# Opportunities in Optoelectronics

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1. Introduction
2. Markets and Applications
3. Technology Segmentation
4. Summary
5. Appendix
    a. Display Components
    b. Optoelectronic Components Content of Selected Equipment
    c. Optoelectronics-based Equipment Market
    d. Optoelectronic Equipment Market
    e. Enabling Optoelectronic Component Content of Equipment Market
    f. Comparison with Components Market in 1993

## 1. Introduction

Two years ago, nine US companies with interest in optoelectronics founded OIDA, the Optoelectronics Industry Development Association. This step was a response to a step taken ten years earlier by the Japanese industry. At the prodding of and with substantial funding from MITI, the Japanese industry formed OITDA in 1980. It quickly became the center for Japan's vision on optoelectronics and focused the industry investments on those opportunities with the greatest long term potential. The result is history: Japan's share of the optoelectronic components market went from 30% in 1980 to 70% in 1992 while the US share shrunk from 50% to 15%.

After getting organized, OIDA quickly realized that the development of a vision for optoelectronics was long overdue. OIDA made the development of a technology roadmap its first major project for 92/93. To assure that this roadmap is market rather than technology driven, Phase 1 became an assessment of market opportunities while Phase 2 will assess progress in technology and tries to identify technology holes, which then become recommendations for future industry investments and federal support. At this point, Phase 1 is practically complete and Phase 2 is in high gear.

OIDA's plans met a responsive cord in Washington. Both NSF and DARPA were supporting research in this field at a substantial level, but the industry's response to this research was quite negative: the supported research had little relevance to the industry's needs in the 2-5 year time frame. To remedy this situation both funding agencies were interested in a closer coupling between industry and

academia and a technology roadmap was considered a valuable guide for project selection.

In parallel, the National Labs are undergoing a significant restructuring of their charter. Optoelectronics has always been a major area of military interest, from smart bombs to spy satellites. An effective coupling of their capability to the industry's needs is one of the most important weapons to improve the competitiveness of the US high-tech industry over the next decade. Again OIDA's roadmap program is a valuable guide for this process.

For this presentation we will use the preliminary data of the Phase 1 report to identify the major opportunities. Next, we will briefly touch each area and highlight the most important technical challenges. In the final part we will focus on the most important challenge, namely displays and develop arguments, why this area needs special attention.

## 2. Markets and Applications

The methodology chosen in this analysis is based on a systematic segmentation of markets into applications and enabling components. Let us use the computer hardware market of Fig.1 as an example. The market is segmented first into four categories frequently used in market analysis: processors, peripherals, communication and miscellaneous categories such as office and retail automation equipment including the important subsegment of copying. Next, each segment is subdivided into sufficient subsegments to identyfy those subsegments that are enabled by key optoelectronic components. The subsegments of Fig.1 are grouped into three categories of optoelectronic content: (1) enabled and included in the analysis, (2) significant content but not included and (3) practically no content.

Table 1 takes a look at those subsegments of the equipment markets that critically depend on enabling optoelectronic components. In other words, without the critical component the product would not be feasible, practicable or cost effective. For instance, a palm-top personal information appliance based on conventional CRT technology does not make any sense by any meaningful criteria. Table 1 summarizes the opportunities by industry or market segment. The 1993-98 time frame is tied to actual data from 1991 or 1992 and to readily available market research reports. The 1998-2013 time frame is based on an industry consensus derived from a series of workshops and industry-wide meetings that included visionaries from academia and private consultants.

In Table 1 the industry segments are: (1)computers including the subsegments of displays, datacom, optical storage and laser/LED printers; (2)telecom including fiber- in-the-loop (FITL) and the fiber optics based portion of cable TV; (3) IME is a mixed bag including industrial, medical and energy applications; (4) transportation, mainly automotive: (5) military/aerospace and finally, (6)

consumer electronics consisting of TV, HDTV, CD players, video disks and video phones.

This analysis has to be taken with a grain of salt: for most market segments the analysis counts end-user equipment value, i.e. street price of printers or TV sets. For automotive or military applications it is inappropriate to count the price of a Thunderbird because of its LED based taillight or the price of an F-15 airplane for its cockpit LCD display. In these cases, only the value of the taillight or cockpit display subassembly is applied to Table 1. These components are an important and valuable part of the system, but they are not enabling.

