:_____ % Ownership:_____ %

Year of acquisition or formation of joint venture: _____

A3. Type of Organization: Please indicate the nature of your optoelectronics business by checking the appropriate box(es):

		Primary Business	Secondary Business
Manufacturing:			
	Material Supplier	☐	☐
	Components Fabricator	☐	☐
	Equipment Fabricator	☐	☐
	Systems Fabricator	☐	☐
Non-Manufacturing:			
	Research	☐	☐
	Distributor	☐	☐
	Reseller	☐	☐
	Other (specify)	☐	☐

_____

_____

_____

A4. Product Categories

Please indicate (✓) which optoelectronics equipment/devices you manufacture/sell/research. Use the codes (i.e., E05 for Sensing Equipment) to identify products in your responses to question A5. Item lists under the categories are not all inclusive. Please select the closest type or category. If a particular subcategory is not listed, check the main box, or if necessary, specify in "other" category.

DEVICES

- ❒ **D01 Semiconductor Lasers**
  - ❒ Blue lasers ❒ VCSELs
  - ❒ Edge-emitting lasers
- ❒ **D02 Non-semiconductor Lasers**
  - ❒ Gas lasers ❒ Liquid (dye) lasers
  - ❒ Solid state lasers ❒ Fiber lasers
- ❒ **D03 Light Emitting Diodes (LEDs)**
  - ❒ Visible LEDs ❒ Infrared LEDs
- ❒ **D04 Detectors**
  - ❒ APDs ❒ Phototransistors
  - ❒ Thermal detectors
- ❒ **D05 Sensors**
  - ❒ Fiber sensors ❒ Reflection sensors
- ❒ **D06 Imaging Arrays**
  - ❒ CCDs ❒ Smart pixel arrays
  - ❒ CMOS arrays ❒ Amorphous arrays
  - ❒ X-ray arrays ❒ Imaging fiber bundles
- ❒ **D07 Hybrid Optical Devices**
  - ❒ Couplers ❒ Photo-interrupters
  - ❒ Optical encoders ❒ Reflection sensors
- ❒ **D08 Edge Laser-based T/R Modules**
- ❒ **D09 LED or VCSEL Optical Links**
- ❒ **D10 Optical Amplifier Modules**
  - ❒ Fiber amplifiers
  - ❒ Planar waveguide amplifiers
  - ❒ Semiconductor optical amplifiers
- ❒ **D11 Flat Panel Display Devices and Modules**
  - ❒ LCDs
- ❒ **D12 Solar Cells**
- ❒ **D13 Optical Fibers**
  - ❒ Single mode fibers ❒ Multimode fibers
  - ❒ Specialty fibers (e.g., hi-bi, doped)
  - ❒ Image fibers, light guides, etc.
- ❒ **D14 Optical Connectors**
  - ❒ Discrete connectors
  - ❒ Array interconnect devices
- ❒ **D15 Passive Optical Devices**
  - ❒ Isolators ❒ Attenuators, filters
  - ❒ Multiplexers ❒ Gratings
  - ❒ Lenses, grated index lenses
  - ❒ Splitters/combiners
- ❒ **D16 Optical Control Devices**
  - ❒ Optical switches ❒ Optical modulators
  - ❒ Spatial light modulators (SLMs)
- ❒ **D17 Optical Storage Media (excluding content)**
  - ❒ CD-Recordable ❒ DVD
  - ❒ Optical WORM disks
  - ❒ Erasable disks (PC and MO)
- ❒ **D18 Optical Materials**
- ❒ **D19 Other Components/Devices**

Specify: _____

EQUIPMENT

- ❒ **E01 Optical Measurement & Test Equipment**
  - ❒ Fiberoptic test equipment
  - ❒ Light measurement equipment
  - ❒ Laboratory apparatus
- ❒ **E02 Commercial Communications Equipment**
  - ❒ Fiberoptic telecom terminal equipment.
  - ❒ Optical amplifier equipment
  - ❒ Fiber CATV distribution equipment
  - ❒ Optical LAN equipment
  - ❒ Optical cross connects
  - ❒ Panels, distribution frames
- ❒ **E03 Other Optical Communications Equipment**
  - ❒ Ground/satellite communications
  - ❒ Satellite-to-satellite communications
  - ❒ Munitions guidance
- ❒ **E04 Optical Imaging Equipment**
  - ❒ Video cameras
  - ❒ Digital cameras
  - ❒ Film cameras
  - ❒ Night vision equipment
  - ❒ LIDAR
  - ❒ FLIR
- ❒ **E05 Sensing Equipment**
  - ❒ Machine vision
  - ❒ Optical gyroscopes
  - ❒ Fiber sensors
- ❒ **E06 Optical Disk Equipment**
  - ❒ Digital audio disk players
  - ❒ Video disk players
  - ❒ Optical disk recording equipment
  - ❒ CD ROM units
- ❒ **E07 Optical Image Processing Equipment**
- ❒ **E08 Optical I/O Equipment**
  - ❒ Printers
  - ❒ Facsimiles
  - ❒ Copiers
  - ❒ Scanners
  - ❒ Bar-code readers
  - ❒ Others (array-sensor applied)
- ❒ **E09 Display Equipment**
  - ❒ Large displays (>50")
  - ❒ Other display systems
- ❒ **E10 Optical Medical Equipment**
- ❒ **E11 High Power Laser Equipment**
  - ❒ CO_2 laser processing equipment
  - ❒ YAG laser processing equipment
  - ❒ Other laser processing equipment
  - ❒ Laser weapons
- ❒ **E12 Photoprinting & Testing Equipment**
- ❒ **E13 Other Optoelectronics Equipment**

