Industry & Trade Summary

Optical Fiber, Cable, and Bundles

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PREFACE

In 1991 the United States International Trade Commission initiated its current *Industry and Trade Summary* series of informational reports on the thousands of products imported into and exported from the United States. Each summary addresses a different commodity/industry area and contains information on product uses, U.S. and foreign producers, and customs treatment. Also included is an analysis of the basic factors affecting trends in consumption, production, and trade of the commodity, as well as those bearing on the competitiveness of U.S. industries in domestic and foreign markets.[1]

This report on optical fiber, optical fiber cable, and optical fiber bundles covers the period 1989 through 1993 and represents one of approximately 250 to 300 individual reports to be produced in this series during the first half of the 1990s. Listed below are the individual summary reports published to date on the instruments and precision manufactures and the electronic technology sectors.

USITC publication number	*Publication date*	*Title*
2445	January 1992	Television receivers, and video monitors
2648	July 1993	Measuring, testing, controlling, and analyzing instruments
2674	September 1993	Medical goods
2708	December 1993	Semiconductors
2728	February 1994	Capacitors
2730	February 1994	Navigational and surveying instruments
2820	October 1994	Telecommunications equipment
2821	October 1994	Computers, peripherals, and computer components
2822	October 1994	Audio and video recording and reproducing equipment
2851	February 1995	Optical fiber, cable, and bundles

[1] The information and analysis provided in this report are for the purpose of this report only. Nothing in this report should be construed to indicate how the Commission would find in an investigation conducted under statutory authority covering the same or similar subject matter.

CONTENTS

INTRODUCTION

The United States is the largest producer of optical fiber, cable, and bundles in the world, accounting for one-half of the $3.1 billion in global shipments of these products in 1993. Despite slower rates of growth in demand for optical fiber in long-distance telecommunications markets, producers have been able to take advantage of rapidly expanding demand for optical fiber and cable in local telephone, cable television, and data communications markets to increase sales in the United States. U.S. companies also have been able to overcome sluggish demand in traditional foreign markets by significantly increasing exports to emerging telecommunications markets in Central Europe, East Asia, and Latin America.

This summary discusses industry, market, and trade developments in the global optical fiber industry during the period 1989 through 1993. The products covered in this summary include optical fiber, optical fiber cable, and optical fiber bundles[1] classified under the Harmonized Tariff Schedule of the United States (HTS) subheadings 8544.70.00 and 9001.10.00. Although a major emphasis of the report is on telecommunications uses of optical fiber and cable, their growing applications in other areas such as cable television, aviation, medicine, defense, and industrial process control also are covered. This introduction will briefly describe (1) the products covered in the summary and the degree of their significance in terms of imports and shipments, (2) the processes and materials used to make the product, and (3) the principal end uses for the product. Following the introduction are brief profiles of the U.S. and foreign optical fiber industries, discussions of trade measures in the United States and important foreign markets, and profiles of U.S. and foreign markets, including analyses of trends in consumption, production, and trade.

Optical fiber consists of hair-thin strands of glass or plastic which are usually incorporated in cable to transmit voice, video, and data information in the form of light pulses from one point to another. Optical fiber cable incorporates optical fibers into an assembly of materials that provide tensile strength, external protection, and handling properties comparable to those of copper or coaxial cable used in traditional communication systems. Optical fiber bundles are collections of optical fibers arranged for various non-communication purposes such as transmitting light or images. The bundles also are increasingly used as sensors.[2]

Optical fiber cable accounted for over one-half of the total $1.8 billion value of U.S. producers' shipments in the U.S. optical fiber industry in 1993, while optical fiber accounted for almost one-third of such shipments. Optical fiber accounted for a larger portion of international trade, representing about one-half of total U.S. exports and almost two-thirds of total imports. Optical fiber cable and bundles accounted for the remaining trade.

The optical fiber manufacturing process is highly automated and capital-intensive, involving complex computer-controlled interactive systems, skilled technicians, and clean environments.[3] The manufacture of optical cable is also capital-intensive but it is not as automated as the production of optical fiber and thus requires a relatively greater amount of labor. The process consists primarily of extruding plastic over optical fibers, stranding them together, and jacketing them to form the finished cable. Processes for manufacturing optical fiber bundles and other optical fiber forms vary depending on final applications, but they also generally involve high-tech processes and skilled workers.

Optical fiber systems[4] now carry the bulk of long-distance telecommunications traffic in the United States, having replaced traditional copper- and coaxial-based systems during much of the 1980s. They also are increasingly used in local telephone networks, cable television networks, computer networks, and military communication systems. Such systems comprise optical cable and associated lightwave transmission, connecting, and receiving components. The transmitted information is converted from

[1] See appendix B for a glossary of technical terms used in this report.

[2] Optical fibers are used in sensors to detect or sense environmental effects, such as pressure, temperature, magnetic and electric fields, rotation, and other effects. Intrinsic optical fiber sensors are made up of optical fibers engaged in the various sensing actions themselves. In extrinsic optical fiber sensors, the optical fibers are used merely to transmit data information from traditional sensing devices, such as electronic sensors. See glossary, appendix B.

[3] The optical fiber production process takes place in two discrete steps. The first step is to produce a preform (see glossary of terms in appendix B), and the second is to draw fiber from the preform. The preform is commonly made of fused silica, containing small traces of selected chemicals to modify the reflective properties of the fiber. The preform descends from a platform just below the top of a vertical draw tower into a furnace heated at very high temperatures to soften the glass. The softened glass is drawn by gravity to produce a fiber that is captured on spinning capstans and wheels. U.S. industry officials, interviews with USITC staff, Raleigh and Hickory, NC, Sept. 27-28, 1994.

[4] Also known as fiber optic systems and lightwave systems.

electrical impulses into lightwaves by a laser or light emitting diode. At the receiving end of the system, the light waves are converted back into electrical impulses by fiber-optic detectors.

Optical fiber, cable, and bundles also are used for non-communications purposes in such areas as medicine, industrial process control,[5] automotive lighting and navigation systems, avionics, and the military.[6] In medicine, optical fiber bundles are used for illumination and image transmission in fiber optic endoscopes which permit physicians to view remote cavities of the body.[7] Due to its immunity to electrical and electromagnetic interference, optical fiber has been used effectively in process control systems in industries such as petroleum, chemicals, and mining and other hazardous environments where there are often lightning or electrical ground loop problems. Sensors made up of optical fiber bundles are replacing electronic sensors for measuring temperature, pressure, flow rate, and many other variables in noisy and sensitive factory environments. They also are used in complex avionic "fly-by-light" systems in civilian and military aircraft. Other noncommunications applications of optical fiber bundles in the military include their use in night-vision devices, including night goggles, tank vision systems, periscopes, and gun sights.

[5] Industrial process control systems continually monitor the critical physical variables in an industrial process and keep them within predetermined limits. In a manufacturing plant, a control system may control a single process, a number of processes, or all of the processes in a plant.

[6] Vincent Martinelli, "How to Select Fiber to Enhance Fiberoptic Sensor Performance," *Laser Focus World*, July 1994, p. 63.

[7] Optical fiber bundles also are increasingly being used by surgeons to transmit laser energy for purposes of cutting tissues and performing other surgical operations.

U.S. INDUSTRY PROFILE

Industry Structure

Figure 1 illustrates the structure of the U.S. optical fiber industry,[8] including the principal materials and components used in production, the major producer types, the major products, and the principal consumers of optical fiber, cable, and bundles. Figure 2 lists major U.S.-based producers of optical fiber products.

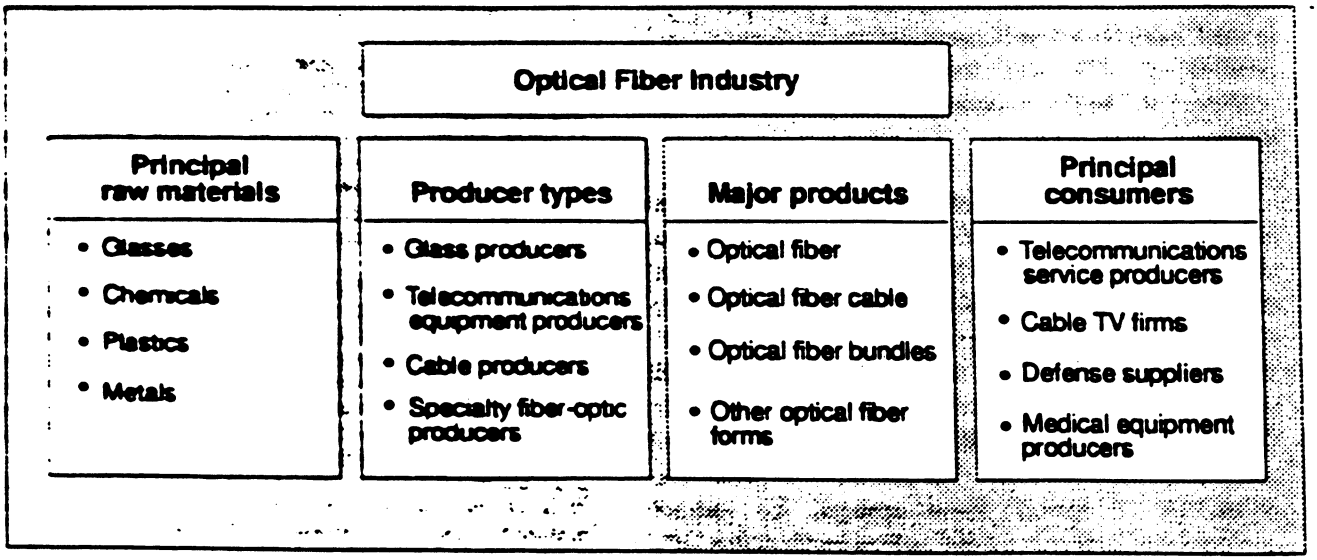
In 1993, an estimated 55 firms produced optical fiber, optical fiber cable, and optical fiber bundles in the United States.[9] These firms employed roughly 7,000 persons.[10] The most concentrated sector of the

[8] The Standard Industrial Classification (SIC) number for optical fiber and bundles is SIC 3231895. The SIC number for optical fiber cable is SIC 33579.