**Observation #1:Today computer and consumer applications dominate but over the next 20 years telecom, industrial, medical, energy and automotive applications will grow to a level of respectability while military applications will disappear into the background noise!**

In Table 2 we are dissecting the above market segments by their underlying technology such as: (1) displays both CRT and all flat panel technologies used in computer, consumer and automotive applications; displays used in industrial, medical or military applications are not included in this line;(2) telecom equipment used in single-mode fiber based voice or data networks and cable TV including fiber optic transmitters, receivers and fibers but not including the cost of installing the cable plant; (3) datacom equipment based on multi-mode fiber networks in computer and automotive applications but not counting fiber use in other market segments; (4) optical storage equipment for computer and consumer applications and (5) laser or LED based printers. The final segment entitled "other" includes those applications that do not fall into the above defined five major categories. For instance, a gas laser based industrial welding machine or a solar cell panel in a satellite are included in this line.

According to Table 2, we expect strong growth in the two communications categories and in optical storage. The laser\LED printing category is significantly lower, but it has substantial upside potential if it becomes the technology of choice for color copying, an application which is not included in this analysis.

**Observation #2: Display based equipment represents approximately two thirds of the equipment market enabled by key optoelectronic components, today and over the next 20 years!**

In Table 3 we are attempting to assess the underlying enabling component content for several equipment categories. For the first four examples the enabling component content is 3% or less at the component level and 7% or less at the

subassembly level. For datacom LAN applications it rises to the 8-12% range. In contrast, for the four display based examples the component content is in the 25-35% range of the equipment's street price. This level is exceptionally high due to the high inherent manufacturing cost of displays in any technology. It also reflects the serious risk exposure to equipment manufacturers that depend on them.

**Observation # 3: The OEM price of display components represents approximately one third of the street price the end-user pays for display based equipment, regardless of its complexity!**

**Note:** A manufacturer of laser printers can still be quite successful if his laser component supplier gouges him by 50%, i.e. $7.50 instead of $5.- for a laser used in a $1000 printer. Access to state-of-the-art components is more important than price! On the other hand, a portable PC manufacturer will be forced out of the market if he has to pay a 20% price premium or if he has only access to a non-current generation of display technology. He will be at the double mercy of his toughest PC competitors: the vertically integrated Japanese display suppliers!

## 3. Technology Segmentation

In order to estimate the value of the underlying components market, we have multiplied the approximate percentage of enabling component from Table 3 with the equipment value from Table 2. The result is displayed in Table 4.

**Observation #4: Displays completely dominate the enabling optoelectronic component content: >90% today, 80% in 20 years!**

Table 5 repeats Table 4 and lists the 1993 actual OEM components market for display components and for semiconductor based optoelectronic components. For displays, the agreement is good. The component content of the identified equipment represents over 90% of the actual component market. On the other hand, the non-display components in the listed categories of enabled equipment represents only 25 % of the actual optoelectronic components market in 1993. This situation is not surprising since the majority of semiconductor based optoelectronic components ends up in applications where they are incremental, but not enabling. Here are some examples: LED lamps in running shoes, fishing bobbins, toys or taillights; fiber optic links in digital audio gear, pachinko machines and one-armed bandits. Similarly*, a laser with an OEM price in the 3-5$ range makes the HP Laserjet 4 technically feasible, but other optoelectronic components such as a 16 character alphanumeric display plus numerous LED lamps and sensors represent a multiple of the laser value but are not counted in the component content of Table 4.*

Let us now examine the segments for printers, storage, datacom and telecom in some detail and then focus on displays.

As shown in Fig. 2, the laser/LED printer market will grow modestly over the next 20 years. This picture could change dramatically if it becomes the technology of choice for color copying. Relative to ink jet printing, laser printers have better resolution, speed and print quality. For black & white printing there are no major technical challenges, but ink jet printers will maintain serious challenges on cost. For color printing there are serious challenges on registration and color accuracy. The black & white market has established speed expectations that will be difficult to meet with a four-pass color system. And again, ink jet color printers will provide a challenge on cost.