Specify: _____

A5. Individual Business Units/Divisions: If your firm has multiple business units/divisions engaged in optoelectronics (including optoelectronic-enabled equipment), please provide the name of each and list the location of all facilities within each business unit/division. Make additional copies of this page if necessary. Please also indicate the status of the facility:
E = existing **N** = new/planned~indicate year **C** = closing~indicate year.

I. Business unit/division: _____
Products (use codes, i.e. D12 for Solar Cells): _____

Facility Name	City, State, Country	Status

II. Business unit/division: _____
Products (use codes, i.e. D12 for Solar Cells): _____

Facility Name	City, State, Country	Status

III. Business unit/division: _____
Products (use codes, i.e. D12 for Solar Cells): _____

Facility Name	City, State, Country	Status

SECTION B

I. FINANCIAL INFORMATION

All remaining pages should be photocopied and distributed to each optoelectronic-related business unit/division. Each completed section should be returned by November 21, 1997 to:

Ms. Karen Swasey
Director, Economic Analysis Division, SIES
Room 3876, BXA, re: Optoelectronics
U.S. Department of Commerce
Washington, DC 20230.
202-482-5954

B1. Employment: Enter the number of workers for your business unit/division at *all facilities* in the United States, including part-time employees, that are employed at year end:

JOB CATEGORY	1996	1997 (est.)	1998 (est.)
Marketing/Sales/General & Administrative			
Scientists, Engineers and Technicians			
Manufacturing			
Other			
TOTAL			

B2. Labor Concerns: Do you have any current or projected labor concerns, such as shortages of certain skills, excessive turnover, liability claims, etc. that have or may adversely affect(ed) your optoelectronics manufacturing or R&D operations.? If so, please describe them below:

_____

_____

_____

_____

_____

_____

3. R&D Expenditures: Please indicate your total expenditures for optoelectronics R&D in dollars for 1996 through 1998. For each year, indicate the sources (both internal and external) of funding for this R&D.

	1996	1997 (est.)	1998 (est.)
TOTAL			
Internally Funded			
Externally Funded:			
Defense (e.g., DARPA, Armed Services)			
Non-Defense Government (e.g., NIST, NASA, NSF)			
Foreign Government			
Non-Government Domestic			
Non-Government Foreign			

B4. Capital Expenditures: Please provide expenditures for optoelectronics-related plant and equipment in dollars for 1996 through 1998. For the totals reported for each year, please indicate your sources (internal and external) for capital funding.

	1996	1997 (est.)	1998 (est.)
Plant			
Equipment			
TOTAL			
Internally Funded			
Externally Funded:			
Defense (e.g., DARPA, Armed Services)			
Non-Defense Government (e.g., NIST, NASA, NSF)			
Foreign Government			
Non-Government Domestic			
Non-Government Foreign			

B5. Sales by Region: Please provide the sales by region for all optoelectronic devices and optoelectronic equipment. Include all intracompany transfers/transports at their fair market value, reported in dollars.

Sales to:	Devices			Equipment		
	1996	1997 (est.)	1998 (est.)	1996	1997 (est.)	1998 (est.)
United States						
Canada/Mexico						
Europe						
Japan						
China (PRC)						
Other Pacific Rim						
Other						
Total Sales:						

B6a. Sales of Goods by Application. Please provide the ***1996*** sales from all optoelectronics by application, in dollars. The table on this page applies to optoelectronic devices; the table on the next page applies to optoelectronic equipment. The totals by applications should sum to the final total at the bottom of the "1996 TOTAL" column. Subtotals and grand totals are required; detailed responses by category will highlight trends in specific subsectors.