[9] Estimated by USITC staff based on industry interviews, company annual reports, and official data of the U.S. Department of Commerce.

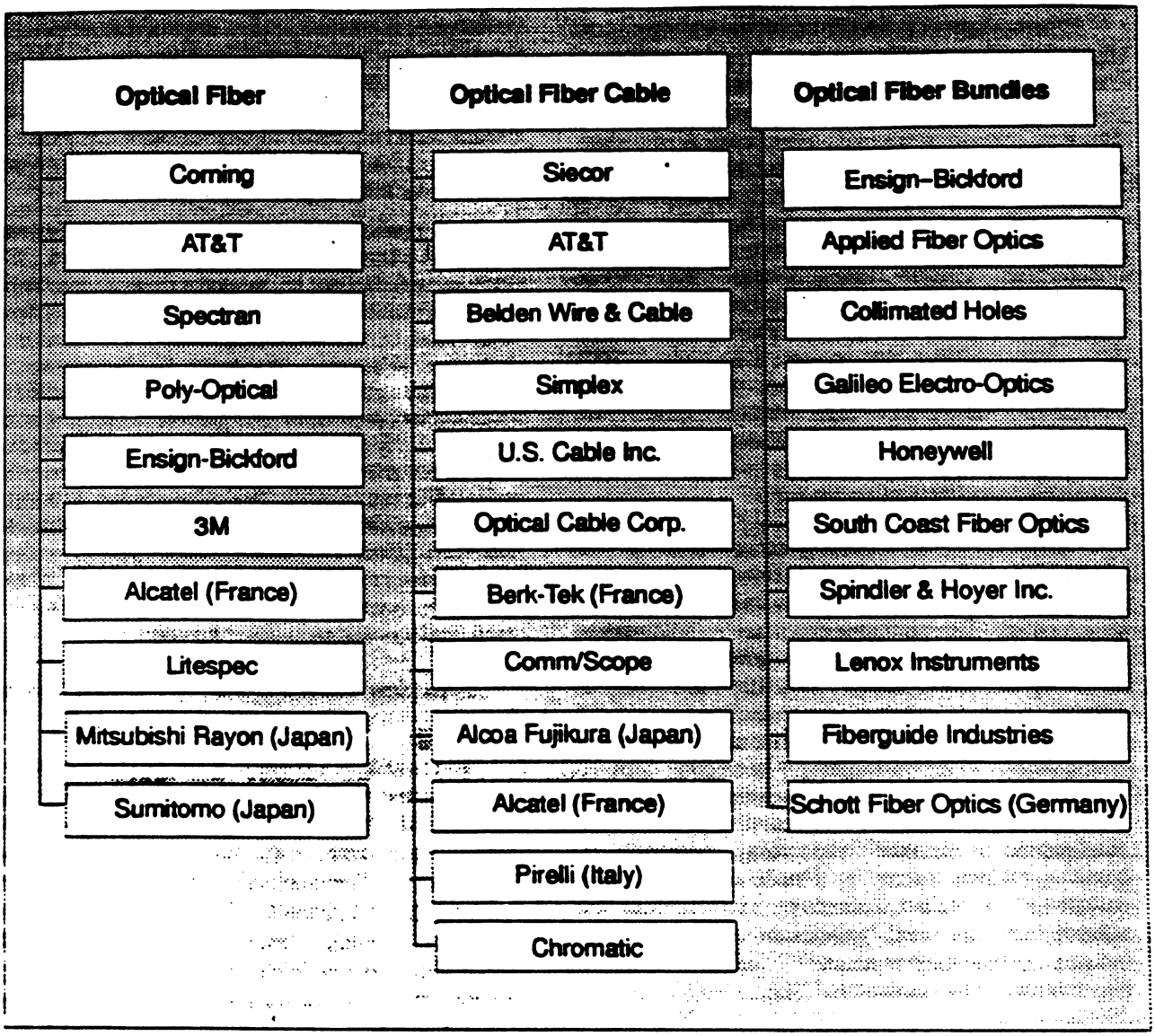
[10] Ibid.

Figure 1
U.S. optical fiber industry: Principal materials, producer types, major products, and principal consumers



Source. Compiled by staff of the U.S. International Trade Commission.

Figure 2
Major U.S. producers of optical fiber, cable, and bundles



Note —Location of headquarters shown in parentheses for foreign-based companies.

Source Compiled by staff of the U.S. International Trade Commission.

industry was the segment producing optical fiber. Two companies, AT&T and Corning, accounted for over 70 percent of total U.S. production.[11] Only a handful of other firms participated in this sector, including several U.S. subsidiaries of foreign-based telecommunications equipment companies. The sector producing optical fiber cable was only slightly less concentrated, with AT&T and Siecor[12] accounting for the largest portion of industry shipments. About 15 companies participated in that sector. Over 30 small and medium-sized companies compete in the much less concentrated sector of the industry that produces optical fiber bundles and other forms of optical fiber products.[13]

Producers of optical fiber are located primarily in the eastern, and particularly the southeastern, part of the United States. Optical cable manufacturers are largely located in the southeastern and midwestern states. Manufacturers of optical fiber bundles and other

[11] Ibid

[12] Siecor is a joint venture between Siemens, a German-based electronics company, and U.S.-based Corning. Siecor is located in North Carolina.

[13] Estimated by USITC staff.

forms are located primarily in the Northeast and Pacific Coast regions.

The two largest producers of optical fiber are the most vertically integrated companies in the industry, albeit in different ways. AT&T assembles optical fiber cable from optical fiber drawn in its own plants. The company also produces a large number of other products and components used in complete fiber optic systems, such as transmitters, connectors, and detectors. Corning's glass division supplies much of the raw materials needed by Corning to manufacture optical fiber, and the Corning optical fiber division supplies a significant portion of its output to Siecor. Most of the other U.S.-based manufacturers of optical fiber cable purchase their optical fiber from AT&T, Corning, or Spectran.[14] Producers of optical fiber bundles or other optical fiber forms principally are specialty producers that obtain their raw materials from outside suppliers, such as Corning, Schott, Dow, and other glass and chemical producers.

The most recent technological advances in the industry have focused on improvements that reduce the number of repeaters,[15] or signal regenerators, needed in an optical fiber transmission line.[16] Dispersion-shifted fiber[17] has replaced first-generation fiber in most long-distance systems. These have increased the distance required between repeaters from about 30 miles to over 50 miles. A more recent development, erbium-doped fiber amplifiers,[18] currently permits transmissions of over 60 miles between regenerators. However, they are still very expensive. Another recent development is soliton[19] technology, supported by optical amplifiers spaced at 70-mile intervals. Some analysts believe soliton technology may represent the solution for the next generation of transoceanic undersea optical fiber systems.[20] Soliton waves can also transmit large amounts of data.

[14] Spectran is a smaller producer of optical fiber which specializes in multimode fiber (see glossary, appendix B), a type of optical fiber used principally in high-speed data networks and premises cable. Corning and AT&T and their major foreign competitors specialize in singlemode fiber (see glossary, appendix B), which is used primarily in longer telecommunications network systems. However, AT&T and Corning also produce multimode fiber.

[15] Repeaters are devices which detect weak signals in optical fiber communications systems, amplify and retransmit them. See glossary, appendix B.

[16] Anthony J. Mocenigo, *A Competitiveness Assessment of the U.S. Fiber Optics Industry* (Washington, DC: U.S. Department of Commerce, Jan. 1994), pp. 14-15.

[17] See glossary, appendix B.

[18] Ibid.

[19] Ibid.

[20] In 1993, AT&T Bell Laboratories researchers were able to transmit communication signals error free over 8,000 miles using soliton waves. Adele Hars, "Soliton Pulses Travel One Million Kilometers Error Free," *Lightwave*, Oct. 1994, pp. 8-10.

The optical fiber industry is a global one, with a significant amount of licensing, cross-licensing, and joint venturing among producers of optical fiber throughout the world. Due to their early technological leadership in the industry, Corning and AT&T are important participants in a number of these agreements. Corning has invested in significant manufacturing facilities in the United Kingdom and Germany, with local partners. AT&T has similar ventures in Europe as well as in Asia.