Figure 3 breaks down the subsegments of the optical storage market. We predict an explosive growth for computer memory to 25B$ and for video disks to 15B$. CD players and CD-ROM will grow more modestly to 10 and 4B$, respectively. The advantages of optical storage over magnetic disks are density, cost per megabyte and interchangability of media. The major technical challenge is increased density by operating at shorter wavelength. A blue laser operating at 400 nm would increase the density by a factor of four compared with today's devices. This wavelength shift represents an extremely tough hurdle. A secondary challenge is the development of a one-pass erase/write cycle.

Fig. 4 illustrates the datacom market based on multi-mode fiber. Datacom by through-the-air infrared systems is under development now, but is not included in this forecast. The data behind Fig. 4 breaks the market into three speed segments: <50, 50-155, and >155 Mbd. The emphasis will shift from the low speed domination today to the medium speed segment because of several standards recently approved or under discussion at this time: FDDI (125 Mbd), ATM (155 Mbd), Sonet-OC3 (151 Mbd) and a 100 Mbd version of Ethernet. Strong demand for higher speed will provide rapid growth for >155 Mbd in the second half of the period.

Multi -mode fiber based datacom has to be compared with four other communication technologies: wire, infrared, single-mode fiber and RF. The three important performance parameters are: speed, distance and interference. And finally, there is the overriding measure: cost. Multi-mode fiber scores high on performance against wire, infrared and RF. Single-mode fiber is clearly superior on speed and distance, but far inferior on cost. A cost comparison with wire, infrared and RF depends on the individual situation. At low speed wire can use an existing wire installation. This option is limited at higher speed/distance combinations, but new modulation and signal processing technology keep expanding the range of datacom over existing wire plants. Over the next five years, wire will prevail at low and medium speeds in existing installations and fiber will make strong inroads in all new installations. At high speeds, multi-mode

fiber will prevail over single-mode fiber for cost reasons, if satisfactory short coherence length lasers or high-speed LED's can be developed. Infrared and RF are formidable contenders because neither requires expensive cable installations. Infrared is especially attractive for desk-top interconnects because of its predictable range and freedom from interference.

There remain many technical challenges, most of which include performance or cost. High speed operation over multi-mode fiber requires low coherence lasers that fill a substantial fraction of the fiber's mode volume. Transmitter, receiver, connector and installation cost have to keep moving downwards to meet the challenge from performance improvements in wire. Another challenge are parallel intra-machine interconnects at a speed equivalent to the system clock rate. These parallel interconnects probably will evolve into optical back planes. Interconnects between multi-chip modules and chip-to-chip represent uncharted waters at this time.

The telecom market of Fig. 5 represents a segment that is quite large, 28B$, and very monolithic. It is completely dominated by fiber-in-the-loop (FITL), also known as fiber-to-the-curb (FTTC) or fiber-to-the-home (FTTH). The prevailing standard will be the Sonet hierarchy: 51, 151 and 622 Mbd. All fibers buried in the public right-of-way will be single-mode fiber operating at a wavelength of 1300 or 1550 nm. The choice of single mode fiber is due to its practically unlimited bandwidth. The installed fiber represents the most expensive segment of the system. The bandwidth capability of a single-mode fiber system can easily be upgraded in the future by exchanging the optoelectronic transducers at either end. This feature allows a start today at a low bit rate or by using analog transmission. In the future upgrades to any level of the Sonet hierarchy can be achieved quite cost effectively. Even upgrades to wavelength division multiplexing or optical heterodyning are feasible.

Presently there are two industries competing for this market: telephone and cable TV companies. Their short term approach for serving private homes differs: The telephone companies propose an FTTC system that provides broad band digital service to a small number of subscribers (4-30)per individual fiber. In contrast, the cable companies propose to utilize their existing broad-band coaxial cable plant and provide broad-band analog service to 150-2000 subscribers per fiber link in their upgraded CATV backbone. It is recognized that in the long run the digital approach will prevail regardless which industry segment provides the service. The market forecast in Fig. 5 represents this scenario of a digital architecture with a fiber link serving 4-12 subscribers towards the end of the time period. From 1993-98 the components content of Fig. 5 is based on the 1993 ratio of Table 4. During the next 20 years the market will start with low bandwidth installations and gradually upgrade the optoelectronic transducers for higher speed. As a result, the components content will shift from 4% in the first 10 years to the 20-25% range towards the end of the period. This transition will make the

telecom optical transducer market of 8B$ in 2013 clearly the second most important market for optoelectronic components!