Devices	Communi-cations	Computers and Business Eq.	Industrial/ Medical Equipment	Non-milit. transpor-tation	Military Equipment	Consumer Equipment	Unknown/ Distributor	**1996 TOTAL**	**1997 Total (est.)**	**Expected Annual Growth Rate ('98-'00)**
Semiconductor Lasers										%
Non-semicond. Lasers										%
LEDs										%
Detectors										%
Sensors										%
Imaging Arrays										%
Hybrid Optical Devices										%
Edge Laser-based T/R										%
Optical Links										%
Optical Amplifier Mod.										%
Flat Panel Displays										%
Solar Cells										%
Optical Fibers										%
Optical Connectors										%
Passive Optical Devices										%
Optical Control Devices										%
Optical Storage Media										%
Optical Materials										%
Other Components										%
Subtotal										%

B6b.

Equipment	Communi-cations	Computer and Business Eq.	Industrial/ Medical Equip.	Non-milit. transpor-tation	Military Equipment	Consumer Equipment	Unknown/ Distributor	1996 TOTAL	1997 Total (est.)	Expected Annual Growth Rate ('98-'00)
Optical Measurement & Test										%
Commercial Communications										%
Other Optical Communication										%
Optical Imaging Equipment										%
Sensing Equipment										%
Optical Disk Equipment										%
Optical Image Processing										%
Optical I/O Equipment										%
Display Equipment										%
Optical Medical										%
High Power Laser										%
Photoprinting & Testing										%
Other Optoelectronics										%
Subtotal										%

TOTAL SALES (Devices + Equipment) (B6a and B6b)									%

SECTION B

II. COMPETITIVENESS ISSUES

B7. **Capacity Utilization Rate:** What is your business unit/division's approximate capacity utilization rate (i.e., for the established production line, what percent of full production output is in operation) ?

_____%

B8. **Marketshare:** In your optoelectronic business unit/division, what is your average estimated worldwide marketshare?

_____%

B9. **Competitors:** Who are your 6 major competitors, domestic or foreign, and what is their estimated share of the world market for optoelectronics (%) ?

Company Name	% Share
1.	%
2.	%
3.	%

Company Name	% Share
4.	%
5.	%
6.	%

B10. **Competitive Prospects:** Please rate how your overall competitive prospects will change over the next 5 years:

- Improve greatly ❒
- Improve somewhat ❒
- Stay the same ❒
- Decline somewhat ❒
- Decline greatly ❒

B11. **Potential Obstacles:** Please indicate the importance of the following potential obstacles to your business: (Score each item from 1-5 with 5 being a great obstacle and 1 being no obstacle)

____ Lack of access to low-cost capital
____ Lack or uncertainty of Government R&D funding
____ U.S. export controls
____ Dumping by foreign firms
____ Foreign government support of your foreign competitors
____ Environmental and health regulations
____ A litigious environment
____ Anti-trust regulations
____ U.S. Government auditing policies and procedures
____ Lack of investment/R&D tax credits
____ Poor quality of workforce
____ Poor educational system
____ Lack of U.S. suppliers for critical manufacturing equipment
____ Reliance on foreign parts
____ Lack of automation/robotics
____ High U.S. labor costs
____ Delays in product development
____ Problems in production scheduling
____ Inability to penetrate foreign markets due to foreign trade barriers
____ U.S. protectionism
____ General state of the U.S. economy
____ Other (specify) _____
____ Other (specify) _____

B12. Government Budget Cuts: Please indicate what impacts government spending reductions have had or will have on your optoelectronics operations. Also indicate what steps your company is considering to offset any negative impact that these reductions have had on your business (i.e. reduced employment, entered new lines of business, closed plants, consolidated product lines, reduced costs).

B12a. Defense Budget Cuts:

_____

_____

_____

_____

_____

B12b. Non-Defense Budget Cuts:

_____

_____

B13. Import of key items for production of optoelectronics devices/equipment: Please complete the table below regarding your use of foreign sources of supply for items that are most critical to your optoelectronics business. Consider manufacturing and test equipment as well as materials and supplies. Use the following reasons to indicate why a foreign source was used:

A.	No known domestic source	D. Lower cost	G. Other - Specify:
B.	Domestic source inadequate	E. Faster delivery	_____
C.	Supplement to domestic source	F. Better quality	

Item Imported	Supplier/Country of Origin	Primary Reason	Secondary Reason

B14. Contingency Planning: For dependencies cited in the last question for which you indicated "A. No known domestic source" or "B. Domestic Source Inadequate," please identify actions you would take if your foreign source were interrupted.

_____

_____

B15. Future Dependency: Does your firm expect to become dependent on imports of equipment, parts and raw material in the next two years? If so, please list the item(s), the company name and the country of origin.

APPENDIX B

KEY ITEMS IMPORTED FOR U.S. PRODUCTION

The following is a compilation of key products (in no particular order) imported by the companies in this survey. The primary and secondary reason for the need to import these items are given in the right hand columns.