The global nature of the industry is perhaps best exhibited by recent events in North America. In 1994, Corning and Siecor, its related cable manufacturer, acquired the Canadian-based optical fiber and optical fiber cable manufacturing plants and businesses of Northern Telecom in Saskatoon, Saskatchewan for $130 million.[21] The acquisitions provide both firms with a direct presence in the growing Canadian market for optical fiber systems. French-based Alcatel and Japanese-owned Sumitomo, meanwhile, produce both optical fiber and cable in the United States. In addition, Italian-based Pirelli and Japanese-based Fujikura both have U.S. optical fiber cable manufacturing operations. Fujikura also maintains a joint venture with U.S.-based Alcoa to manufacture specialized optical fiber and cable used in electric utility networks.

Consumer Characteristics and Factors Affecting Demand

The principal purchasers of optical fiber are manufacturers of optical fiber cable. The largest customers of optical cable are telephone companies, both long-distance and local telephone service providers.[22] Other consumers of optical fiber, cable, and bundles include cable TV companies, data service providers, utility service providers, defense contractors, medical equipment companies, industrial process control firms, and automobile manufacturers.

The key factor affecting demand for optical fiber, cable, and bundles is the demand for services in downstream applications. Growth in demand for optical fiber and cable for use in long-distance telecommunications networks has slowed considerably since the late 1980s, when optical fiber systems of the major service providers were completed. However, the attraction of multimedia is accelerating the deployment of optical fiber cable, especially by local telephone companies and cable television firms.[23] These two

[21] George Kotelly, "U.S. Fiber and Cable Companies Enter Canadian Market Via Plant Purchase," *Lightwave*, May 1994, pp. 29 and 32.

[22] Marcy Koff, "Government Report Cites Widespread Increases in Fiber-Network Deployments," *Lightwave*, July 1994, p. 51.

[23] "Fiber Optics Market," in *NATA Telecommunications Market Review and Forecast* (Washington, DC: National Telecommunications Association, 1994), pp. 122-26.

industries are reconstructing their network platforms to prepare for a highly competitive future wherein many firms may provide voice, data, and video communications to all homes and businesses.[24]

The emergence of urban fiber communications systems is expected to further increase the demand for telecommunications-grade optical fiber. Metropolitan networks provide services to large commercial customers by installing a ring or loop of fiber in areas of high business concentration.[25] Key customers of the urban systems are large downtown office buildings. As urban systems spread to more cities, many analysts expect them to place greater competitive pressures on local telephone companies. The metropolitan networks already appear to have motivated local telephone firms to price special access services closer to cost and to serve larger companies via redundant facilities and fiber rings.[26]

Although the market for optical fiber bundles and other optical fiber forms has not grown as rapidly as for optical fiber and cable, this third business segment is expected to profit in the near future as optical fiber technology gains greater acceptance in non-communication applications.[27] Applications in this segment are expected to increase particularly in the industrial process control, medical, computer, defense, and transportation industries.[28]

FOREIGN INDUSTRY PROFILE

The dominant foreign producers in the optical fiber industry are located in Japan, Europe, and Canada (figure 3). Foreign subsidiaries, licensees, and joint-venture partners of the major U.S.-based optical fiber companies are responsible for a significant portion of the overseas manufacture of optical fiber and cable. The general practice of major global producers of optical fiber and cable has been to produce some optical fiber and cable in important overseas markets and supply the remaining demand through exports from their home countries.

The Japanese optical fiber industry is very concentrated. The largest three manufacturers of optical fiber and cable, Sumitomo Electric Industries, Ltd., Fujikura Ltd., and Furukawa Electric Co., held a combined 83 percent share of the Japanese market in 1993.[29] Sumitomo accounted for one-third of the market, while the other two companies each had a 25-percent share. Hitachi Cable and Mitsubishi Cable maintained 5-percent shares. Sumitomo accounted for about 9 percent of total worldwide production of optical fiber in 1993,[30] making it the third largest producer after AT&T and Corning.

Japan is the largest producer of plastic optical fiber. About 90 percent of the estimated 180,000 miles of plastic optical fiber produced annually in the world is manufactured by Mitsubishi Rayon Co.,[31] Toray Industries, and Asahi Chemical Co.[32] Some analysts suggest that Japanese producers have been successful in this sector of the market because they have been more aggressive than others in developing new high-end uses of plastic fiber, notably in automobiles, industrial process control systems, short data transmission networks, and consumer electronics.[33] Major Japanese manufacturers of optical bundles include Olympus, Dainichi-Nippon Cables, and Icon.

In Europe, Alcatel, Siecor, and Pirelli are the largest manufacturers of optical fiber and cable. French-based Alcatel maintains large manufacturing facilities in France and Germany as well as in a number of other countries. Alcatel accounted for about 8 percent of the total global production of optical fiber, making it the fourth largest global producer.[34] It is also one of the leading world producers of optical cable. Italian-based Pirelli[35] is also a major global supplier of optical fiber and cable, while German-based Siecor is the largest producer of optical fiber in Europe.[36] Other important players in the European optical fiber and cable industry include Philips (Draka) in the Netherlands and BICC, a licensee of Corning, in the United Kingdom. Schott and Zeiss in Germany, Leti in France, and Smiths Industries in the United Kingdom, are the leading producers of optical fiber bundles in Europe.

Canadian-based Northern Telecom has been a major producer of optical fiber and cable over the past

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[24] Ibid.

[25] Marcy Koff, "Government Report Cites Widespread Increases in Fiber-Network Deployments," *Lightwave*, July 1994, pp. 48 and 51; and Jonathan Kraushaar, *Fiber Deployment Update—End of Year 1993* (Washington, DC: Federal Communications Commission, 1994), p. 1.

[26] Ibid.

[27] 1993 Spectran Corporation Annual Report, Feb. 1994, pp. 5, 10, and 11.

[28] U.S. industry officials, telephone interviews with USITC staff, Oct. 17-19, 1994.

[29] "Optical Fiber Sales Cool Off in Japan," *Fiber Optics Weekly Update*, Sept. 24, 1993, p. 1.

[30] Mocenigo, *A Competitiveness Assessment of the U.S. Fiber Optics Industry*, p. 24.

[31] U.S.-based Dow Chemical was the largest producer of plastic optical fiber in the world until it sold its technology to Mitsubishi Rayon and exited that segment of the market in 1989.

[32] "Fivefold Increase Forecast for Plastic Fiber Sales," *Photonics Spectra*, Apr. 1994, p. 68.

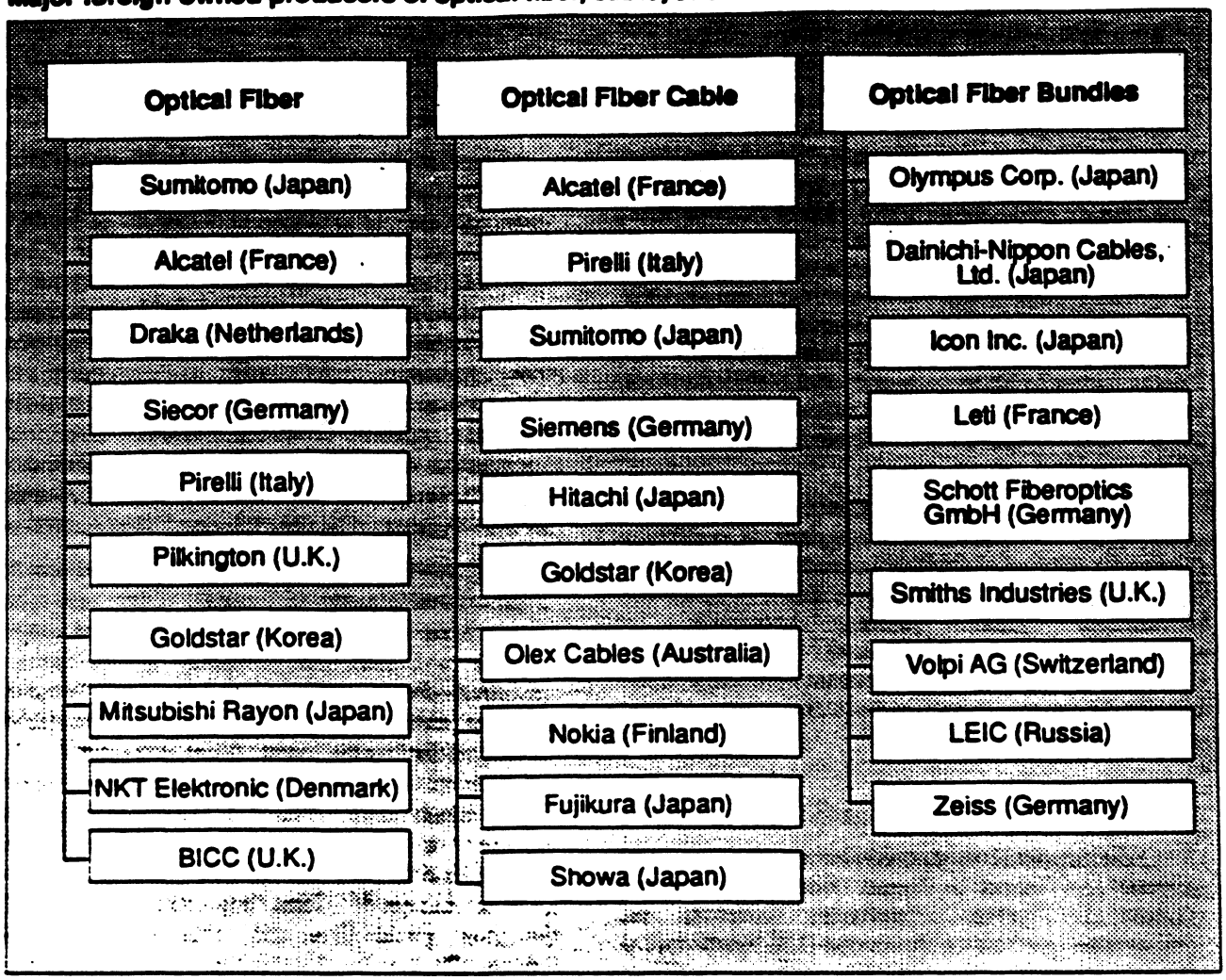
[33] Ibid.