Figure 6 summarizes the market opportunities for displays, both flat panel and CRT. Today, the three large segments are: TV and computer/PC monitors based on traditional CRT technology and portable PC's using flat panel displays. HDTV will become a significant segment in the second half of the period. The advantage of flat panel over CRT technology is basically due to five factors: thickness, weight, flat instead of curved front surface, lower power consumption ( which is true only for some FPD technologies) and, finally, reduced disposal problems. The challenges are formidable: cost, cost & cost. The issues for the prevalent color FPD technology, namely AM-LCD are: process complexity, process yield and capital depreciation.

The display market represents an interesting challenge. Today , it is dominated by CRT's. They are practically unchallenged in performance, reliability and cost. If any FPD technology can meet the CRT performance at an equal or slightly higher cost, then the CRT will disappear into history. Challenges come from various directions: At the low end (<5" diagonal), AM-LCD displays and projection light valves will be formidable competitors. In the mid range (5-15" diagonal), AM-LCD displays have cost and color STN-LCD displays have performance problems, leaving this market open for new entries that promise to beat the established technologies in performance and power consumption. There are several contending technologies but the dark horse, at this time, is the field emission display.

The field emission display represents a multitude of new technical challenges, but it has a reasonable chance to emerge as the winning technology. Its success will depend on timely and massive investments in processes for field emission cathodes, low voltage phosphors, high aspect ratio spacers, vacuum stability and panel assembly. Feasibility for most of these issues has been proven, but no one has demonstrated that all required features and processes can be successfully integrated. The real challenge for this technology is a timely manufacturing implementation before predictable cost reductions in AM-LCD will pre-empt its success.

The larger displays (15-50") have several technologies competing for today's position of the CRT. At the low end, plasma displays with their demonstrated capability in both monochrome and color seem to be the leading flat panel contender. Field emission displays may become viable depending on their success in the medium size market. At the high end, various projection display technologies will prevail, but plasma and field emission technologies are two dark horses to watch.

The historical perspective of the computer/information technology market presented in Fig. 7 illustrates the importance of flat panel displays. During the

last 40+ years computers evolved in the 50's from the early equivalent of a mainframe. The next generation of mini-computers appeared in the mid 60's and desk-top engineering computers in the mid 70's. These engineering computers branched into workstations in the late 70's and into personal computers around 1980. In 1993, the desk-top PC segment installed more computational horse-power than any of the older computer segments! It is important to note that practically all of these applications can be served by CRT based displays.

Portable computers emerged in the early to mid 80's and palm-top personal information appliances (PIA) with spread-sheet capability in 1990. This trend will continue. By the end of the decade, the portable PC and PIA market will most likely dominate the installation of computation/communication horse-power.

**Observation #6: The fastest growing segment of the computer market is critically dependent on color, flat panel, low power displays! Conventional CRT technology is not a viable option!**

The availability of cost effective and low power flat panel displays is the most critical factor in accelerating or retarding this important segment of the computer/consumer market. The display will dominate product cost and power consumption (battery life) - and it will be the most important differentiating factor to influence product choice by the end-user! By the end of the decade this dynamic segment of the computer/consumer market will critically depend on a well functioning, competitive and open market for flat panel displays. If the Japanese industry with its overwhelming lead in flat panel display technology remains unchallenged, then the US computer industry will suffer the same fate as the US consumer electronics industry. With all its consequences , such an outcome is politically unacceptable!

## 4. Summary

Equipment based on enabling optoelectronic components represents a rapidly growing fraction of the electronics industry. While many components such as lasers, LED's and detectors are absolutely critical for enabling several important equipment markets, the overriding challenge in components technology is the flat panel display. The CRT dominates display applications today, but its customers are begging for a flat version with equal performance and comparable cost. A display based equipment market with an annual value in the range of 280B$ and an underlying components market of 80B$ is, over the next two decades, the most important opportunity and the most formidable challenge for businessmen and technologists alike!