Key Reasons:

A. No known domestic source
B. Domestic source inadequate
C. Supplement to domestic source
D. Lower cost
E. Faster delivery
F. Better quality
G. Other -specify

ITEM IMPORTED	COUNTRY OF ORIGIN	PRIMARY REASON	SECONDARY REASON
Step Index plastic optical fiber	Toray/Asahi/Mitsubishi - all from Japan	A	
Fluoromonomer	Ausimont - Italy	B	Domestic inability to license use of fluromonomers
Resins	Hitachi - Japan	A	B
LCD Panels	Japan	A	
Ceramic Ferrule	Toto, Kyocera, Sanwa - Japan	A	F
SLD Source	Enritsu - Japan	A	
Lasers	Lambda Physic- Germany	B	F
Phase Masks	Lasiris - Canada	A	
Spectrum Analyzers	Ande - Japan	F	B
PreForm	Heraeus - Germany	B	F
Germanium	Union Miniere - Belgium	B	D
Non-linear Crystals	China	A	B

Slit Lamps	Japan/Germany	B	G
InAs Wafers	MCP-UK, Sumitomo-Japan	A	
Ge Wafers	Aframet-Belgium	B	D
MCT Wafers	Russia; SAT-France	B	D
Ceramic Packages	Japan	B	
Cold Cathode Fluorescent lamps	Japan, Taiwan	D	A,E
Glass	Germany, Russia	A	
Diodes, Hybrid Circuits	Taiwan	D	
Lead Frames	Taiwan	D	B
Cadmium Sulfide	Japan	A	F
Silicon Wafers	Germany, Denmark	A	
Headers, Lids	Mackin, Kyocera, Shinko - Japan	F	C
Substrates, Fiber	Sumitomo, Kyocera - Japan	F	E
Dicing equip.	Kulick & Soffa - Israel	F	
Couplers	IP FiberOptics -UK	F	C
Photo-diodes	EG&G - Canada	E	D
Laser diode	Hitachi - Japan	D	E
Optical sub-assembly	SFO - India	D	C
Polishing equip., Return loss meters	JDS - Canada	F	D
Ferrules	Rikei - Japan	F	D
Metal Castings	IPO - Taiwan	D	E
Encapsulated lasers	Fujitsu - Japan	D	F
Laser chips	Furukawa - Japan	D	Not a competitor.

Ceramic Packages	Kyocera - Japan	F	Access to technology
Glass/Metal Seal Packages	Schott - Germany	F	Access to technology
Silicon Platforms	Hitachi - Japan	D	C
Lenses	Dross - Switzerland	D	F
Liquid Crystal Displays	Hosiden - Japan	B	B
LCD	NEC - Japan	B	B
LCD	Samsung - Japan	B	B
Laser Led	Hitachi - Japan	F	A
CCD	Hitachi - Japan	A	F
820nm LED (Mil Temp)	Mitel - Sweden	B	Required for European customer.
Lensed 850nm VCSEL	Honeywell - England	B	
Low Noise Field Effect Transistor	Fujitsu - Japan	A	
Optical Connectors	Deutsch ltd. - England	A	Required for European customer.
High Speed Photodiodes	EG&G - Canada	B	F
Cast Mechanical Darts	Shelcast, Elcan - Canada	B	F
Memory ICs	Various	B	
Pin Diodes	EG&G	G	A
Silicon Wafers	Waca - Germany	A	A
Optical Grade Glass	Schott Glass - Germany	C	
Lead Screws	SKF Assoc. - France	A	F
Optical Grade Glass	Heraeus Amersil - Japan	A	

Lasers	Lambda Physik - Germany	C	E
Controllers	Mitsubishi - Japan	E	F
Detector, IR	Germany, France	A	
Detector, IR	Japan	A	F
Detector, IR	England	A	D
Optical Production Machinery	Germany	F	B
Laser Optics, Etalons, Optical Measurement Equipment	UK	F	A
Sapphire Raw Material	Russia	D	C
Polishing Pitch	Gogolz - Switzerland	A	
Calcium Fluoride Raw Material	Nihon - Japan	D	C
Finished BKT Lenses	China	D	G
Semiconductor, Laser Diodes, APD(P?)	Japan	A	Best product.
Single Crystal Salts	Russia	A	D
Germanium	Russia	D	E
CsI Crystals	UK	A	
Electronic components	Pacific Rim	D	F
Optical Sensors	Pacific Rim	B	D
Optical Components	Japan	Better Price	
Optical Components	Russia, China, Korea	D	C
Specialized Edgers, Generators, Polishers, some CNC, some Digital	Germany	F	B
Semi-finished Glass Components	Japan	D	C