[34] Mocenigo, *A Competitiveness Assessment of the U.S. Fiber Optics Industry*, pp. 18-19.

[35] Pirelli manufactures optical fiber and cable in Italy and in a number of other countries throughout the world, including developing countries in Latin America and East Asia.

[36] Siecor, located in Darmstadt, Germany, is another joint-venture of U.S.-based Corning and German-based Siemens. It is not related to their joint-venture of the same name in North Carolina, which produces only optical cable.

Figure 3
Major foreign-owned producers of optical fiber, cable, and bundles



Source: Compiled by staff of the U.S. International Trade Commission.

decade. However, recent acquisitions of its Canadian manufacturing operations by Alcatel, Corning, and Siecor have reduced its optical fiber production capacity considerably.[37] Northern Telecom no longer produces optical fiber cable. Almost all of Canadian production of optical fiber and cable is by Canadian subsidiaries of the U.S., Japanese, and European firms.

U.S. TRADE MEASURES

Tariff Measures

The general column 1 rate of duty for imports of optical fiber, cable, and bundles was 8.4 percent ad valorem in 1994 (table 1).[38] Imports of such goods entered the United States duty-free during 1989-93 from eligible countries under the Generalized System of Preferences, the Caribbean Basin Economic Recovery Act, the United States-Israel Free-Trade Area Implementation Act, and the Andean Trade Preference Act, and under reduced tariffs under HTS subheading 9802.00.80.

Optical fiber, cable, and bundles all are included in the North American Free Trade Agreement (NAFTA). Imports of such products from Mexico receive duty-free treatment under the NAFTA, while imports from Canada are subject to gradual duty reductions. The current rate of duty for imports from Canada is

[37] U.S., French, and Canadian industry officials, telephone interviews with USITC staff, Oct. 27, 1994.

[38] Refer to appendix A for an explanation of tariff and trade agreement terms.

Table 1
Optical fiber, cable, and bundles: Harmonized Tariff Schedule subheading; description; U.S. col. 1 rate of duty as of Jan. 1, 1994; U.S. exports, 1993; and U.S. imports, 1993

HTS subheading	Description	Col. 1 rate of duty As of Jan. 1, 1994 General	Special[1]	U.S. exports, 1993	U.S. imports, 1993
				Million dollars	
8544.70.00	Optical fiber cables, made up of individually sheathed fibers, whether or not assembled with electric conductors or fitted with connectors	8.4%	Free(A,E,IL,J,MX) 3.3%(CA)	162.9	10.8
9001.10.00	Optical fibers, optical fiber bundles and cables other than those of heading 8544	8.4%	Free(A,E,IL,J,MX) 3.3%(CA)	162.3	79.1

[1] Programs under which special tariff treatment may be provided, and the corresponding symbols for such programs as they are indicated in the "Special" subcolumn, are as follows: Generalized System of Preferences (A); Automotive Products Trade Act (B); Agreement on Trade in Civil Aircraft (C); North American Free Trade Agreement: Goods of Canada (CA) and Goods of Mexico (MX); Caribbean Basin Economic Recovery Act (E); United States-Israel Free Trade Area (IL); and Andean Trade Preference Act (J).

Source: USITC, *Harmonized Tariff Schedule of the United States* (1994); and U.S. exports and imports compiled from official statistics of the U.S. Department of Commerce.

3.3 percent ad valorem. NAFTA is not expected to have an adverse impact on the U.S. optical fiber industry. The United States is the leading supplier of optical fiber goods to Mexico and is expected to retain this position for the foreseeable future.

The general column 1 rate of duty for optical fiber, cable, and bundles, classified under subheading 9001.10, was reduced by 20-percent in the recently completed Uruguay Round of trade negotiations under the General Agreement on Tariffs and Trade (GATT).[39] The reduction will be implemented in five equal stages beginning January 1, 1995, with an initial reduction to 8.1 percent ad valorem, and a final reduction to 6.7 percent ad valorem in 1999. Industry officials do not believe the tariff reduction will have a significant effect on U.S. production or trading patterns.[40]

Nontariff Measures

There are no known nontariff measures to trade in optical fiber, cable, and bundles in the United States.

FOREIGN TRADE MEASURES

Tariff Measures

Tariffs generally do not serve as barriers to trade in the principal foreign markets for U.S. exports of optical fiber, cable, and bundles. Foreign duties are lower on average than in the United States in most overseas markets. In the European Union (EU), the MFN rate of duty for optical cable under Harmonized System (HS) subheading 8544.70 is 8 percent ad valorem. The EU rate of duty for optical fiber, bundles, and other cable under subheading 9001.10, is 7.5 percent ad valorem. In Japan, the MFN duties under HS subheading 8544.70 and 9001.10 for optical fiber, cable, and bundles are zero. Brazil and Argentina have the highest tariffs, amounting to 12 and 15 percent ad valorem, respectively.

[39] The Uruguay Round resulted in the negotiation of a series of agreements, all part of the Agreement Establishing the World Trade Organization (WTO). The GATT agreements that are most likely to have an effect on the optical fiber sector are the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) and the Agreement on Rules of Origin. The TRIPs are likely to have a positive effect on trade by strengthening intellectual property rights and the mechanisms to enforce these measures. The Agreement on Rules of Origin seeks to harmonize and simplify nonpreferential rules of origin, thereby facilitating trade between countries. For further information on these agreements, see U.S. International Trade Commission (USITC), *Potential Impact on the U.S. Economy and Industries of the GATT Uruguay Round Agreements* (investigation No. 332-353), USITC publication 2790, June 1994.

[40] U.S. industry officials, interviews with USITC staff, North Carolina, Sept. 27-28, 1994; and telephone interviews with USITC staff, Oct. 27, 1994.

Nontariff Measures

According to industry sources, the most significant nontariff measures that affect U.S. sales of optical fiber, cable, and bundles to foreign markets are preferential government procurement practices in the telecommunications sectors of Europe and Japan.[41] The purchase of optical cable constitutes a significant portion of government procurement contracts in these countries.

A longstanding U.S.-EU dispute over public procurement intensified on in February 1993, when the President announced that the United States would impose sanctions on the EU under Title VII of the Omnibus Trade and Competitiveness Act of 1988[42] in response to EU implementation on January 1, 1993, of its Utilities Directive,[43] which allegedly discriminates against foreign firms bidding on EU public utility contracts. Although the EU directive opens up procurement practices to EU-wide competition in the water, energy, transport, and telecommunications sectors, it allows procuring entities to exclude offers from consideration when less than half of the value of the tender is of EU origin. Article 29 of the directive mandates a 3- percent price preference to EU bids over equivalent non-EU-origin offers. Negotiations to resolve this issue continue.

U.S. optical fiber and other telecommunications industry officials believe that Japan continues to maintain impediments to full market access for telecommunications equipment in its procurement practices. Consequently, the U.S. Government included telecommunications equipment as part of a U.S.-Japan economic framework negotiation initiated in 1993 to improve market access in Japan for foreign producers.[44] The role of Japan's largest telecommunications services provider, Nippon Telegraph and Telephone (NTT), is a key issue in the U.S.-Japan framework trade talks.[45] The United States would like NTT to be included in government procurement negotiations because the Japanese Government still owns part of the company.[46]

[41] U.S. industry officials, interviews with USITC staff, Sept. 27-28, 1994.

[42] Office of the United States Trade Representative (USTR), "Title VII Action With Respect to the EC: Statement of Ambassador Michael Kantor," press release, Feb. 1, 1993.

[43] See *Council Directive No. 90/531/EEC on the Procurement Procedures of the Entities Operating in the Water, Energy, Transport and Telecommunications Sectors, Official Journal of the European Communities, OJ* No. L 297 (Oct. 29, 1990), p. 1.

[44] "Joint Statement on the United States-Japan Framework for a New Economic Partnership," July 12, 1993.

[45] "US-Japan Trade: Foreign purchases by NTT up 20 percent in 1993-94," *Tribune Business News*, June 24, 1994, p. 1.

[46] Ibid.