# Display Components

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Application** | | | | | | | | | | | |
| Computer | 1174 | 1621 | 1931 | 2130 | 2581 | 3060 | 3558 | 4068 | 4703 | 4911 | |
| Bus./Commercial | 330 | 364 | 406 | 430 | 473 | 505 | 562 | 606 | 669 | 716 | |
| Industrial | 458 | 506 | 554 | 588 | 645 | 736 | 821 | 916 | 1027 | 1061 | |
| Transportation | 180 | 209 | 286 | 329 | 395 | 504 | 635 | 721 | 799 | 882 | |
| Consumer | 393 | 499 | 533 | 603 | 749 | 983 | 1282 | 1527 | 1722 | 1869 | |
| Subtotal | 2535 | 3199 | 3710 | 4080 | 4843 | 5788 | 6858 | 7838 | 8920 | 9439 | |
| | | | | | | | | | | | |
| **Technology** | | | | | | | | | | | |
| STN-LCD | 1687 | 1932 | 2087 | 2230 | 2538 | 2783 | 3037 | 3298 | 3632 | 3811 | |
| AM-LCD | 462 | 892 | 1227 | 1439 | 1800 | 2255 | 2734 | 3159 | 3628 | 3782 | |
| Other LCD | 15 | 21 | 29 | 42 | 75 | 124 | 171 | 219 | 273 | 310 | |
| Plasma | 293 | 269 | 272 | 265 | 287 | 337 | 402 | 465 | 540 | 600 | |
| TFEL | 78 | 85 | 95 | 103 | 119 | 163 | 215 | 255 | 292 | 307 | |
| Other FPD | 0 | 0 | 0 | 1 | 24 | 126 | 299 | 442 | 555 | 629 | |
| Subtotal | 2535 | 3199 | 3710 | 4080 | 4843 | 5788 | 6858 | 7838 | 8920 | 9439 | 0.145 |
| | | | | | | | | | | | |
| CRT/Projection | 11900 | 12900 | 13900 | 15000 | 16300 | 17600 | 19000 | 20300 | 21700 | 23000 | 0.075 |
| | | | | | | | | | | | |
| Total Displays | 14435 | 16099 | 17610 | 19080 | 21143 | 23388 | 25858 | 28138 | 30620 | 32439 | 0.092 |

Source: Stanford Resources, Inc

# Optoel. Components Content of Selected Equipment

| Equipment | | Component | | Content |
|---|---|---|---|---|
| Type | Street Price $ | Type | OEM Price $ | Optoel. Comp. % |
| Laser Printer | 1000 | Laser | 5 | 1% |
| | | Subassembly | 50 | 5% |
| CD Player | 150 | Laser | 2 | 1% |
| | | Subassembly | 10 | 7% |
| Erasable Opt.Disk | 3000 | Laser | 30 | 1% |
| | | Subassembly | 200 | 7% |
| FITL or FTTC | 10000 | LD/Det/Connect. | 300 | 3% |
| | | Subassembly | 500 | 5% |
| LAN Connection | 500 | LED/Det/Connect. | 40 | 8% |
| | | Subassembly | 60 | 12% |
| 14" CRT Monitor | 300 | Color Tube | | |
| | | Tube & Yoke | 100 | 33% |
| 19" Color TV | 250 | Color Tube | | |
| | | Tube & Yoke | 85 | 34% |
| Notebook Comp. | 3000 | Color Panel | | |
| (8.4" AM-LCD) | | Displ.w.Drive El. | 900 | 30% |
| Portable PC | 6000 | Color Panel | | |
| (10.4" AM-LCD) | | Displ.w.Drive El. | 1500 | 25% |