Electronic Components	Japan	A	
Various optical materials	various suppliers -Japan, UK	F	D
LEDs	Japan	B	
Fusion Splicer	Sweden	A	
Non-Linear Crystal	China	A	B
Machine Parts	Devtek/Shellcast - Canada	F	C
IR Sensors	Siemens - Germany	B	A
CCD Arrays	Sony - Japan	B	B
Equipment	Nokia-Moillifer - Finland, Medek & Shorner - Switzerland	F	B
Optical Fibers	Furukawa - Japan	Parent	C
Steelwire	Trefil Aubed - Germany	B	F
Optical Fibers	Lycon - Denmark	C	
Water Block Tapes	Geca - Netherlands	F	
Connectors, Connector Housing	Seiko - Japan	C	
D4 Connectors	Kyocera - Japan	A	
Laser Machines	Yamazaki - Japan	G	A
Precision Optical Lenses	Japan	D	E
Electronic Autocollimator	Germany	We are the U.S. distributor of a German corp.	
Connector	England	A	Sister company
Photomultiplier Tubes	Hamamatsu - Japan	B	F/D
Ferrules (ceramic)	Kyocera - Japan	B	F
Special Fiber	NOI - Canada	A	

Substrates	Sumitomo - Japan	C	D
Epi (GaP, green)	Showa Denko - Japan	A	F
Epi Reactors	Hixtron - Germany	C	F
Assembly Machinery	Misc. Japanese Suppliers	B	F
Parts, i.e. Lead Frames	Misc. SEA & Japan. Sup	D	F
CDR Mechanism	Phillips - Netherlands	A	G
DVD Mechanism	Sony - Japan	A	D
Optical Drive	Sony - Japan	F	D
Print Engine	Canon - Japan	F	D
DRAM	Multiple sources	C	D
Tunable Laser Source	HPBID - Germany	B	D
Lithium Niobar Modulator	Sumitomo - Japan, IOC - UK	B	F
Lightwave Switches	JDS - Canada	B	F
Lasers	Mitsubishi - Japan	B	F
Rofin Sinar Laser	Germany	F	D
LASAG	Switzerland	F	D
High Powered Lasers	Japan	A	
Packages	Kyocera - Japan	F	D
Packages	Egide - France	D	E
Glass Lense	CDHC - China	D	E
Large Glass Lense	CDHC - China	B	D
Lense	Kerisick(?) - Japan	D	F
Optical Glass	Japan	D	
Te02	China, Russia	F	D/G - supplier is our competitor.

Active Devices	Furukawa - Japan	F	B
Jumper Cables	Chieng Shang - Taiwan	D	E
DC Power Supply	Japan	A	C
CCD Arrays	Sony - Japan	A	
Soda Lime LCD Glass	Pilkington - UK	A	A
Optical Material	Schott - Germany	F	B
Printed Circuit Boards	Olympic - Canada	D	E
Enclosures	Schroff - Germany	F	G
Electronic Components	varies	D	E
Optical Glass	Schott - Germany	A	
Optical Glass	Ohara - Japan	A	D
Lens Generator	Loh - Germany	D	F
Polished Substrates	Korea, China, UK	F	D
Synthetic Crystals	Russia, China	F	D
Image Sensors, Optical Lenses, Video Processing	Japan	A	B
AFOCAL Variators	ISCO Optics - Germany	A	D
LBO, Non-linear Crystals	China	G	
Laser Diodes	Japan	F	C
Microphones	Bruel & Kiaer -Denmark	F	B
Raw materials	Japan, Malaysia	B	D
Substrates	Taiwan, China, South Korea	D	C
Finished Lenses	Taiwan	C	D
CCD Camera	Japan	A	D
Fused Silica Preforms	Heraus - Germany	A	F
Draw Tower Automation	Heathway - UK	B	F
Injection Molding Machine	Nissei - Japan	B	F

Robots for Molding	Yushin - Japan	B	G
Coordinate Measuring Machine	Mitsutoyo - Japan	B	G
Acrylic Sheet	Notz - Switzerland	B	F
COC Molding Material	Ticona or BF Goodrich - Japan	A	
High Power Semiconductor	Japan	A	
Acousto-optic Modulators	Germany	B	
Special Glasses	Germany	A	
Lithium Niobate Material	Japan, Russia, PRC	C	D
Fused Silica Material	Germany	B	
Tooling	Germany, Pacific Rim	D	
Sapphire Material	Switzerland	D	
Backside thinned CCD	EEV - United Kingdom	B	F
Lenses	Parent - Germany		
Photomultiplier Tubes	Japan	B	D
Image Intensifiers	Japan	B	F
Optical Crystals	Russia, China	D	G
Piezoelectric Plates	Russia, China	D	C
InGa Slices	Epitaxial Products - UK	F	B
GE Slices	Sogem - Belgium	F	B
Laser to Fiber Coupler	Oz Optics	C	E
Cameras & Video Processors	Qualisys	F	E
Silicon Detectors	Singapore	D	C
Isolator	Sumitomo Osaka Cement - Japan	F	D, E