However, Japan maintains that NTT is a private firm since about 40 percent of the company has already been privatized.[47] Nevertheless, on June 24, 1994, NTT announced that purchases of equipment from foreign companies grew by over 20 percent during 1992-93, to $1.1 billion. Both countries announced a tentative agreement with respect to procurement in the Japanese telecommunications sector under the framework discussions on September 30, 1994.[48]

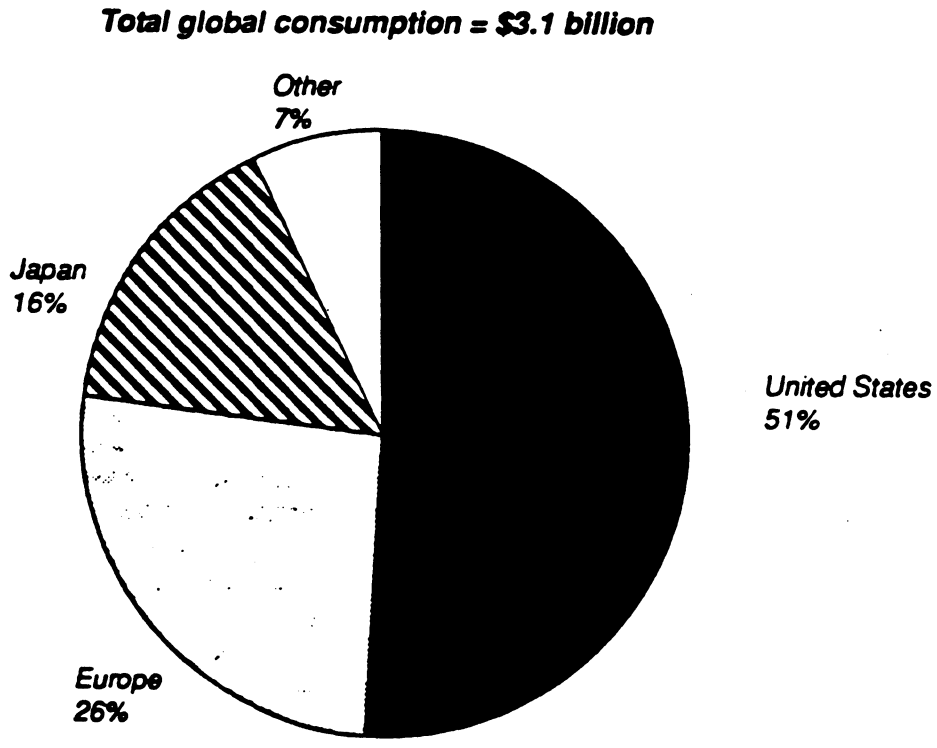
U.S. MARKET

Consumption

The United States is the largest market for optical fiber, cable, and bundles in the world (figure 4). Apparent U.S. consumption of optical fiber, cable, and bundles increased at an average annual rate of 17 percent during 1989-93, to almost $1.6 billion (table 2). Although telecommunications continued to dominate the consumption of optical fiber and cable, cable television and data communications grew more rapidly.[49] Furthermore, rapidly growing demand in local and private communications networks made up for declining growth in demand in domestic long-distance networks. New Federal and State regulations facilitating entry and promoting competition in telecommunications and cable television markets contributed toward increased demand for optical fiber and cable.[50] Growth in U.S. consumption of optical fiber bundles was slower than for optical fiber and cable. This was due primarily to a slowing in the increase in demand in the medical equipment sector and reduced expenditures in the defense sector, important markets for optical fiber bundles.

[47] Japanese Government officials, telephone interviews with USITC staff, Sept. 21-22, 1994.
[48] White House Press Release, Sept. 30, 1994.
[49] Optical fiber industry official, telephone interview with USITC staff, Sept. 28, 1994; and Stephen Montgomery, "Strong Growth Illuminates Fiber Markets For the '90s," *Lightwave*, Dec. 1993, pp. 42-45.
[50] Ibid.

Figure 4
Optical fiber, cable, and bundles: Global consumption, by region, 1993



Source: Estimated by staff of the U.S. International Trade Commission based on official statistics of the U.S. Department of Commerce and private sector sources.

Table 2
Optical fiber, cable, and bundles: U.S. producers' shipments, exports of domestic merchandise, imports for consumption, and apparent consumption, 1989-93

Year	Producers' shipments[1]	Exports	Imports	Apparent consumption	Ratio of imports to consumption
	Million dollars				*Percent*
1989	965	143	40	862	5
1990	1,184	172	62	1,074	6
1991	1,256	247	57	1,066	5
1992	1,602	293	85	1,394	6
1993	1,829	325	90	1,594	6

[1] Estimated by the staff of the U.S. International Trade Commission.

Source: Compiled from official statistics of the U.S. Department of Commerce, except as noted.

During 1989-93, the ratio of imports to consumption for optical fiber, cable, and bundles increased from 5 to 7 percent. Imports increased to meet the growing demand for optical fiber and cable in local telephone, cable television, and data communications markets.

Production

The United States was the largest global producer of optical fiber, cable, and bundles in 1993 (figure 5). U.S. producers' shipments of these products increased by an average annual rate of 17 percent during 1989-93, to $1.8 billion (table 2). However, growth in the total sales value of optical fiber and cable slowed somewhat in 1993, compared with 1992, despite a significant increase in the quantity of fiber and cable sold. This was due to significant price competition in sales to regional phone companies and cable television companies.[51] Sales of optical fiber bundles also slowed toward the end of the period due to reduced growth in expenditures on medical and defense-related equipment. Nevertheless, overall sales of optical fiber, cable, and bundles remained healthy, increasing by 14 percent during the last year of the period.

Imports

U.S. imports of optical fiber and cable increased by an average annual rate of 22 percent during 1989-93 to nearly $90 million (table 3). The largest suppliers of imports in 1993, Canada, Japan, and Denmark, jointly accounted for over 80 percent of total imports (figure 6). Germany and China also were significant suppliers to the U.S. market.

The bulk of imports from all foreign sources, except Japan, was supplied by subsidiaries or joint-venture partners of U.S.-based optical fiber and cable producers. U.S. producers needed the imports to supplement their own domestic production in order to meet growing demand in the U.S. market.[52] The fierce price competition in 1993 for long-term contracts in the U.S. market for optical cable favored the U.S.-based producers, including their foreign subsidiaries, whose cost structures were significantly lower than those of foreign suppliers.[53] Japanese and German-based firms remained the largest suppliers of imported optical fiber bundles to the U.S. market during the period.

FOREIGN MARKETS

Foreign Market Profile

Europe is the largest market for optical fiber, cable, and bundles after the United States (figure 4), accounting for just over one-fourth of total global consumption. However, during 1992 and 1993, the European market contracted significantly due to recessions in important markets such as France, Germany, and Italy. Better economic conditions and a more liberalized regulatory environment enabled the British market to expand despite problems elsewhere in Europe. Central European markets also expanded as governments in those countries increased investments in modern telecommunications infrastructures to attract foreign investment.

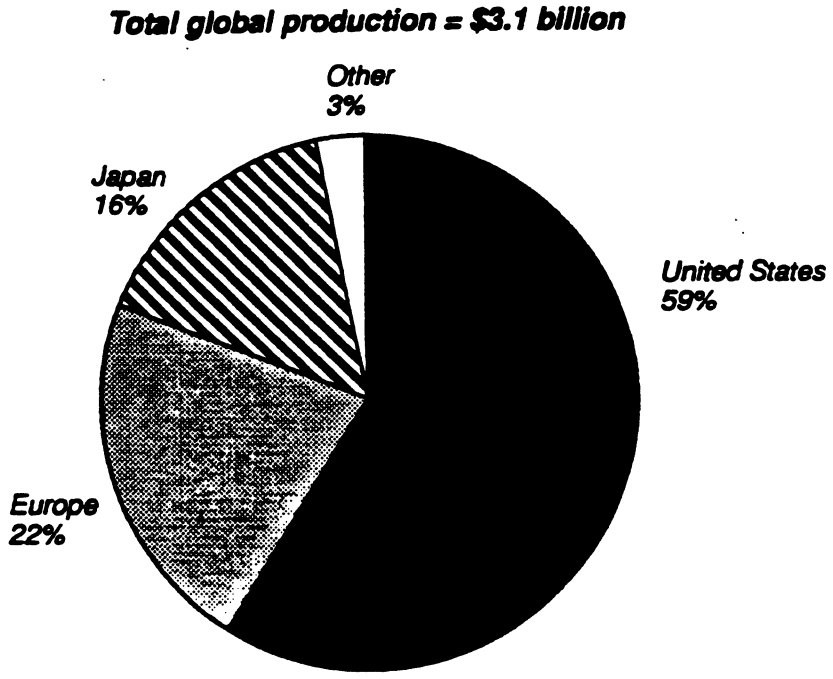
Although the Japanese market for optical fiber, cable, and bundles is the second largest individual country market in the world (figure 4), it is not nearly as advanced or as sophisticated as the U.S. market.

[51] Officials of optical cable company, interviews with USITC staff, North Carolina, Sept. 27, 1994; and official of optical fiber and cable company, telephone interview with USITC staff, Georgia, Sept. 29, 1994.

[52] U.S. and Japanese industry officials, interviews with USITC staff, Sept. 17 and 18, 1994; and European industry officials, telephone interviews with USITC staff, Oct. 27, 1994.

[53] U.S. optical fiber and cable companies, interviews with USITC staff, North Carolina, Sept. 27 and 28, 1994; Corning, Inc., *Annual Report 1993*, Jan. 2, 1994, pp. 1-52; and Spectran Corp., *Form 10-K for Fiscal Year Ending Dec. 31, 1993*, Feb. 28, 1994, pp. 2-20.

Figure 5
Optical fiber, cable, and bundles: Global production, by region, 1993



Source Estimated by staff of the U.S. International Trade Commission based on official statistics of the U.S. Department of Commerce and on information from company annual reports.