# Optoelectronics-Based Equipment Market

8/4/2015

| Market | 1993 | 1998 | 2003 | 2008 | 2013 | Enabl.Tech. |
|---|---|---|---|---|---|---|
| **Computer** | | | | | | |
| Portable PC | 15.3 | 31.1 | 45.6 | 63.0 | 82.9 | Display |
| Display Monitor | 10.0 | 18.3 | 24.6 | 31.4 | 38.3 | Display |
| Optical LAN | 0.8 | 2.6 | 6.3 | 14.1 | 31.6 | Datacom |
| Optical Memory | 1.7 | 5.1 | 9.9 | 15.8 | 25.1 | Storage |
| Laser/LED Printer | 3.3 | 5.1 | 8.2 | 11.0 | 14.8 | Printer |
| Subtotal | 31.1 | 62.2 | 94.6 | 135.3 | 192.7 | |
| **Telecom** | | | | | | |
| FITL | 2.3 | 7.7 | 21.0 | 26.7 | 28.2 | Telecom |
| CATV | 0.2 | 0.5 | 1.6 | | | Telecom |
| Subtotal | 2.5 | 8.2 | 22.6 | 26.7 | 28.2 | |
| **Consumer** | | | | | | |
| CD & Recordable CD | 5.4 | 6.4 | 7.6 | 8.7 | 9.8 | Storage |
| Video Disk | 1.7 | 4.6 | 6.8 | 10.2 | 15.2 | Storage |
| CD ROM | 0.5 | 1.9 | 2.8 | 3.4 | 4.2 | Storage |
| TV | 28.2 | 38.2 | 49.7 | 60.6 | 70.5 | Display |
| HDTV | | 1.2 | 6.7 | 34.9 | 69.4 | Display |
| Video Phone | 0.2 | 4.0 | 7.5 | 9.5 | 12.0 | Display |
| Subtotal | 36.0 | 56.3 | 81.1 | 127.3 | 181.1 | |
| **Automotive** | | | | | | |
| Display | 0.4 | 0.6 | 1.6 | 3.0 | 5.8 | Display |
| Optical LAN | | 0.1 | 0.5 | 2.0 | 4.1 | Datacom |
| LED Lighting | | 0.3 | 0.5 | 0.7 | 0.9 | Other |
| Optical sensors | | | 0.1 | 0.7 | 3.0 | Other |
| Subtotal | 0.4 | 1.0 | 2.7 | 6.4 | 13.8 | |
| **Industrial** | 2.7 | 5.1 | 9.3 | 16.0 | 27.4 | Other |
| **Medical** | 1.6 | 2.7 | 4.5 | 6.9 | 10.5 | Other |
| **Energy** | 0.7 | 1.5 | 3.3 | 6.1 | 11.4 | Other |
| Subtotal | 5.0 | 9.3 | 17.1 | 29.0 | 49.3 | |
| **Military/Aerospace** | 0.4 | 0.6 | 0.8 | 1.1 | 1.5 | Other |
| **Total** | 75.4 | 137.6 | 218.9 | 325.8 | 466.6 | |

| Technology | | | | | | |
|---|---|---|---|---|---|---|
| **Display** | | | | | | |
| Portable PC | 15.3 | 31.1 | 45.6 | 63.0 | 82.9 | |
| Display Monitor | 10.0 | 18.3 | 24.6 | 31.4 | 38.3 | |
| TV | 28.2 | 38.2 | 49.7 | 60.6 | 70.5 | |
| HDTV | | 1.2 | 6.7 | 34.9 | 69.4 | |
| Video Phone | 0.2 | 4.0 | 7.5 | 9.5 | 12.0 | |
| Display (Auto.) | 0.4 | 0.6 | 1.6 | 3.0 | 5.8 | |
| Subtotal | 54.1 | 93.4 | 135.7 | 202.4 | 278.9 | |
| **Datacom** | | | | | | |
| Optical LAN (Comp.) | 0.8 | 2.6 | 6.3 | 14.1 | 31.6 | |
| Optical LAN (Auto.) | | 0.1 | 0.5 | 2.0 | 4.1 | |
| Subtotal | 0.8 | 2.7 | 6.8 | 16.1 | 35.7 | |
| **Optical Storage** | | | | | | |
| Optical Memory | 1.7 | 5.1 | 9.9 | 15.8 | 25.1 | |
| CD & Recordable CD | 5.4 | 6.4 | 7.6 | 8.7 | 9.8 | |
| Video Disk | 1.7 | 4.6 | 6.8 | 10.2 | 15.2 | |
| CD ROM | 0.5 | 1.9 | 2.8 | 3.4 | 4.2 | |
| Subtotal | 9.3 | 18.0 | 27.1 | 38.1 | 54.3 | |
| **Laser/LED Printers** | 3.3 | 5.1 | 8.2 | 11.0 | 14.8 | |
| **Telecom** | 2.5 | 8.2 | 22.6 | 26.7 | 28.2 | |
| **Other Equipment** | 5.4 | 10.2 | 18.5 | 31.5 | 54.7 | |
| **Total** | 75.4 | 137.6 | 218.9 | 325.8 | 466.6 | |