Complex High Power System	Bystronic - Switzerland	G - Central Manufacturing Site.	
Glass	Japan	F	B
PWA, Power Supply	Diratron Inc. - Taiwan	A	G - Engineered in part.
Card Ejectors	Schroff Inc. - Germany	A	G - Engineered in part.
Resistors, CF	Priebe/Pacom - Taiwan	D	E
Optics	Gaepoong Optical - Korea	D	F
Epitaxial Wafers	EPI - United Kingdom	F	B
DC-DC Convertor	UMC	D	A
InP Semiconductor Wafers	Showa Denko and Nippon Mining - Japan	F	B
	Thomas Swan - UK		
Commercial Communication Equipment	Hitachi Ltd. - Japan	G - Parent	
Solar Module	Kyocera - Japan	G - Parent	
Video Cameras, CCD Arrays	Japan	F	B
Detectors, Motor	Japan	F	B
Optical Encoders	Japan, Germany	F	B
Flat Thin Sheet Glass	Belgium, Germany	A	
Capacitors	Japan	A	B
Photomultiplier Tube, Material to Assemble PMTs	Hamamatsu Photonics - Japan	B	F
Fire Polished Optical Glass	Germany	A	
Assy./Test Equipment, Molded Components	Japan	G - Parent	
Electronic Components	Japan	D	

Certain Crystals	PRC	A	B
Optical Fiber	Plasma - The Netherlands	D	B
Aramic Yarn	Akzo - The Netherlands	D	B
Excimer Laser	Germany	F	B
Optics	Germany	A	
FiC	Tong Hsing - Taiwan	D	
Various items	Russia	B	C
Glass	Germany	A	
High Precision Machine Parts	Germany	F	A
Fiber Cleaver	Fujikura - Japan	F	D
Polymide Alighnet Material, Rubbing Machine, LEDs	Japan	A	
Polymer Spacers	Japan	B	F
Glass Wafers	Japan	F	C
Doped Fiber	Fibercore - UK	G - Captive Supplier	F
Optical Modules	Japan	G - Parent	
Grin Lenses	NSG - Japan	A	B
Capillary	NEG - Japan	A	B
Faraday Rotators	Mitsubishi, Sumitomo - Japan	C	F
YVO4 Crystals	Casix - China	B	D
Materials	China	F	D
Component	Japan	F	C
Pulse Transformer	UK	D	F
Line Filters	Switzerland	B	
Integrated Circuit	India	A	

Handheld boxes	Bopla - Germany	B	F
Lense Manufacturing Equip.	Lott - Germany	A	
Raw Glass, Tubes, Rods	Schott - Germany	F	B
Lenses, Prisms, Filter	Germany	F	D
Lenses, Prisms, Filters	Japan	F	D
Prisms	Switzerland	F	D
Computer Processors	DY4 - Canada	A	E
Detector	EG&G Optoelectronics	D	E
Glass Preforms	Hereaus Amersil - Germany	A	
Glass Preforms	Shinetsu - Japan	A	
Glass Preforms	Quartz Producers - UK	A	
Fiber Drawing Tower	Heathway - UK	F	E
Spectro-photometer	Bentham - England	A	E
Color Printer	Shinko - Japan	F	D
Color Monitor	Mag Innovision - Taiwan	F	D
Color Monitor	Viewsonic - Taiwan	F	D
Non-Linear Optical Crystals - BBO, LBO	China and Russia	D	
Detector-grade Silicon	Topsil - Denmark	B	F
TO Window Caps	Schott - Germany	F	D
Plastic Encapsulant	Nitto - Japan	F	B
LEDs, Photo Diodes	Japan	B	
Ge	Ukraine	D	
Laser Emitters	HP - UK	F	D
Lenses	Nittoh - Japan	F	D
Benders	Polytech Institute - Germany	F	B

Calcium & Magnesium, Fluoride Powder	Germany	A	
Optical Components	China	D	
Galvanized Wire	Stefil - Canada	D	
Fiber Preforms	Heraeus - Germany	F	A
OTDR	Canada	A	
Power Meters	Canada	B	F
Wire	Canada	C	B
Plastic PBT	Germany	E	
Optical Fiber	Europe	D	G - Customer requirement.
Microscope	Panasonic - Japan	A	
Optical Inspection Equipment	Nikon - Japan	G - Parent	A
CO2 Pulsed Laser	Germany	A	
RAM	Pacific Rim	D	
Machinery	Germany	B	F
Glass	Japan	D	B
Glass Fiber	Germany	C	B
Power Supplies	Taiwan	D	
Connectors/Cables	Taiwan	D	
Charge-coupled Devices	Japan	B	F
Fiber Optics	Germany, Japan	B	F
Ceramics	Japan	D	C
Thermionic Cathode	France	B	D
Printed Circuit Boards	Matrox - Canada	F	B
Objectives	US office of Nikon, Capra - Japan	B	F