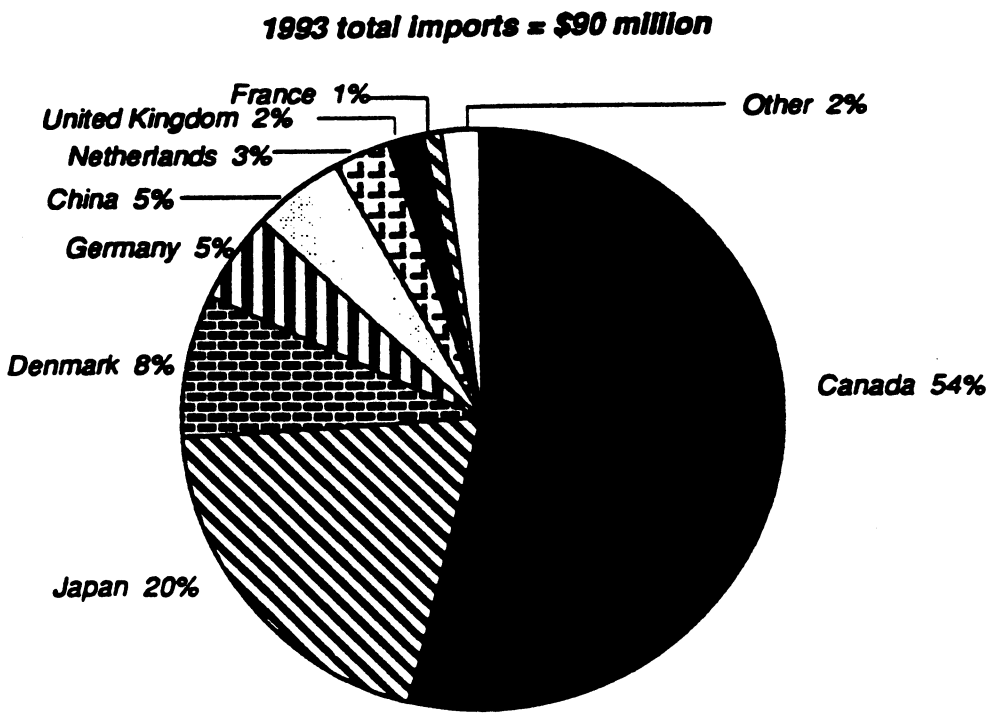
Table 3
Optical fiber, cable, and bundles: U.S. imports for consumption, by principal sources, 1989-93

Sources	1989	1990	1991	1992	1993
	Value (1,000 dollars)				
Canada	13,979	21,347	21,087	51,614	48,374
Japan	7,913	13,018	9,705	11,121	18,266
Denmark	588	1,846	1,038	885	7,451
Germany	13,675	19,880	19,634	15,545	4,549
China	1	0	0	0	4,264
Netherlands	29	282	8	781	2,914
United Kingdom	1,657	1,779	1,792	685	1,431
France	247	326	451	1,951	858
Mexico	0	3	2	3	569
Singapore	902	1,093	518	524	516
All other	988	2,432	2,690	1,564	693
Total	39,980	62,006	56,925	84,673	89,886

Note —Because of rounding, figures may not add to the totals shown.

Source Compiled from official statistics of the U.S. Department of Commerce.

Figure 6
Optical fiber, cable, and bundles: U.S. imports from major sources, 1993



Source: Compiled from official statistics of the U.S. Department of Commerce.

Analysts suggest that the reason Japan's market for optical fiber and cable has not grown as fast as that of the United States may be due, in part, to the strictness of its telecommunications regulations, which have left Japanese cable television companies undercapitalized and fragmented.[54] In Tokyo, only about 3 percent of households subscribe to cable services in contrast to 60 percent in the United States. Thus, optical fiber suppliers have not benefited from increased demand in this segment of the market in Japan to the extent that they have in the United States.[55]

However, Japan currently is trying to increase its fiber deployment. Based on a detailed investigative report, the Japanese Ministry of Posts and Telecommunications has announced the construction of a national optical fiber network linking every home and business in Japan by 2010.[56] Estimated costs for this program range from ¥33 trillion ($300 billion) to ¥53 trillion ($482 billion).[57] Although the Japanese Government expects the private sector to build the network, it is considering a number of incentive programs, including the provision of interest-free loans and tax incentives to motivate private business.[58] It is also expected to dramatically overhaul the government laws and policies that affect the Japanese telecommunications and broadcasting industries. U.S. and Japanese industry analysts assert that if the program is implemented as envisioned, the Japanese market for optical fiber and cable will increase significantly.

[54] "Japanese Fear Lag Behind the US - Rethink Their Fiber Deployment Plans," Fiber Optics Weekly Update, Information Gatekeepers Inc., June 3, 1994, pp. 4 and 5; and "Japan to Stage Nationwide Fiber-optic Network by 2010," *Lightwave*, Aug. 1994, pp. 6 and 8.

[55] Ibid.

[56] "NTT May Face Break-up in Japan's Telecommunications Review," *Financial Times Telecom Markets*, Aug. 18, 1994, pp. 253/9-253/11.

[57] Japan Telecommunication Council, *Reforms Towards the Intellectually Creative Society of the 21st Century: Program for the Establishment of High-Performance Info-Communications Infrastructure*, May, 1994, p. 1.

[58] Ibid.

Some of the most dynamic growth in demand for optical fiber and cable is currently taking place in developing East Asian countries such as China,[59] Taiwan, Singapore, Thailand, Malaysia, and Indonesia.[60] With relatively under-developed telecommunications infrastructures in these countries, there is little resistance to adoption of optical fiber and other modern high-performance technologies. Countries lacking a telecommunications infrastructure based on traditional copper wire and cable are able to move directly into optical fiber networks. As a result, the major U.S., European, and Japanese producers of optical fiber and cable have recently established significant investments in optical fiber and cable sales and manufacturing facilities in these East Asian countries.

One of the fastest growing international markets for optical fiber and cable in recent years has been that for undersea cable. Since the establishment of submarine optical fiber cable networks in the 1980s, international fiber capacity has grown over tenfold.[61] Most of the undersea cable investments have been in the Atlantic and Pacific regions.[62] In the past several years, over 20 percent of the money invested in submarine cable was in Southeast Asia. During the next several years, significant investments in submarine cable systems linking the Far East with Europe via the Middle East are expected.[63]

U.S. Exports

U.S. exports of optical fiber, cable, and bundles increased by an average annual rate of 23 percent during 1989-93, to over $325 million (table 4), or almost 18 percent of total U.S. producers' shipments of such products in 1993. The major markets for U.S. exports were Canada, Japan, and Mexico. The United Kingdom and China were also important markets (figure 7).

Canada and Japan were the largest markets for U.S. exports, together accounting for almost one-third of the total. Much of the increase in U.S. exports to Canada is attributed to significant expansion by Bell Canada and some of the larger provincial telephone companies in long-distance and local optical fiber networks.[64] Even though Bell Canada is affiliated with the largest Canadian producer of optical fiber and cable, its substantial requirements could not be satisfied solely by that producer. According to U.S. and Japanese industry officials, the largest U.S. producer of optical cable finally was able to penetrate the Japanese market as the result of U.S. pressures on the Japanese Government to increase the openness of its telecommunication market.[65]

The EU market for U.S. exports of optical fiber, cable, and bundles declined by 18 percent during the period, as severe recessions in important markets such as France and Germany stalled further expansion of fiber networks.[66] However, exports to Central European countries increased rapidly to $9 million in 1993[67] as those countries sought to improve their climates for foreign investment by substantially improving their telecommunications infrastructures. Other rapidly expanding markets for U.S. exports of optical fiber and cable are developing countries in Asia and Latin America. By 1993, China, Hong Kong, Argentina, and Brazil were all among the top ten importers of U.S.-made optical fiber and cable, as these countries made substantial investments in their telecommunications infrastructures to meet the demands of their rapidly growing economies.[68]

U.S. TRADE BALANCE

The U.S. surplus in trade for optical fiber, cable, and bundles (table 5) increased by an average annual rate of 23 percent during 1989-93, to $235 million in 1993 (figure 8). The U.S. industry maintained significant surpluses with the United Kingdom, Canada, and Japan throughout much of the period. These countries followed the United States by several years in constructing extensive optical fiber systems. During the latter half of the period, much of the increase in the surplus resulted from increased exports to Mexico, China, Argentina, Poland, and Brazil as these developing countries dedicated significant resources to improving telecommunications infrastructures.[69] Due to the strength and manufacturing capacity of the U.S. optical fiber industry, the United States did not experience trade deficits with any countries in 1993.

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[59] A 1994 research study reported that telecommunications is the fastest growing sector of China's economy. China's Ministry of Posts and Telecommunications is building a national fiber-optic network. As part of the eighth five-year plan (1991-95), the network will contain 22 trunk lines totaling 32,000 kilometers by the end of 1995. Ten trunk lines were completed during 1993, and work began on another 10 trunk lines. *Information Technology Market Opportunities in China*, Dataquest Inc., San Jose, 1994.

[60] Howard Rausch, "Asia Talks and the World Listens: Far Eastern Telecommunications Boom Means Big Business for Photonics Companies," *Photonics Spectra*, July 1994, pp. 89-100.