# Optoelectronic Equipment Market Market
## (B$)

| By Application: | 1993 | 1998 | 2003 | 2008 | 2013 | Comments: |
|---|---|---|---|---|---|---|
| Computer | 31.1 | 62.2 | 94.6 | 135.3 | 192.7 | Equipment |
| Telecom | 2.5 | 8.2 | 22.6 | 26.7 | 28.2 | Equipment |
| Industr./Med./Energy | 5.0 | 9.3 | 17.1 | 29.0 | 49.3 | Equipment |
| Automotive | 0.4 | 1.0 | 2.7 | 6.4 | 13.8 | Subassembly |
| Military/Aerospace | 0.4 | 0.6 | 0.8 | 1.1 | 1.5 | Subassembly |
| Consumer | 36.0 | 56.3 | 81.1 | 127.3 | 181.1 | Equipment |
| Total | 75.4 | 137.6 | 218.9 | 325.8 | 466.6 | |

| By Technology: | 1993 | 1998 | 2003 | 2008 | 2013 | Comments: |
|---|---|---|---|---|---|---|
| Display | 54.1 | 93.4 | 135.7 | 202.4 | 278.9 | Mixed |
| Telecom | 2.5 | 8.2 | 22.6 | 26.7 | 28.2 | Equipment |
| Datacom | 0.8 | 2.7 | 6.8 | 16.1 | 35.7 | Mixed |
| Storage | 9.3 | 18.0 | 27.1 | 38.1 | 54.3 | Equipment |
| Laser/LED Printer | 3.3 | 5.1 | 8.2 | 11.0 | 14.8 | Equipment |
| Other | 5.4 | 10.2 | 18.5 | 31.5 | 54.7 | Mixed |
| Total | 75.4 | 137.6 | 218.9 | 325.8 | 466.6 | |

# Enabling Optoelectronic Component Content of Equipment Market
## (B$)

| By Technology: | 1993 | 1998 | 2003 | 2008 | 2013 | Content |
|---|---|---|---|---|---|---|
| Display | 54.1 | 93.4 | 135.7 | 202.4 | 278.9 | 30% |
| Telecom | 2.5 | 8.2 | 22.6 | 26.7 | 28.2 | 5% |
| Datacom | 0.8 | 2.7 | 6.8 | 16.1 | 35.7 | 10% |
| Storage | 9.3 | 18.0 | 27.1 | 38.1 | 54.3 | 4% |
| Laser/LED Printer | 3.3 | 5.1 | 8.2 | 11.0 | 14.8 | 3% |
| Other | 5.4 | 10.2 | 18.5 | 31.5 | 54.7 | 5% |
| Total | 75.4 | 137.6 | 218.9 | 325.8 | 466.6 | |

| Comp. Content | 1993 | 1998 | 2003 | 2008 | 2013 | |
|---|---|---|---|---|---|---|
| Display | 16.2 | 28.0 | 40.7 | 60.7 | 83.7 | |
| Telecom | 0.1 | 0.4 | 1.1 | 2.4 | 8.2 | |
| Datacom | 0.1 | 0.3 | 0.7 | 1.6 | 3.6 | |
| Storage | 0.4 | 0.7 | 1.1 | 1.5 | 2.2 | |
| Laser/LED Printer | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | |
| Other | 0.3 | 0.5 | 0.9 | 1.6 | 2.7 | |
| Total | 17.2 | 30.1 | 44.8 | 68.2 | 100.8 | |

| Comp. Market | 1993 | | | | | |
|---|---|---|---|---|---|---|
| Display | 17.6 | | | | | |
| Opto.Semicond. | 4.4 | | | | | |
| Total | 22.0 | | | | | |

# Comparison with Components Market in 1993

**(B$)**

| **Comp. Content** | 1993 | 1998 | 2003 | 2008 | 2013 |
|---|---|---|---|---|---|
| Display | 16.2 | 28.0 | 40.7 | 60.7 | 83.7 |
| Telecom | 0.1 | 0.4 | 1.1 | 2.4 | 8.2 |
| Datacom | 0.1 | 0.3 | 0.7 | 1.6 | 3.6 |
| Storage | 0.4 | 0.7 | 1.1 | 1.5 | 2.2 |
| Laser/LED Printer | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 |
| Other | 0.3 | 0.5 | 0.9 | 1.6 | 2.7 |
| Total | 17.2 | 30.1 | 44.8 | 68.2 | 100.8 |

| **Comp. Market** | 1993 |
|---|---|
| Display | 17.6 |
| Opto.Semicond. | 4.4 |
| Total | 22.0 |