Pifocs	US office of Polytec PI - Germany	F	E
Industrial Glass	Germany	A	
Optics	Canada, UK, Germany	D	C
Image Intensifiers	Germany	C	D
Power Supplies	Israel	D	C
Pump	Knaver, Pharmacia - Germany	F	
CCD Array	Sony - Japan	B	D
Ceramic Ferrules	Seiko Instruments Japan	B	F
Ceramic Waveguides	Germany	D	
Photomultiplier Tubes	Japan		
Grin Lense	NSG - Japan	A	F
Garnet	Mitsubishi, - Japan	B	F
Garnet	Sumitomo - Japan	C	F
Glass Capillary	NEG - Japan	C	F
Prism	Casix - China	B	F
Ferrule	SFI, CO - Japan	C	F
Plastic Containers	Amko - Taiwan	C	D
Everything	Spindler & Hoyer GmbH	G	F
Germanium	Affirmet - Indusa	B	E
Laser Diode Optics	Japan	F	D
Laser Diode Controllers	Germany	F	D

Semiconductor lasers, non-semiconductor lasers, Light Emitting Diodes, LED Optical links, Flat Panel display devices, Optical Fibers, Optical Materials, etc.	Russia	G - They work as importers, using personal contacts to obtain products.	D
Optical Imaging Equipment	Germany	G - We import 90% of our products from our parent in Germany.	
CCD TV Camera, TV Monitor	Japan	F,G - features	B
CNC LensGrinder	Loh Optical - Germany	A	F
Lens Tester	Trioptics - Germany	B	F
Lenses	Japan	B	B,F
Photomultiplier Tubes	Hummatsu - Japan	B	D
SMPP Fiber	Alcoa-Fujikara - Japan	B	F
Light Lens Optics	FW1 Photo-optics - Japan	A	G - Fuji Xerox Design Control
The following are DC 220 Family Production Materials: Raster Output Scanner Optic	Fuji Xerox (FX) Suzuka - Japan	A	D
Document Handler	Niska - Japan	A	G - Fuji Xerox design control.
MAG Roll	FX Suzuka - Japan	B	D
Bias Charge Roll	Tokai - Japan	B	D

Raw Glass	Schott - Germany	A	G - Not enough government support over the years for domesitic industry.
Raw Glass	Ohara - Japan	A	"
Raw Glass	Pilkington - UK	A	"
Thyratron	E.E.V. - England	A	
Turbo Pump	Leybold Hereaus - Germany	B	
Ceramic PFN Tube	Haldenwanger - Germany	D	
Blower Wheel	Eucania - Canada	B	
Everything	Israel	G - Parent	
Precision	Oriental Motors - Japan	B	F
Plastic Ferrules	Switzerland	D	F
Ceramic Ferrules	Japan	E	D, F
IR Lenses	V&S Scientific - England	D	F
Rutile Material	Japan	A	
Schott Glass	Germany	A	
Lenses	China	D	F
Silicon Wafers	Germany	A	
Lenses	Japan	D	F
Lenses	China	D	F
Microscope Objectives	Japan	B	D
Components	Adament - Japan	D	F
Video Camera, Integrated Circuits	Japan	A	B
Yttrium Oxide, Rare Earth Oxides	Nippon Yttrium - Japan	F	D

Rare Earth Oxides	China, Russia	D	
Half-size Computer Board	Taiwan	D	
Laser Diodes	Japan	D	F
Optical Glass	Germany, Japan	A	B
CNC Generating	Germany	B	F
Fiber Optic Couplers & WDMs	Sifam - UK	F	
F/O RF Links	Foxcom - Israel		
Optical Prisms	Nitto Optical - Japan	D	F
UV Grade Fused Silica	Heraeus Amersil - Germany	B	D
Optical Glasses	Schott Optical - Germany	A	D
Fused Silica	Heraeus - Germany	C	F
Optical Manuf. Equipment	LOH Machinery - Germany	B	F
Avalanche Photodiodes	Canada	A	
Semicondutor Lasers	Canada	F	
Pockels Cell	Germany	E	D
LBO/BBO Crystals	China	A/D	
Chromium Doped YAG Crystals	China	A	
CLBO Crystals	Japan	A	
F-18 Substrates	Nippon Silica Glass - Japan	B	E&F
F-15 ROA Castings	Shellcast Foundries - Canada	D	
ROA Optics Housing Castings	Cercast - Canada	D	
Polycarbonate Substrates	Pilkington - England	A	
50 & 75mm Camera Lense	ABC Tracking - Japan	E	D
Ferrules	Kyocera - Japan	B	F