[61] U.S. industry officials, interviews with USITC staff, Sept. 18-19, 1994.

[62] Marcy Koff, "Submarine Fiber-optic Cables Swim to Distant Shores," *Lightwave*, May 1994, p. 1; and U.S. and Japanese industry officials, interviews with USITC staff, Sept. 18-19, 1994.

[63] Ibid.

[64] Canadian industry officials, telephone interview with USITC staff, Oct. 25, 1994.

[65] U.S. and Japanese industry officials, interviews with USITC staff, Sept. 27-28, 1994.

[66] European industry officials, telephone interviews with USITC staff, Oct. 25-27, 1994.

[67] Official statistics of the U.S. Department of Commerce.

[68] Latin American and Asian government officials, telephone interviews with USITC staff, Oct. 25 and 26, 1994.

[69] Ibid.

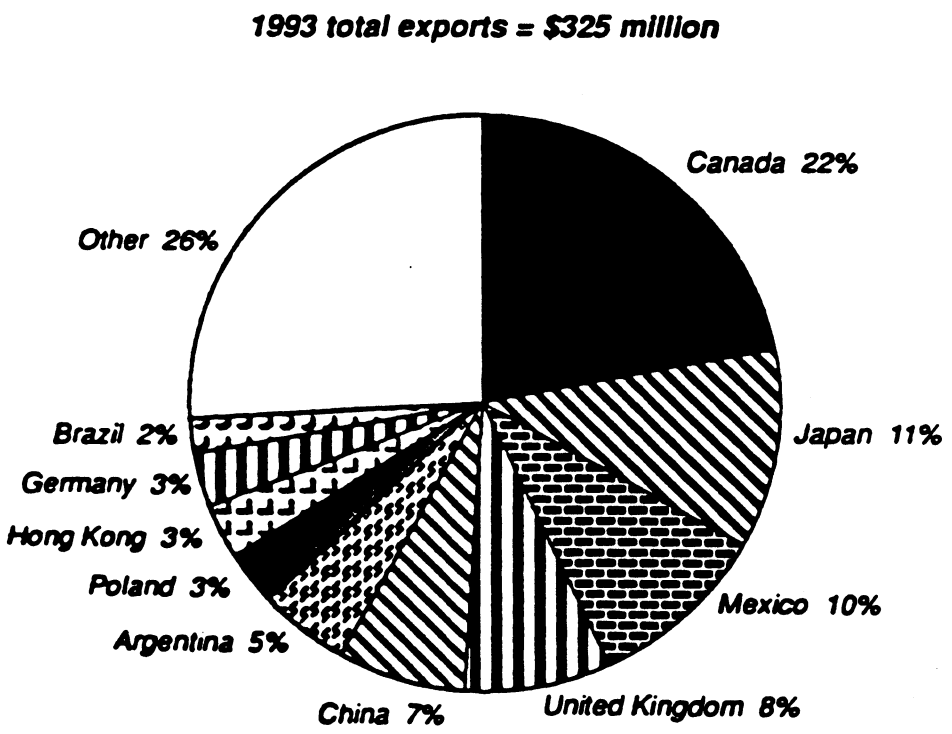
Table 4
Optical fiber, cable, and bundles: U.S. exports of domestic merchandise, by principal markets, 1989-93

Market	1989	1990	1991	1992	1993
			Value (1,000 dollars)		
Canada	18,573	46,386	44,760	79,723	70,124
Japan	12,409	33,514	43,403	28,904	36,570
Mexico	1,112	4,039	14,106	25,798	31,863
United Kingdom	18,392	12,919	13,907	20,974	25,044
China	3,802	4,751	8,374	18,011	22,063
Argentina	0	46	424	5,105	16,212
Poland	15	14	37	3,426	8,969
Hong Kong	363	151	170	3,504	8,786
Germany	12,313	11,061	20,744	21,227	8,663
Brazil	0	32	149	6,150	7,423
All other	75,807	58,793	101,343	80,062	89,532
Total	142,785	171,707	247,417	292,884	325,249

Note.—Because of rounding, figures may not add to the totals shown.

Source: Compiled from official statistics of the U.S. Department of Commerce.

Figure 7
Optical fiber, cable, and bundles: U.S. exports to major markets, 1993



Source: Compiled from official statistics of the U.S. Department of Commerce.

Table 5
Optical fiber, cable, and bundles: U.S. exports of domestic merchandise, imports for consumption, and merchandise trade balance, by selected countries and country groups, 1989-93[1]

(Million dollars)

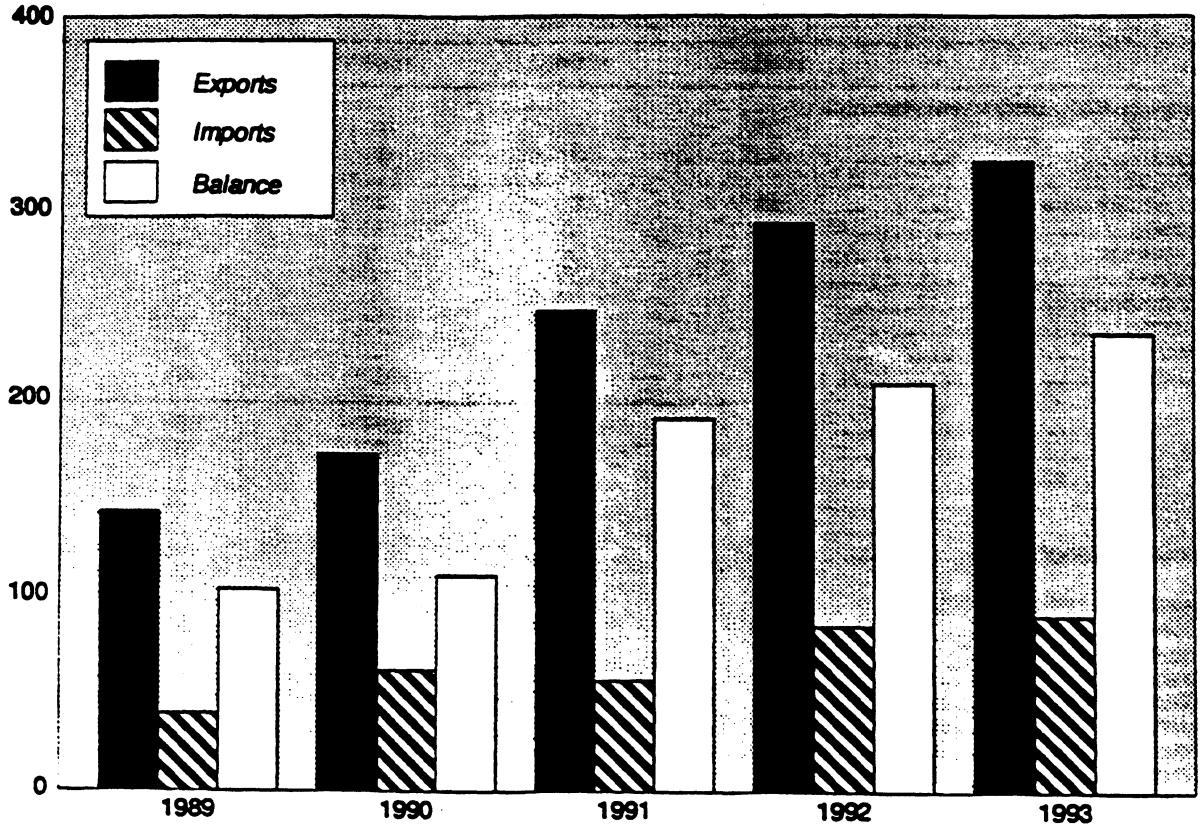
Item	1989	1990	1991	1992	1993
U.S. exports of domestic merchandise:					
Canada	19	46	45	80	70
Japan	12	34	43	29	37
Mexico	1	4	14	26	32
United Kingdom	18	13	14	21	25
China	4	5	8	18	22
Argentina	0	0	0	5	16
Poland	0	0	0	3	9
Hong Kong	0	0	0	4	9
Germany	12	11	21	21	9
Brazil	0	0	0	6	7
All other	77	59	102	80	89
Total	143	172	247	293	325
EU-12	67	49	80	70	55
OPEC	1	2	3	1	10
ASEAN	1	2	4	10	8
CBERA	4	5	3	2	1
Central Europe	0	0	0	4	9
U.S. imports for consumption:					
Canada	14	21	21	52	48
Japan	8	13	10	11	18
Mexico	0	0	0	0	1
United Kingdom	2	2	2	1	1
China	0	0	0	0	4
Argentina	0	0	0	0	0
Poland	0	0	0	0	0
Hong Kong	0	0	0	0	0
Germany	14	20	20	16	5
Brazil	0	0	0	0	0
All other	2	6	4	5	0
Total	40	62	57	85	90
EU-12	16	24	23	20	17
OPEC	0	0	0	0	0
ASEAN	1	1	1	1	1
CBERA	0	0	0	0	0
Central Europe	0	0	0	0	0
U.S. merchandise trade balance:					
Canada	5	25	24	28	22
Japan	4	21	33	18	19
Mexico	1	4	14	26	31
United Kingdom	16	11	12	20	24
China	4	5	8	18	18
Argentina	0	0	0	5	16
Poland	0	0	0	3	9
Hong Kong	0	0	0	4	9
Germany	-2	-9	1	5	4
Brazil	0	0	0	6	7
All other	75	53	98	75	95
Total	103	110	190	208	235
EU-12	51	25	57	50	38
OPEC	1	2	3	1	10
ASEAN	0	1	3	9	7
CBERA	4	5	3	2	1
Central Europe	0	0	0	4	9

[1] Import values are based on customs value; export values are based on f.a.s. value, U.S. port of export. U.S. trade with East Germany is included in "Germany" but not "Eastern Europe."

Source: Compiled from official statistics of the U.S. Department of Commerce.

Figure 8
Optical fiber, cable, and bundles: U.S. exports, imports, and trade balances, 1989-93

In millions of dollars



Source Compiled from official statistics of the U.S. Department of Commerce.

APPENDIX A
EXPLANATION OF TARIFF AND TRADE AGREEMENT TERMS

The ***Harmonized Tariff Schedule of the United States*** (HTS) replaced the *Tariff Schedules of the United States* (TSUS) effective January 1, 1989. Chapters 1 through 97 incorporate the internationally adopted Harmonized Commodity Description and Coding System through the 6-digit level of product description and have U.S. product subdivisions at the 8-digit level. Chapters 98 and 99 contain special U.S. classifications and temporary rate provisions, respectively.

Duty rates in the ***general*** subcolumn of HTS column 1 are most-favored-nation (MFN) rates, many of which have been eliminated or are being reduced as concessions resulting from the Uruguay Round of Multilateral Trade Negotiations. Column 1-general duty rates apply to all countries except those enumerated in HTS general note 3(b) (Afghanistan, Azerbaijan, Cuba, Kampuchea, Laos, North Korea, and Vietnam), which are subject to the rates set forth in ***column 2***. Albania, Armenia, Belarus, Bosnia, Bulgaria, the People's Republic of China, Croatia, the Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Macedonia, Moldova, Mongolia, Poland, Romania, Russia, Slovakia, Slovenia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan are accorded MFN treatment. Specified goods from designated MFN-eligible countries may be eligible for reduced rates of duty or for duty-free entry under one or more preferential tariff programs. Such tariff treatment is set forth in the ***special*** subcolumn of HTS column 1 or in the general notes. If eligibility for special tariff rates is not claimed or established, goods are dutiable at column 1-general rates. The HTS does not enumerate those countries as to which a total or partial embargo has been declared.

The *Generalized System of Preferences* (GSP) affords nonreciprocal tariff preferences to developing countries to aid their economic development and to diversify and expand their production and exports. The U.S. GSP, enacted in title V of the Trade Act of 1974 for 10 years and extended three times thereafter, applies to merchandise imported on or after January 1, 1976 and before the close of July 30, 1995. Indicated by the symbol "A" or "A*" in the special subcolumn, the GSP provides duty-free entry to eligible articles the product of and imported directly from designated beneficiary developing countries, as set forth in general note 4 to the HTS.

The ***Caribbean Basin Economic Recovery Act*** (CBERA) affords nonreciprocal tariff preferences to developing countries in the Caribbean Basin area to aid their economic development and to diversify and expand their production and exports. The CBERA, enacted in title II of Public Law 98-67, implemented by Presidential Proclamation 5133 of November 30, 1983, and amended by the Customs and Trade Act of 1990, applies to merchandise entered, or withdrawn from warehouse for consumption, on or after January 1, 1984. Indicated by the symbol "E" or "E*" in the special subcolumn, the CBERA provides duty-free entry to eligible articles, and reduced-duty treatment to certain other articles, which are the product of and imported directly from designated countries, as set forth in general note 7 to the HTS.

Free rates of duty in the special subcolumn followed by the symbol "IL" are applicable to products of Israel under the ***United States-Israel Free Trade Area Implementation Act*** of 1985 (IFTA), as provided in general note 8 to the HTS.

Preferential nonreciprocal duty-free or reduced-duty treatment in the special subcolumn followed by the symbol "J" or "J*" in parentheses is afforded to eligible articles the product of designated beneficiary countries under the ***Andean Trade Preference Act*** (ATPA), enacted as title II of Public Law 102-182 and implemented by Presidential Proclamation 6455 of July 2, 1992 (effective July 22, 1992), as set forth in general note 11 to the HTS.

Preferential or free rates of duty in the special subcolumn followed by the symbol "CA" are applicable to eligible goods of Canada, and those followed by the symbol "MX" are applicable to eligible goods of Mexico, under the ***North American Free Trade Agreement***, as provided in general note 12 to the HTS, implemented effective January 1, 1994 by Presidential Proclamation 6641 of December 15, 1993.

Other special tariff treatment applies to particular products of insular possessions (general note 3(a)(iv)), goods covered by the ***Automotive Products Trade Act*** (APTA) (general note 5) and the Agreement on Trade in Civil Aircraft (ATCA) (general note 6), ***articles imported from freely associated states*** (general note 10), ***pharmaceutical products*** (general note 13), and ***intermediate chemicals for dyes*** (general note 14).

The ***General Agreement on Tariffs and Trade 1994*** (GATT 1994), annexed to the Agreement Establishing the World Trade Organization, replaces an earlier agreement (the GATT 1947 [61 Stat. (pt. 5) A58; 8 UST (pt. 2) 1786]) as the

primary multilateral system of disciplines and principles governing international trade. Signatories' obligations under both the 1994 and 1947 agreements focus upon most-favored-nation treatment, the maintenance of scheduled concession rates of duty, and national (nondiscriminatory) treatment for imported products; the GATT also provides the legal framework for customs valuation standards, "escape clause" (emergency) actions, antidumping and countervailing duties, dispute settlement, and other measures. The results of the Uruguay Round of multilateral tariff negotiations are set forth by way of separate schedules of concessions for each participating contracting party, with the U.S. schedule designated as Schedule XX.

Officially known as "The Arrangement Regarding International Trade in Textiles," the ***Multifiber Arrangement*** (MFA) provides a framework for importing and exporting countries to negotiate bilateral agreements limiting textile and apparel shipments, or for importing countries to take unilateral action in the absence or violation of an agreement. These agreements establish quantitative limits on textiles and apparel of cotton, other vegetable fibers, wool, man-made fibers or silk blends in an effort to prevent or limit market disruption in the importing countries—restrictions that would otherwise be a departure from GATT provisions. The United States has bilateral agreements with many supplying countries, including the four largest suppliers: China, Hong Kong, the Republic of Korea, and Taiwan.

APPENDIX B
GLOSSARY OF TECHNICAL TERMS

GLOSSARY OF TECHNICAL TERMS

Dispersion-Shifted Fiber: A singlemode optical fiber that has a nominal zero dispersion wavelength near 1550 nanometers (see singlemode fiber).

Erbium-Doped Fiber: Erbium-doped fibers are optical fibers chemically treated with erbium which provides the fiber with optical amplification properties. Optical amplifiers, or repeaters, employ the erbium-doped fiber to boost optical fiber signals periodically over long distances without having to convert to electronic signals. In contrast, traditional fiber-optic repeaters employ opto-electronic circuits to convert the optical signals to electrical equivalents, regenerate and retime the signals and then convert the improved signals back to optical signals for onward transmission along the cable.

Industrial Process Control Systems: Systems that continually monitor the critical physical variables in an industrial process and keep them within predetermined limits. In a manufacturing plant, a control system may control a single process, a number of processes, or all of the processes in a plant.

Light-Emitting Diode: A semiconductor diode which emits visible or infrared light. It is used as a transmitter in optical fiber systems, especially those used in shorter distance network applications.

Multimode Fiber: An optical fiber that supports the propagation of more than one wavelength of light. Due to a relatively larger core and entrance aperture than singlemode fiber, it does not require a laser source but may use a light emitting diode for its input signal (also see singlemode fiber).

Optical Fiber: A long thin strand of transparent glass, plastic, or other material usually consisting of a fiber optical core and a fiber optical cladding capable of conducting light along its axial length by internal reflection.

Optical Fiber Bundles: Collections of optical fibers arranged to permit the transmission of light or images. Optical fibers arranged non-randomly to permit the transmission of images are known as coherent bundles. Optical fibers arranged randomly to permit the transmission of light, but not images, are known as noncoherent bundles.

Optical Fiber Cable: Optical fibers incorporated into an assembly of materials that provides tensile strength, external protection, and handling properties comparable to those of equivalent coaxial cables.

Optical Fiber Sensors: Also known as fiber optic sensors, these are optical fibers used in apparatus designed to detect or sense environmental effects such as pressure, temperature, magnetic fields, electric fields, and rotation.

Preform: A glass structure that is a magnified version of the fiber to be drawn from it.

Repeater: A device which detects a weak signal in a optical fiber communications system, amplifies and retransmits it.

Semiconductor Laser: The most commonly used long distance light transmission source used in long distance telecommunications optical fiber systems (also see light emitting diode).

Singlemode Fiber: An optical fiber that supports the propagation of only one wavelength. Usually a low-loss optical fiber with a small core (2 to 9 microns). It requires a laser source for the input signals because of the very small entrance aperture (acceptance cone). The small core radius approaches the wavelength of the source: consequently, only a single wavelength is propagated (also see multimode fiber).

Solitons: Light pulses that travel without distortion over long distances.