Couplers	ADC AOFR - Australia	C	
Split Sleeves	Kyocera - Japan	A	
Test Equipment	HP - Germany	A	
Connector Components	Huber Suhner - Switzerland	G - patent	
Precision Reflectometer	Optoelectronics - Canada	A	
Excimer Laser	Lambda - Germany Lumonics - Canada	A	
Isotopically Enriched Cadmium Gas	Russia	A	
LBO Crystal	Lithuania	B	F
Imaging Equipment	DGP(/) - Netherlands	A	B
Test Equipment	Sinbick Instruments - Germany, Sobie Instruments - France, Scantron, Ltd. - UK	G - we distribute foreign equip. in U.S.	
Crystals	China, Russia, Germany	D	
Ceramic Parts	Germany	D	B
Fiber Optic Connectors	Seiko - Japan	F	D
Graded Index Fiberoptics	Japan	B	F
NEC 856 (transistor)	NEC - Japan	B	A
PCH1800 22130 A2M	NSG - Japan	B	A
P35-1110-0	GEC - France	B	A
Crystals	Europe, China	B	D,E
Lenses	Japan, China	A	D,E,F
Video Monitor, Video Monitor	Sony - Japan	B	D
Zoom Lens	Universe Kogaku - Japan	A	F
Iodine Cells	Bureau des Poids of Mesures - France	B	F

Modules	Limate Corp. - Taiwan	D	E
CCD's	UK	G	
LCD's	UK	G	
Solar Cells	UK	G	
Thermal Imaging Cameras	UK	G	
Multimode Optical Fiber	Plasma (DVARA) - Nertherlands	C	D
?	Japan	F	
Optics	ICOS - UK	A	
FFT Spectrum Analyzer	SIOS - Germany	B	
Cesium Iodide Coating	Hamamatsu - Japan	A	
TAB Packages	Shindo - Japan	A	
Custom Asic Devices	AMS - Australia	B	
Row Drivers	Japan	A	
Pulsed ND-Yag lasers	Lasag AG - Switzerland	F	A
Parts for lasers	Lasag AG - Switzerland	A	
Optical Components	China	D	E
Lense	Avimo - Singapore	A	A
Polishing Machines	Schneider - Germany	F	C
Gain Block	Germany	G - supply chain requirement.	
Fiber Optic Connector	Diamond - Switzerland	A	B
Industrial Computer	UK, Taiwan	D	
Wouldn't answer.			
Hi-res scanners	UK, Germany	A	B
Calcium & Magnesium, Fluoride powder	Germany	A	

Case	UK	F	D
Eyepiece	China	D	
Lenses	Japan	C	F
not included			
Molding material, Molds, Testing equipment	Japan		G - proprietary source.
Optoisolator, Phototransistor, Photodiode	Japan	G - "Business type"	F
MFG/Test Equip	Singapore, Japan	B	D
PCB, LED CHIPS	Taiwan, Japan	D	B
Silicon Wafers	Wallker - Germany	D	F
Cables	Cablemaster - Taiwan	D	E
LEDs	Mitsubishi - Japan	D	B
Crystals	Hilgar - UK	D	E
Non-Linear Crystal and Laser Crystal Assemblies	Coretech Crystals - China	D	F
Entire system	Germany	B	D
LEDs	Siemens - Germany	B	E
LEDs	Mitsubishi, Stanley - Japan	A	
Reflectors	IMOS Gubela GMBH - Germany	B	F
Semiconductor Laser	Japan	D	C
Optical Components	Misc.	D	F
Metal Ferrules	France	F, D	B
1 watt C.W. Laser Diodes	Casix - Taiwan	D	E
Multimode Diffraction Grating	ILDA - Germany	D	A
Taps & WDMs	Sifam - UK	F	

Erbium Doped Fiber	Fibercore - UK	D	F
Fiber Optic Cable	Alcoa, Fujikura - Japan	D	C
Germanium	Afrimat - Belgium	D	
Charred Couple Device	Thompson - France	B	F
All items.	Various	G - exclusivity of supply.	
AO QSwitch	UK	C	D
LBO Crystal	China	A	
Finished Optical Comp.	Sister/Parent Company - UK	D	G - intercompany
Optical Fiber	China	D	C
LEDs	Japan	C	D
Optics		D	
850nm LEDs	Sweden	A	F
1300/850 Duplexers	England	D	F
Sensors	Sony - Japan	D	F
Grin Lenses	Selfoc - Japan	A	
Pulse Transformer	EEV - UK	F	
Capacitors	TDK - Japan	F	
Filters	UK	B	
Substrates	Japan	D	
Diode Pumped Double YAG Lasers	Russia, Taiwan	D	B
Visible Diode Lasers	Japan	A	
Lenses	Japan	F	D
Mixed Metal Mon-linear Optical Materials	Znanie Ltd. - Russia	A	D

CCD Camera Arrays	Thompson - France	C	F
Mold Compound	Nitto Denko, Sumitomo, Amoco - Japan	A	
Connector Pins	Pressac - UK	G - customer specified.	
Glass Lense	British Optical - UIC	C	
Magnets	Shintoa Intl. - Japan	D	


DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA