Ministry of Education and Science of Ukraine
Ternopil Ivan Puluj National Technical University

Faculty of Computer Information System and Software Engineering
(full name of faculty)
Department of Computer Science
(full name of department)

QUALIFYING PAPER

For the degree of

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(degree name)

topic: Optical fiber computer network development based on spectral compression of channels

Submitted by: fourth year student 4 , group ICH-42
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(signature) Obi Munachimso Wisdom
(surname and initials)

Supervisor (signature) Dozorskyi V.G. (surname and initials)

Standards verified by (signature) Matsiuk O.V. (surname and initials)

Head of Department (signature) Bodnarchuk I.O. (surname and initials)

Reviewer (signature) (surname and initials)

Ternopil
2023

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Department Department of Computer Science
(full name of department)

APPROVED BY
Head of Department
Bodnarchuk I.O.
(signature) (surname and initials)
« » 20___

ASSIGNMENT
for QUALIFYING PAPER

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(surname, name, patronymic)

1. Paper topic Optical fiber computer network development based on spectral compression of channels

Paper supervisor Dozorskyi V.G., PhD, Associate Profesior
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Principles of operation of fiber optic networks; the concept of FO data transmission lines; elements of FOCL; specifics of FO networks; SM and MM fiber; properties of OF; optical fiber parameters; losses in OF; signal dispersion in OF; method of spectral compression in of networks; ways to increase the FO throughput; basic principles of dense wave multiplexing technology; advantages and disadvantages of DWDM technology; technical implementation of optical fiber computer network; methods of laying an optical cable; analysis and selection of DWDM equipment; selection of DWDM equipment; control system selection. Life safety, basics of labor protection

6. Advisors of paper chapters

Chapter	Advisor's surname, initials and position	Signature, date	
		assignment was given by	assignment was received by
LABOR PROTECTION			

7. Date of receiving the assignment ______________________

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	Analysis of the task for qualifying work		
	Writing chapter 1		
	Writing chapter 2		
	Writing chapter 3		
	Writing chapter 4		
	Preliminary defense of work		
	Defense of work		

Student ______________ (signature) Obi Munachimso Wisdom (surname and initials)

Paper supervisor ______________ (signature) Dozorskyi V.G. (surname and initials)

ANNOTATION

Information Technology: Optical fiber computer network development based on spectral compression of channels // Qualification work of the educational level "Bachelor" // Obi Munachimso Wisdom // Ternopil Ivan Puluj National Technical University, Faculty of Computer Information System and Software Engineering,

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Diagrams – , Annexes. – , References – .

In the qualifying work, the development of fiber-optic computer network based on spectral compression of channels was carried out. The principles of operation of optical fiber computer networks were analyzed, their advantages and disadvantages were evaluated. It has been established that today the main task in the design of such networks is the expansion of bandwidth. For this, the method of spectral compression of channels was used. This method was analyzed and the design of such an optical fiber computer network was carried out. The selection of technical components and hardware, on the basis of which a high-speed optical fiber computer network can be implemented, has been made.

CONTENTS

INTRODUCTION

Traditionally, an information network consists of networks of computers - clients connected to dedicated servers. Such a network organization is designed as a hierarchy, which takes into account the leadership of the server, which contains data and applications. With this configuration of the network, the computer stations were not connected to each other. However, with the invention of more powerful computers, centralized information systems became obsolete. Modern operating systems offer users various ways of network interaction, along with built-in network support, various sets of applications and a huge space for storing information.

The main advantages of connecting computers to a network are the possibility of data transmission over the network, access to a printer for printing documents from any computer on the network, monitoring of workstations by the server and controlled access of workstations to the worldwide network, etc. determination of a single database for accounting.

Today, the construction of a productive computer system is not in doubt, as it provides users with the following advantages: joint continuous access to corporate resources; joint use of expensive office equipment; fast and simple replacement or addition of new workstations; provision of additional security of corporate data of special confidentiality.

When building a network, it is necessary to solve many issues. First of all, it is the choice of network architecture and topology, it is necessary to choose switching equipment. Switching equipment is usually chosen, relying on such facts as the place of laying the network (indoors or on the street), the task set before the network, the necessary productivity. Networks for computing, which are usually created at enterprises, are flexible networks with rather expensive equipment. Private networks have limitations, so they are most often created with the same types of topology, and have an average speed.

Comparing different types of networks, it was found that fiber optic (FO, OF) networks have the best characteristics in terms of speed, cost, security and availability. However, their feature is the need to organize multi-channel data exchange.

The purpose of this thesis is to design a computer network based on fiber-optic cables with increased bandwidth based on the application of the method of spectral channel compression.

CHAPTER 1
PRINCIPLES OF FIBER OPTIC NETWORKS CONSTRUCTION

1.1 The concept of FO data transmission lines

FO (dielectric waveguides) has the highest bandwidth among all existing means of communication. Cables based on such fibers are used to create fiber-optic communication lines (FOCL) capable of providing the highest speed of information transmission (depending on the type of active equipment used, the speed of transmission can be tens of gigabytes and even terabytes per second). Quartz glass, which is a carrier medium, in addition to unique transmission characteristics, has another valuable property - low losses and insensitivity to electromagnetic fields. This favorably distinguishes it from ordinary copper cable systems. The use of FOCL allows you to locally combine workplaces, ensure high-speed simultaneous Internet downloads on all machines, high-quality telephone communication and television reception. Unlike ordinary cables, which have electrical conductivity and conduction current, OF have a completely different mechanism - they do not use displacement currents, on the basis of which radio transmission also works. The difference from radio transmission is that the wave does not propagate in free space, but is concentrated in the optical fiber itself and transmitted along it in a given direction. The transmission of the wave along the light guide is carried out due to its reflections from the core boundary and the shell. In ordinary cables, the carrier of transmitted information is an electric current, and in OF - a laser beam. Transmission through waveguide systems is possible only in the range of very high frequencies, when the wavelength is smaller than the transverse dimensions of the waveguide.

1.2 Elements of FOCL

1) Active elements:

- Multiplexer/Demultiplexer;
- regenerator;
- amplifier;
- laser;
- modulator;
- photodetector (Photodiode).

2) Passive elements:

- optical cable;
- optical coupler;
- optical cross.

1.3 Specifics of FO networks

It is difficult to imagine modern telecommunications without FO communication lines.

Thousands of kilometers of optical fiber are laid around the world every year. However, it has become a serious competitor to other types of wired communication relatively recently.

In a relatively short period of its development, FOCLs have taken a leading position in information transmission systems and have become an important link in the information infrastructure of modern society.

FOCL is a communication line, in which optical signal is transmitting over FO cable. FO networks have huge advantages over conventional lines (coaxial cable), which are susceptible to electromagnetic fields, which affects the quality of transmission of signal.

FO networks do not have such a disadvantage, in addition, they have a number of advantages - a wide bandwidth (frequency 1014 Hz, allows you to transfer up to several Tbits/sec.), based on this technology, you can create lines up to a hundred kilometers, which have high protection against interference.

Cost of interface equipment. Electrical signals must be converted to optical and vice versa. The price of optical transmitters and receivers is still quite high. When creating an optical CL, highly reliable specialized passive switching equipment, effective optical connectors and a long connection-disconnection resource, optical splitters, and attenuators are also required.

Installation and maintenance of optical lines. The cost of installation, testing and support of FOCL also remains high. If the FO cable is damaged, then it is necessary to weld the fibers at the break point and protect this section of the cable from the external environment. Manufacturers, meanwhile, are supplying the market with increasingly sophisticated FO installation tools, driving down their prices.

Requirement for special fiber protection. To increase reliability, the optical fiber is coated with a special varnish based on epoxyacrylate during manufacture, and the optical cable itself is strengthened, for example, with Kevlar-based threads. If even tougher breaking conditions are required, the cable can be reinforced with a special steel cable or fiberglass rods.

1.4 SM and MM fiber

Taking into account the light trajectory, SM(SM) and multi-mode (MM) fibers are distinguished. MM fiber has a rather large core diameter of 50 or 62.5 µm with a sheath diameter of 125 µm. SM fiber has of 7,9 or 9,5 µm core diameter with the same sheath diameter. Figure 1.1 shows SM / MM fiber example, where: a – SM, b – MM; 1 - core; 2 - optical shell; 3 - protective coating; 4 - buffer (optional).

Outside, the shell has a 60 μm thick plastic protective coating, also called a protective shell. Light guide with a protective coating is called FO.

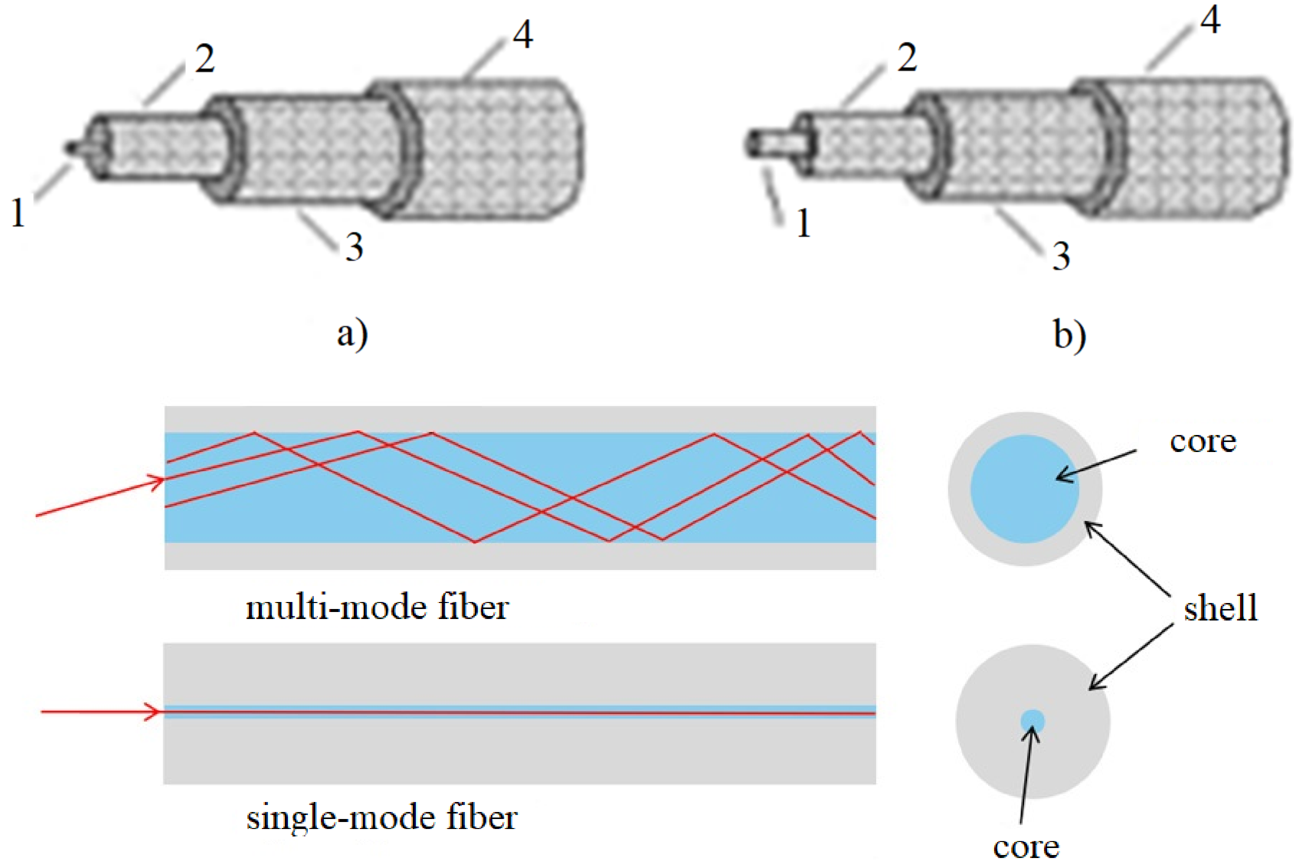


Figure 1.1. SM / MM fiber.

The main difference in SM / MM fiber is the thickness of the core and cladding. SM fiber is typically 8/125 μm thick, while a MM fiber is 50/125 μm thick. These values correspond to the diameter of the core and the diameter of the core and sheath combined.

The light beam propagating through the relatively thin core of a SMcable is not reflected from the jacket as often as it does in the thicker core of a MM cable. For data transmission, the latter uses polychromatic light, and SM uses light of only one frequency (monochrome radiation). The signal transmitted by SM cable is generated by a laser, and is a wave, of course, of one length, while the MM signals generated by an LED carry waves of different wavelengths. In a SMcable, signal attenuation is virtually eliminated. This and a number of the above qualities allow a SM cable to operate with a higher bandwidth than a MM cable and cover distances 50 times longer.

On the other hand, SMcable is much more expensive and has a relatively large bend radius compared to multi-mode optical cable, which makes it inconvenient to work with. Most FO networks use MM cable, which, while inferior in performance to SMcable, is significantly more efficient than copper. Telephone companies and cable television, however, tend to use SMcable because it can carry more data over longer distances. Figure 1.2 shows the input of light into a waveguide, where: 1 - input cosine; 2 – axial mode; 3 – low order mode; 4 – high order mode; 5 - critical angle.

In order for the beam to propagate along the fiber, it must enter it at an angle no more than critical relative to the fiber axis, that is, it must fall into an imaginary entrance cone. The sine of this critical angle is called NA that means numerical aperture of the fiber.

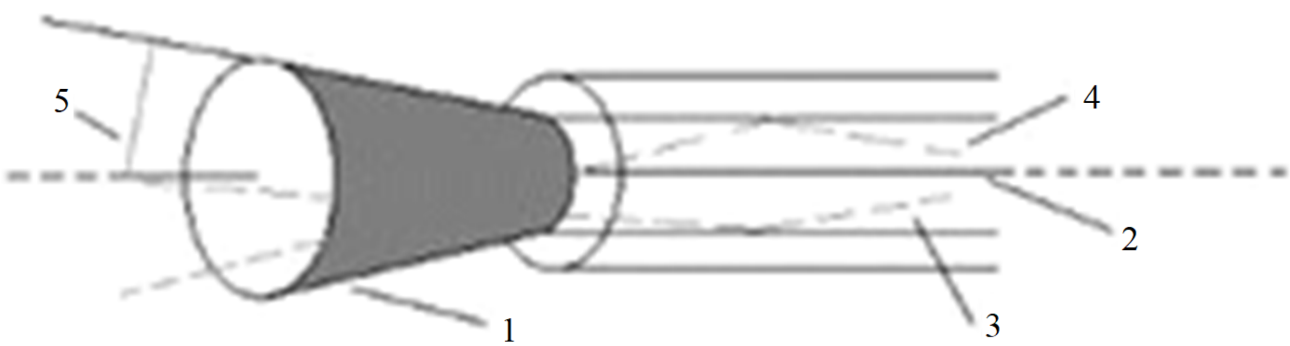


Figure 1.2. Entering light into OF

In a MM fiber, the refractive indices of the core and cladding differ by only 1-1.5% (for example, 1.515:1.50). In this case, the aperture NA is 0.2-0.3, and the angle at which the beam can enter the fiber, does not exceed 12-18° from the axis. In a SMfiber, the refractive indices differ even less (1.505:1.50), the aperture NA is 0.122, and the angle does not exceed 7° from the axis. The larger the aperture, the easier it is to insert the beam into the fiber, but this increases the modal dispersion and narrows the bandwidth.

Numerical aperture characterizes all components of the optical channel - light guides, sources and receivers of radiation. To minimize energy losses, the apertures of the connected elements must be matched with each other.

If we consider signal propagation from the standpoint of geometric optics, then light rays entering at different angles will propagate along different trajectories. Higher modes correspond to rays entering at a higher angle, they will have more internal reflections along the path in the fiber and will travel a longer path. The number of modes for a particular fiber depends on its design: the refractive indices and diameters of the core and cladding, as well as the wavelength.

1.5 Properties of OF

OF can be SM or MM. The core diameter of SM fibers is 7 to 9 μm. Due to the small diameter, only one mode of electromagnetic radiation is transmitted through the fiber, which eliminates the influence of dispersion distortions. Currently, almost all manufactured fibers are SM.

There are three main types of SM fibers:

SM stepped fiber with unshifted dispersion (SMF) is defined by ITU-T G.652 recommendation and is most ofeen used.

Dispersion Shifted SM Fiber (DSF), defined by ITU-T G.653. In DSF fibers, with the help of impurities, the zero dispersion region is shifted to the third transparency window, in which the minimum attenuation is observed.

Non-Zero Dispersion Shifted SM Fiber (NZDSF) is defined by ITU-T G.655.

MM fibers differ from singlemode fibers in their core diameter, which is 50 micrometers in the European standard and 62.5 micrometers in the North American and Japanese standards. Due to the large diameter of the core, several radiation modes propagate through the MM fiber - each at its own angle, due to which the light pulse experiences dispersion distortion and turns from rectangular to bell-shaped.

MM fibers are divided into stepped and gradient fibers. The refractive index changes stepwise from the cladding to the core in stepped fibers. In gradient fibers, this change occurs differently - the refractive index of the core increases smoothly from the edge to the center. This leads to the phenomenon of refraction in the core, thereby reducing the effect of dispersion on the distortion of the optical pulse. Refractive index profile can be parabolic, triangular, broken, etc. for the graded fiber.

An optical fiber, as shown in Figure 1.3, consists of a core through which light waves propagate and an optical cladding.

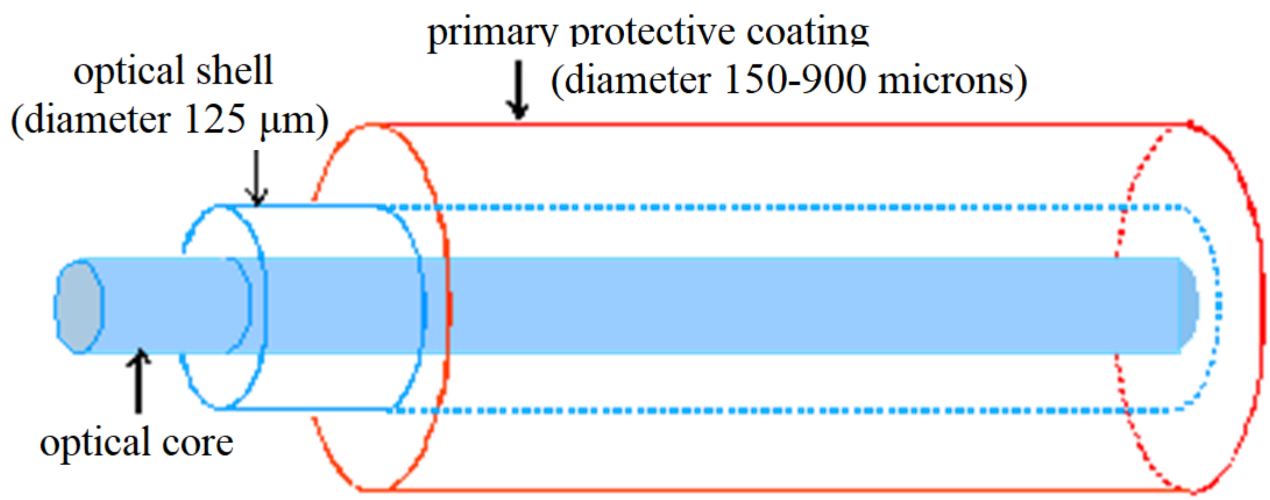


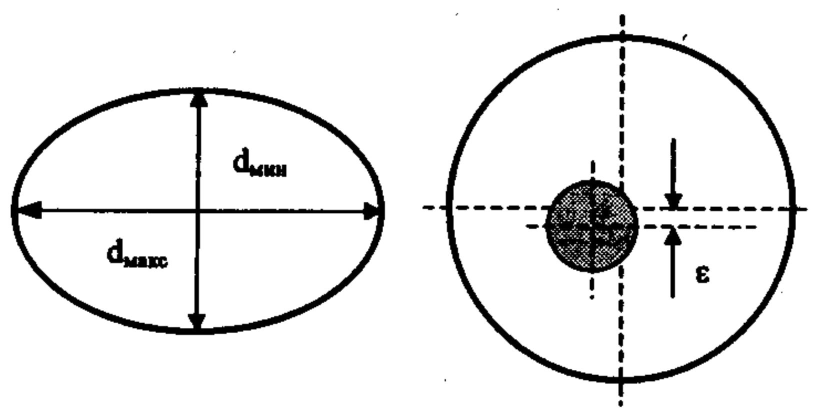
Figure 1.3. The structure of the optical fiber

The purpose of the optical cladding is to create the best conditions for reflection interface and to protect against radiation of waves into the surrounding space. A primary protective-strengthening coating is applied over the cladding, which increases the strength of the optical fiber.

1.6 Optical fiber parameters

It should be noted that there are several types of optical fiber parameters: geometric, optical, mechanical and transmission parameters of optical fibers.

The main geometrical parameters of an optical fiber are: core diameter; shell diameter; protective coating diameter; non-circularity (ellipticity) of the core; non-circularity of the shell; non-concentricity of the core and shell.



a) b)

Figure 1.4. Examples of inhomogeneities in the OF: a - non-circularity; b - non-concentricity of the core

The non-circularity of the core of an optical fiber is defined like a difference between core maximum and minimum diameters, divided by the nominal core diameter, and is determined only in MM fibers, the non-circularity of the cladding - in MM and SM fibers.

Geometric parameters are standardized for different OF types.

The main optical parameters of the fiber are:

- relative difference of refractive indices (Δ);
- NA;
- normalized frequency (v);

- number of propagating modes (M);
- mode field diameter (dmp);
- cutoff wavelength (critical wavelength λcr).

Numerical aperture. One of the main characteristics that determine the conditions for the input of optical signals and the processes of their propagation in an optical fiber is the numerical aperture.

Gradient optical fibers use the concept of local numerical aperture. Its value is maximum on the fiber axis and equals 0 at the core–cladding interface.

Normalized frequency. This parameter is equal to:

$$v = \frac{2\pi\pi}{\lambda} NA,$$

where λ is the wavelength.

The mechanical parameters of the OF include:
- fiber strength;
- dynamic tensile strength;
- fracture load parameter;
- resistance to bending;
- the force of removing the protective coating.

1.7 Losses in OF

The most common, cheap, and popular loss measurement devices are meters of optical power, often used in conjunction with a source of stable optical radiation.

Meters of optical power are used to measure the output power of passive and active components of a FO system. Many meters of optical power can directly display losses in a fiber or individual components of an optical cabling system. To do this, they provide a mode for measuring relative power levels, with the help of which a reference level is stored (for example, the power level of the light source), and all subsequent measurements are carried out relative to this level.

It is difficult to overestimate the role of losses in the operation of an optical cable, because their value determines the ability of fibers to cope with the transmission of the transmitted information stream over the required distance, including when the network structure becomes more complex or the speed of transmission systems increases. Knowledge of the magnitude of losses is necessary to control the reserve of the cable system for repair and modernization. When laying a cable, knowledge of the power attenuation of the transmitted signal in optical fibers is of great importance, because the ability of the light propagation medium to transmit signals without distortion over long distances subsequently depends on this. Therefore, the procedure for testing the cable after it has been received from the manufacturer (input control) is very important, as well as control of losses during installation. The need for fast transmission, especially over long distances, leads to a change in the old and the emergence of new principles and technologies for signal transmission. The expanding scope of optical fiber and the increasing influence of effects that were previously simply not paid attention to, makes it necessary to look for ways to overcome various limitations, both in terms of transmission speed, distances covered, and in the accuracy of waveform transmission. The requirements for the transmission medium begin to change, which responds to new conditions by complicating the structure. In turn, changes in the structure of the transmission medium lead to the emergence of new factors and phenomena, without taking into account which it is impossible to correctly assess the performance of the fiber and its suitability for certain applications. Thus, an increase in speed, an increase in the volume of transmitted information and an expansion of the field of application of FOs lead to changes in transmission technologies and the very medium of light propagation, which, in turn, entails the appearance of other limiting factors and, accordingly, another change in the medium. All this cannot but affect the methods of measurement. Changing the structures and quality of the optical signal transmission medium leads to a gradual increase in the requirements for the technical parameters of measuring instruments for testing optical fibers until the threshold of the maximum capabilities of modern measuring equipment is reached, after which a qualitative leap usually occurs in methods and measuring instruments.

Optical power loss (attenuation) is the decrease in the light signal propagating in the medium as the distance traveled increases, including all losses that occur during transmission. Therefore in speed transmission systems, accurate knowledge of the attenuation in the cable and cable system components is decisive for assessing its performance and determining the margin of the optical medium in terms of transmission speed and loss level.

Direct loss is the attenuation of the signal when passing from the radiation source to the photodetector located at the far end of the optical fiber. This type of loss imposes limits on the distance and, indirectly, on the bandwidth of the fiber, and hence on the transmission rate. Direct losses are divided into absorption losses and scattering losses. Absorption losses are in turn divided into infrared absorption losses (predominant at wavelengths > 1500 nm) and ultraviolet absorption (effective up to a wavelength of 1400 nm). Scattering losses are divided into Rayleigh losses and stimulated Raman scattering.

Return loss is of great importance for high-quality signal transmission and determines the amount of optical power returned to the radiation source. They represent the logarithmic ratio of the reflected and direct signals and are measured in decibels with a negative sign. The greater the return loss, the lower the optical power returned to the source and, consequently, the better the operating conditions of the optical radiation source. Two methods for measuring attenuation are defined: the break method and the insertion loss method.

1.8 Signal dispersion in OF

Dispersion is one of most important parameters of OF, which determines its information throughput.

OF transmits not just light energy, but also a useful information signal. The pulses of light, the sequence of which determines the information flow, are blurred in the process of propagation. With a sufficiently large expansion, the pulses begin to overlap, so that it becomes impossible to separate them during reception (Figure 1.5).

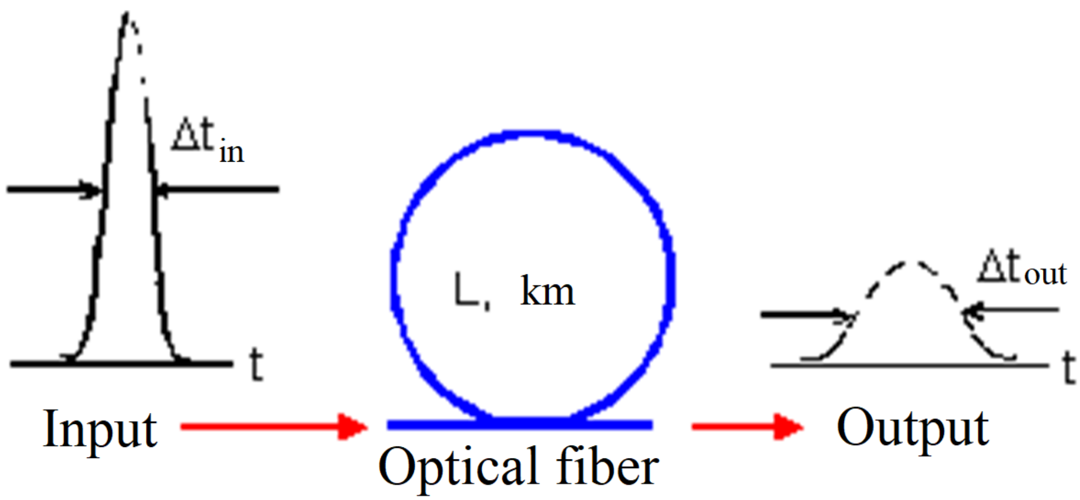


Figure 1.5. Influence of dispersion

The smaller the dispersion value, the more information can be transmitted over the fiber. Dispersion not only limits the frequency range of the fiber, but significantly reduces the signal transmission distance, since the longer the line, the greater the increase in pulse duration.

Dispersion is generally determined by three main factors:

- the difference in the propagation velocities of guided modes (intermode dispersion),

- guiding properties of OF (waveguide dispersion),

- parameters of the material from which it is made (material dispersion).

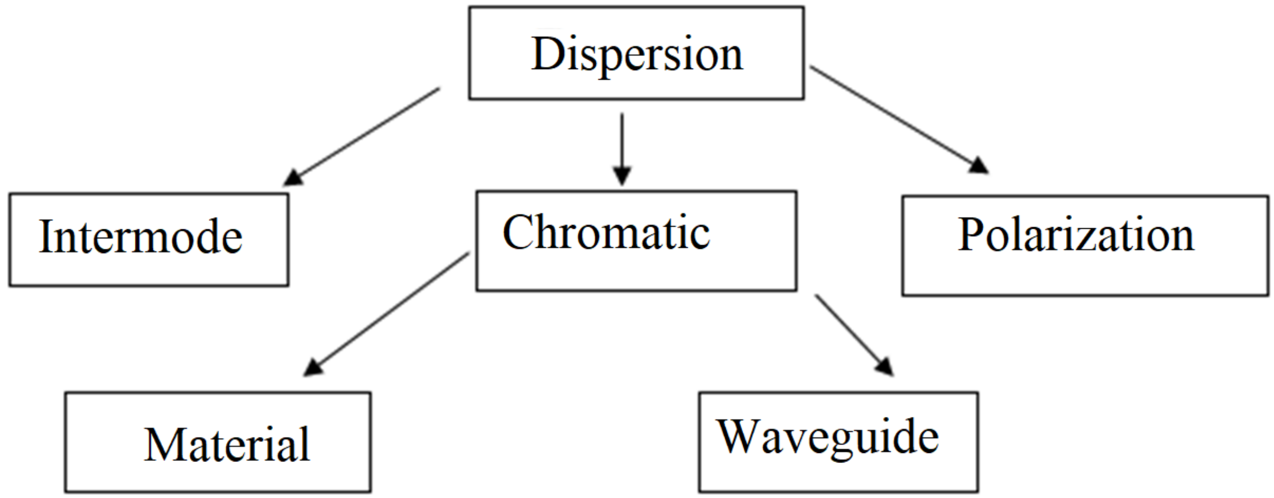


Figure 1.6. Types of dispersion

The main reasons for the occurrence of dispersion are, on the one hand, a large number of modes in an optical fiber (intermode dispersion), and on the other hand, the incoherence of radiation sources that actually operate in the wavelength spectrum (chromatic dispersion).

The difference in the propagation paths of guided modes at a fixed frequency (wavelength) of the radiation of an optical source leads to the fact that the time of passage of these modes along the optical fiber is different. As a result, the pulse generated by them at the output of the optical fiber expands. The magnitude of the pulse expansion is equal to the difference in the propagation time of the slowest and fastest modes. This phenomenon is called intermode dispersion. In stepped OF it can be completely eliminated if the structural parameters of the optical fiber are appropriately selected.

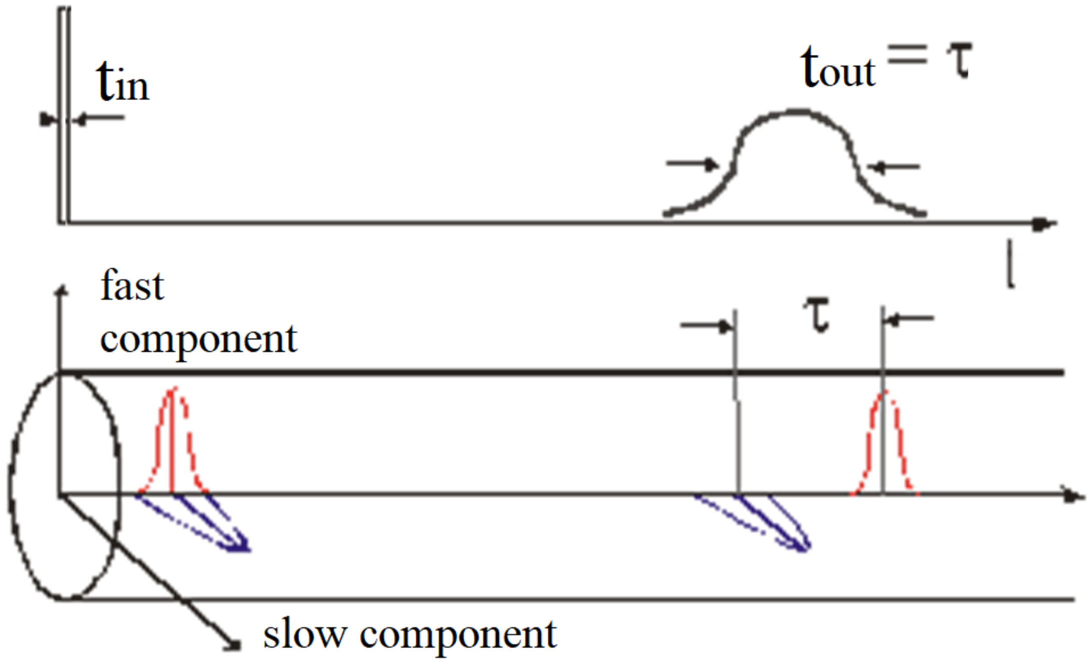


Figure 1.7. Polarization mode dispersion

1.9 Conclusions to chapter 1

In this chapter, an analysis of the principles of the work of FO data transmission lines was carried out. The main elements, from which such lines are formed, are analyzed. Also, the advantages and shortcomings of FOCL were analyzed and it was established that these lines have the best characteristics in paired with other methods of data transmission. However, it is important to ensure the high capacity and richness of such lines.

CHAPTER 2
METHOD OF SPECTRAL COMPRESSION IN OF NETWORKS

2.1 Ways to increase the FO throughput

At the moment, the length of standard SM fibers laid around the world is very large, so many owners of systems based on them are faced with the question of how to upgrade the system so that its throughput meets modern requirements. One way is to leverage optical technologies and build backbones based on all-optical networking technology.

It is possible to increase the throughput of a FOCL by increasing the bit rate or by adding channels with several wavelengths, i.e. building systems that provide WDM (Wave Division Multiplexing) or, in other words, wavelength multiplexing. The commissioning of WDM systems is dictated by economic considerations, since it is much cheaper to replace the terminal equipment than to lay new cables and install additional regenerators.

The essence of WDM is that independent optical information streams are combined and transmitted over one fiber at different wavelengths (Figure 2.1). This means that carriers can increase the capacity of their fibers without the heavy capital investment associated with building or leasing new fibers. By transmitting signals at n wavelengths (that is, over n channels), you can increase the network throughput by n times.

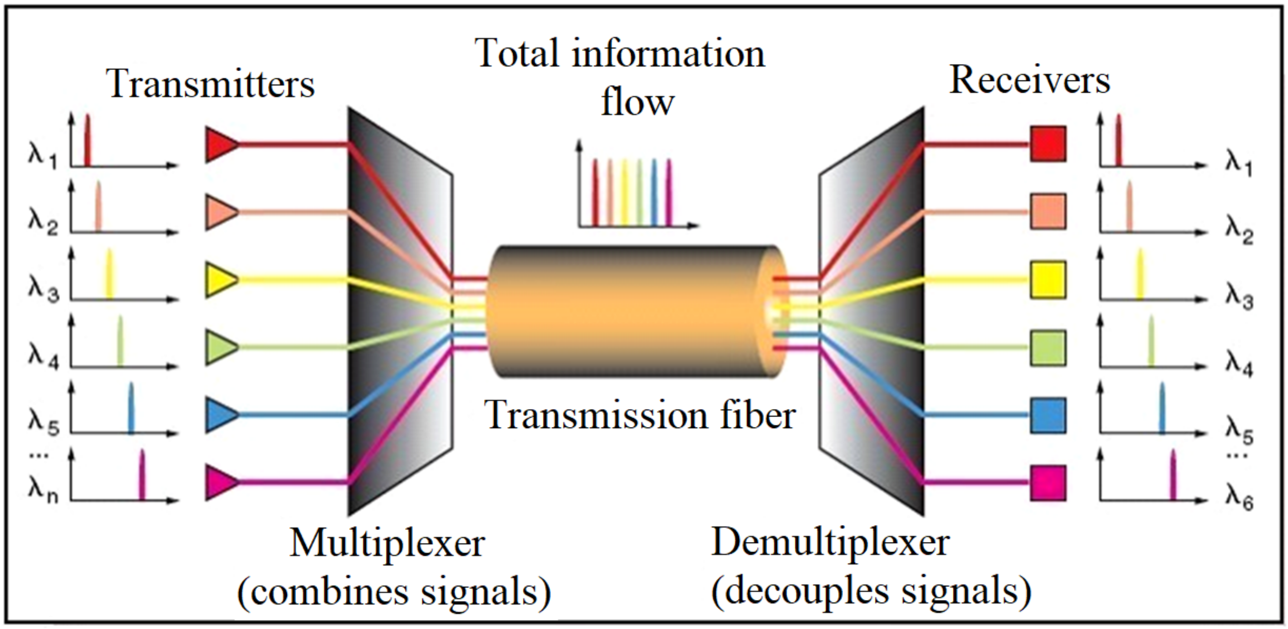


Figure 2.1. WDM principle

Let's estimate the bandwidth of the optical range 1280-1620 nm. The frequency band in the 2nd, 3rd, 4th transparency windows ΔF=49.2 THz. With an inter-channel interval of 100 GHz, 492 channels can be organized. If we use equipment with a transmission rate of 2.5 Gb / s in each channel, then the total throughput will be B = 1230 Gb / s, and when using a speed of 10 Gb / s, we will get almost 5 Tb / s.

New low-dispersion optical fibers are the best fit for building next-generation FO systems using WDM technology, providing many opportunities for further upgrades and efficient use of bandwidth. For example, some of the channels can be used for analog video transmission, some for data transmission, and some for speech. The distribution of different services across wavebands certainly has its advantages, and more operators are beginning to realize this.

Almost no one today doubts that the future belongs to WDM systems.

When analyzing WDM technology, the following phenomena should be considered: non-linear refraction, stimulated light scattering, and four-wave mixing.

Nonlinear refraction is caused by the fiber core refractive index dependence, and hence the phase of the output signal, on the intensity of the optical signal. When the signal power is large enough, its fluctuations lead to self-phase modulation and phase cross-modulation. In the first case, the signal acts on itself, in the second - on the signal in another channel. Each of these effects can interfere when transmitting using phase shift keying. The maximum allowed channel power is inversely proportional to the number of multiplexed channels.

Stimulated scattering of light is scattering on elementary excitations of the medium induced by the scattered wave. Since the scattering process is stimulated by the scattered light itself, the scattered radiation is characterized by highdegree of coherence, narrow radiation patterns of the individual components, and an intensity comparable to that of the incident light. Thus, when a medium is excited by a powerful light source, its parameters are modulated, which leads to amplitude modulation of the scattered light and, consequently, to the appearance of new spectral components in it.

Four-wave mixing consists in the fact that in the presence of two passing waves with frequencies f_1 and f_2 $(f_1 < f_2)$, two more waves arise, with frequencies $2f_1 - f_2$ and $2f_2 - f_1$, propagating in the same direction and amplifying due to the original ones. Similar processes also occur when there are three (or more) incident waves. In this case, the harmonization of the values of the frequencies and wave vectors of all waves must be ensured.

This type of nonlinearity is more closely related to the parameters of the system than others: it is influenced not only by the length of the fiber and the cross-sectional area of its core, but also by the distance between adjacent channels and dispersion. Of all the phenomena considered, four-wave mixing is of the greatest importance for modern DWDM systems.

Four-wave mixing can be eliminated by selecting unequal frequency differences between adjacent channels. In addition, this effect is suppressed by dispersion, since it destroys phase matching. For this reason, dispersion-shifted fiber (DSF), designed to eliminate chromatic dispersion in the 1550 nm band, is of little use for WDM at 50 GHz (0.4 nm) and smaller steps; instead, special types of fiber are used (TrueWave, AllWave, etc.).

In a conventional stepped index SM fiber, there is no four-wave mixing between channels f_1 and f_2 if $f_2 - f_1 > 20$ GHz. The maximum allowable channel power in this case is practically independent of the number of multiplexed channels. For a conventional fiber at WDM with a distance between channels of 10 GHz, it is equal to several milliwatts.

2.2 Basic principles of dense wave multiplexing technology

The technology of dense wave multiplexing (DWDM) is designed to create a new generation of optical highways operating at gigabit and terabit speeds. Such a qualitative leap in performance is provided by a fundamentally different method of multiplexing than that of SDH - information in an optical fiber is transmitted simultaneously by large number of light waves. Each wave carries its own information, while for DWDM equipment it doesn't matter how it is encoded, and what protocols are used for data transmission - DWDM devices are only concerned with combining different waves in one light beam, as well as extracting from a common signal.

Thanks to DWDM technology, it is possible to multiply the throughput of FOCLs without laying new cables and without installing new equipment on each fiber. Dense wave multiplexing technology will enable communication and data service companies to ensure that they can fully meet the growth in data transmission speed demands.

To date, according to ITU-T recommendations, the entire area of "transparency" of quartz optical fibers is divided into a number of ranges, which are presented in Figure 2.2 and are given in Table 2.1. Initially, “transparency windows” were understood to mean sections of wavelengths near narrow local minima depending on the losses on the wavelength: 850 nm (1st), 1310 nm (2nd), 1550 nm (3rd). Gradually, with the development of quartz glass purification technology, the entire low-loss region from 1260 nm to 1675 nm became available.

Region C is recommended as the most optimal for practical use.

Table 2.1 Spectral wavelength ranges for SM optical fibers

Designation	Name	Wavelength range, nm
O	basic	1260-1360
E	extended	1360-1460
S	shortwave	1460-1530
C	standard	1530-1565
L	longwave	1565-1625
U	extra longwave	1625-1675

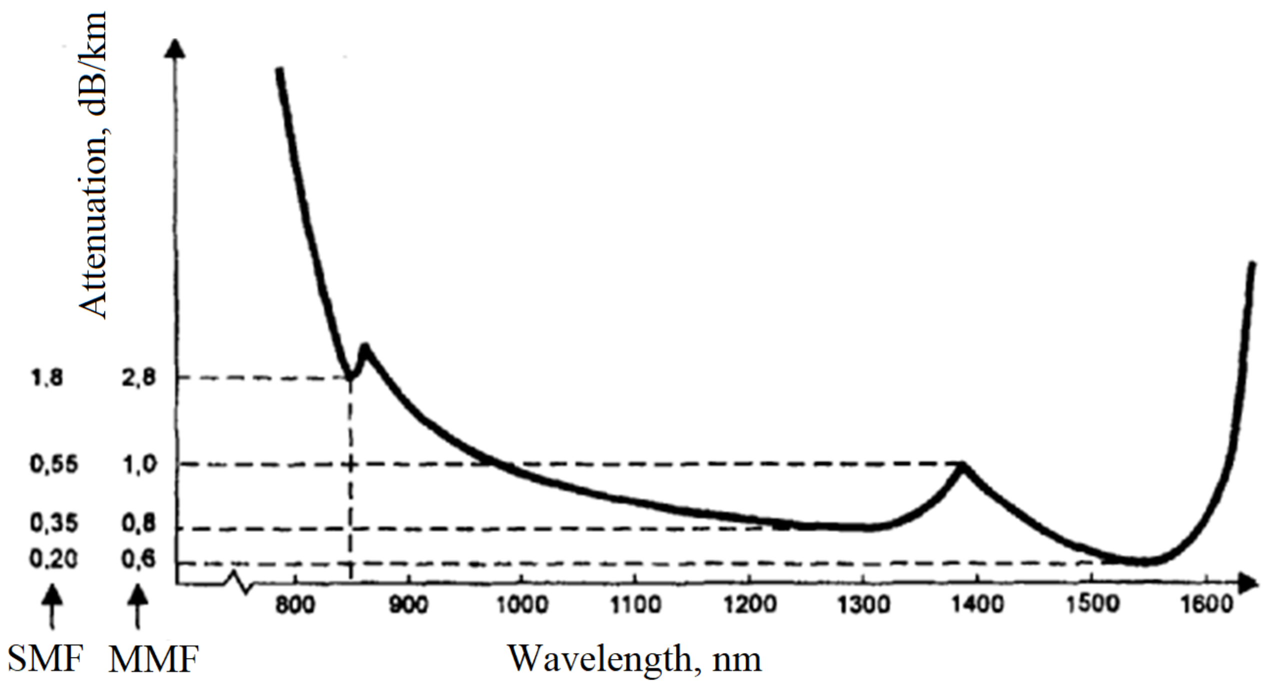


Figure 2.2. The main "windows of transparency" for quartz fibers.

When using DWDM equipment for 160 channels simultaneously in the C and L (C + L) bands, there are certain requirements for optical cables, namely: the attenuation in the C and L bands should be approximately the same. This means that it is necessary to use an optical cable with symmetrical attenuation characteristics in these ranges. Such cables have been developed relatively recently. In the vast majority of cases, operators use cables with unbalanced characteristics in the C and L-bands. So, for cables that comply with the requirements of recommendation G.652, the attenuation difference in the specified ranges can reach 0.02 dB/km. In this case, the largest attenuation should be considered for equipment location calculations, which leads to the need to install transmission equipment more often and, ultimately, increase its price.

At present, fundamentally new, soliton DWDM systems have appeared on the market, which can significantly increase the channel capacity and transmission range. A soliton is an intensity-modulated optical pulse, which, due to the nonlinear interaction between the spectral components, maintains the shape of the optical signal unchanged as it propagates through the fiber. In linear media, the spectral components of an optical pulse do not interact with each other, which leads to dispersion spreading of the signal. If the nonlinear effect of energy redistribution between the spectral components is taken into account, it is possible to avoid dispersive spreading of the signal propagating along the fiber. This technology seems to be the most promising for transmitting the STM-256 signal (40 Gb / s) over long distances. However, soliton technologies impose certain requirements on optical cables, which may necessitate their complete replacement on existing networks.

An increase in the number of transmitted channels can be performed smoothly with an increase in the need for information transmission volumes over an existing FO communication line. At the same time, qualitative control is needed, taking into account and measuring such parameters as: backward reflection, chromatic dispersion, nonlinear effects, which until recently were not taken into account. It is also necessary to provide for measures to compensate or minimize them. In DWDM systems, special attention must be paid to non-linear interactions between system channels.

It should be noted that no matter what problems arise in the technology of dense wave multiplexing, none of the existing technologies is able to completely replace it at the moment.

Modern WDM systems based on a standard frequency plan (ITU-T Rec. G.692) can be divided into three groups:

- coarse WDM (CoarseWDM - CWDM) systems with a frequency channel spacing of at least 200 GHz, allowing multiplexing no more than 18 channels (operating in the band from 1270nm to 1610nm).

- dense WDM (DenseWDM - DWDM) systems with a channel spacing of at least 100 GHz.

The frequency plan for DWDM systems is defined by ITU G.694.1 standard. According to ITU recommendations, DWDM systems use ”C” (1525…1565nm) and L” (1570…1610nm) transparency windows. Each band includes 80 channels with a step of 0.8 nm (100 GHz). Usually, only the “C” band is used, since the number of channels that can be organized in this band is more than enough, besides, the attenuation in the G.652 standard fiber in the C-band is somewhat lower than in the L-band.

- high-density WDM (HighDenseWDM - HDWDM) systems, allowing multiplexing of at least 64 channels.

Figure 2.3 shows the frequency range used in the WDM system.

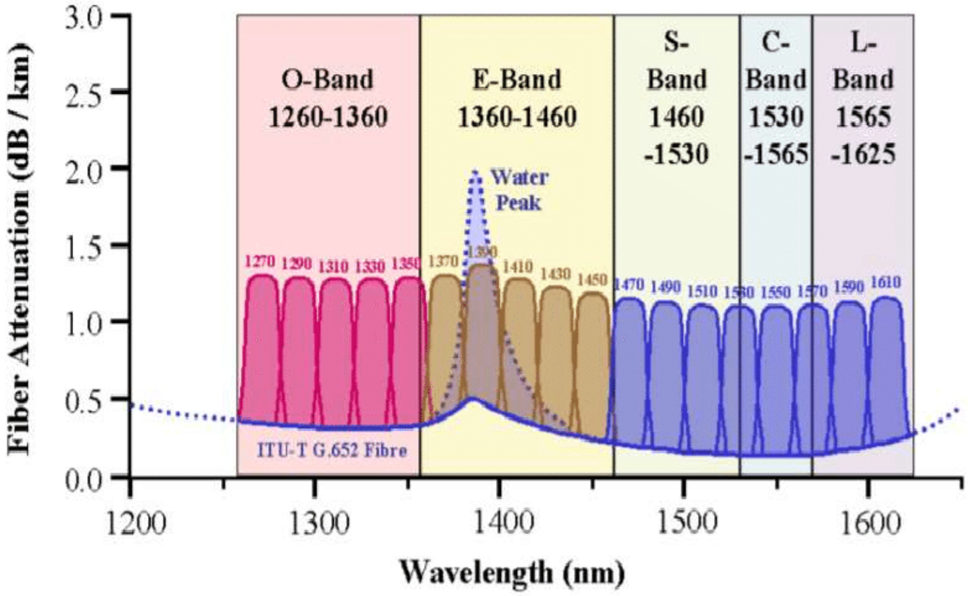


Figure 2.3. The frequency range of the WDM system.

Possibility of conduction of many signals over fiber happens just as the light visible to the human eye consists of various colors into which it can be decomposed and then reassembled, so the light flux transmitted using DWDM technology include different wavelengths (λ). Figure 2.4 shows a schematic example of the passage of different wavelengths in one fiber.

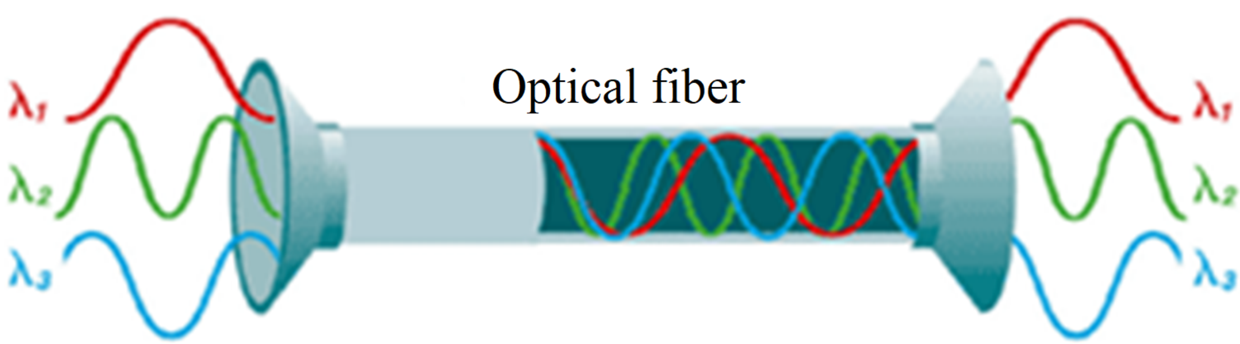


Figure 2.4. An example of the passage of different wavelengths in one fiber

An example of the process of combining / separating various optical signals is shown in Figure 2.5.

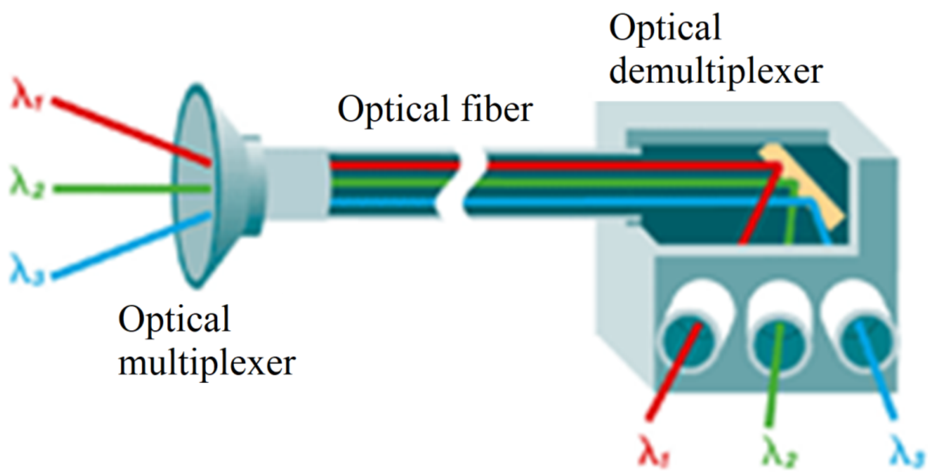


Figure 2.5. The process of combining / extracting optical signals.

Figure 2.6 shows a simplified diagram of a WDM system.

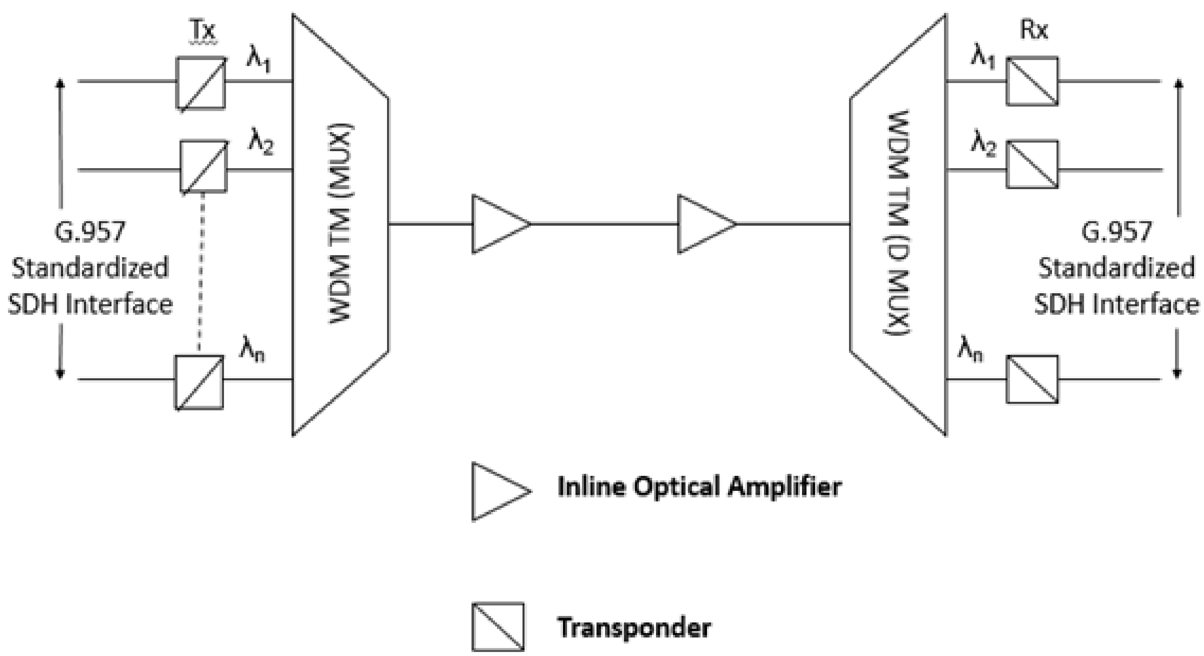


Figure 2.6. Simplified system diagram with WDM

2.3 Advantages and disadvantages of DWDM technology

The main advantage of DWDM technology is that it allows you to overcome the limitations on the channel bandwidth and significantly increase the data transfer rate. Moreover, an already laid FO cable and standard time multiplexing equipment are used, and it is not required to increase the transmission rate over a separate channel to 10 Gbit / s and higher.

The latest technological advances contribute to the spread of DWDM: the creation of narrow-band semiconductor lasers with an emission spectrum width of less than 0.1 nm, broadband optical amplifiers and optical filters for separating close channels.

WDM technology is a universal solution to the problem of increasing throughput.

Speaking about the economic side, the introduction of DWDM in local networks is constrained by the high cost of the corresponding equipment, especially transmission devices, and the complexity of traffic switching. However, studies show that DWDM-based solutions can also be cost-effective in smaller networks. To do this, in particular, they should use inexpensive input / output multiplexers installed at the junction of local and core networks.

The factor of high hardware cost is even more significant for the implementation of DWDM technology. When using close frequencies, narrow-band semiconductor lasers with high wavelength stability of the generated radiation are required, which are the most expensive element of DWDM systems, which hinders the spread of the latter.

Among the technical problems, one should mention significant signal power losses in multiplexers / demultiplexers, mismatch, in many cases, of the operating wavelengths of WDM equipment and time multiplexing devices, the need to increase the performance of switching nodes, the complexity of network management due to differences in data transmission technologies over multiplexed channels, lack of industry standards. Finally, not the last place in this list is occupied by nonlinear phenomena, which, when transmitted simultaneously on several carriers, can lead not only to signal attenuation and distortion, but also to its penetration into other channels.

2.4 Conclusions to chapter 2

In this chapter, the methods of increasing the bandwidth of optical fibers are analyzed and it is established that the method based on the application of the spectral compression method is particularly promising. The peculiarities of this method were analyzed and used for the subsequent design of a FO computer network.

CHAPTER 3
TECHNICAL IMPLEMENTATION OF OPTICAL FIBER COMPUTER NETWORK

3.1 Methods of laying an optical cable

Currently, there are several types of optical cable laying. They differ in the conditions and methods of laying, in addition, a special type of cable is used for each type of laying.

Here are the main types of optical cable laying:

- laying optical cable indoors;
- laying of an optical cable in the sewer;
- laying the optical cable in the ground;
- laying of an optical cable over the air (air-cable transition).

Let's dwell on each method of laying the cable in more detail.

A lighter optical cable for internal laying, or the so-called universal cable, is used to lay an optical cable indoors. Such cable example shows by Figure 3.1. The cable of imported production, such as Teldor or Hyperline, is mainly used. Such a cable can be 3-5 times more expensive than cables for external street laying. However, it is quite light, soft and does not cause special difficulties when laying. The complexity of laying such a cable is comparable to laying a twisted pair. However, due to the fact that this cable is less protected, it can be damaged quite easily. Therefore, greater accuracy and attentiveness of installers is required when working with it.

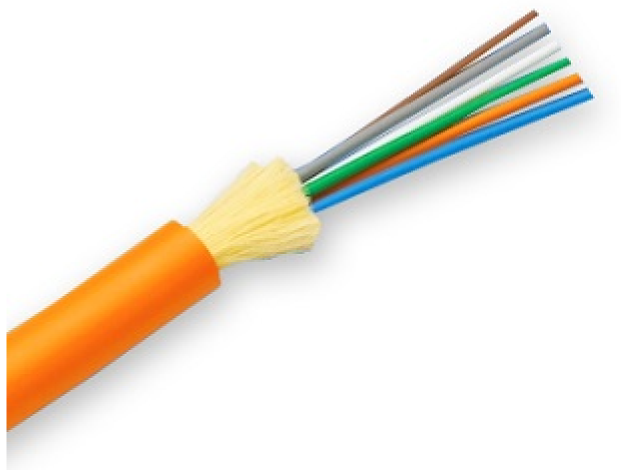


Figure 3.1. Optical cable for laying indoors.

As a rule, laying the cable indoors does not present any difficulties. In general, the laying is carried out along the existing communications, but in some cases the installation of additional cable channels is required. Indoors, the cable can be laid:

• in an existing or specially mounted plastic box. In this case, the box is attached to the walls;

• in special metal trays or cable channels;

• in cable risers;

• on a suspended cable, as a rule in attics, basements and technical floors.

The cable used for laying in the sewer is heavier and protected. Its design includes additional protective and power elements, such as a central power element, an additional plastic shell, Kevlar fibers, corrugated steel tape and hydrophobic filling. All these elements are designed to protect the cable from the effects of an aggressive external environment. Such cable appearance of is shown in Figure 3.2.

Figure 3.2. Appearance of an optical cable for laying in the sewer.

When laying a cable in the ground, as well as in the case of laying a cable in a sewer, a special, more protected cable is used. A cable for laying in the ground, in addition to those elements that contain a cable for laying in the sewer, armoring with a steel wire and a metal central power element are added. Here, more attention is paid to protecting the cable from rodents and soil shrinkage.

A special suspension cable with an external power element (rope) or a self-supporting cable (rope inside) is used for aerial suspension of FO cable. The appearance of such a cable is presented in Figure 3.4.

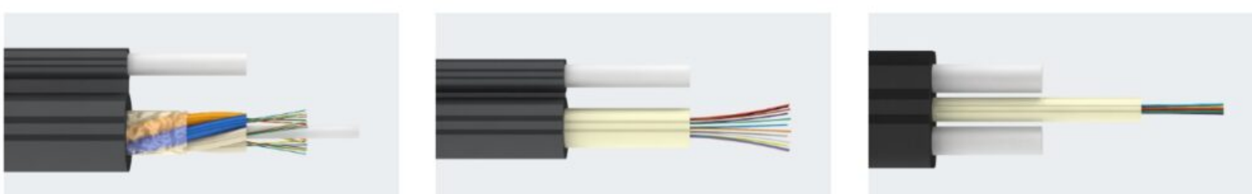


Figure 3.3. Appearance of a suspended cable

3.2 Analysis and selection of DWDM equipment

For trunk networks, cables with wavelength 1.55 μm are of interest, allowing to implement regeneration sections up to 170 km long. Given that the maximum distance between populated areas is 125 km, it is necessary to choose a cable with such parameters that it would be possible to do without expensive unmaintained regeneration points.

We choose the following type of cable manufactured by "Siemens":

A D F (ZN) 2Y 4×24 E 9/125 0.36 F 3.5+0.24 H 18LG. We will give the decoding of the letter and number symbols:

A - linear cable;

D - multi-fiber module, filled;

F - hydrophobic filling;

ZN - non-metallic reinforcing element;

2Y - polyethylene shell;

4 - number of modules;

24 - the number of fibers in the module;

E – SM fiber;

9 - core diameter, μm;

125 - diameter of the shell, μm;

0.36 - attenuation coefficient at a wavelength of 1.55 μm, dB/km;

F - wavelength 1.3 μm;

3.5 - specific chromatic dispersion coefficient at a wavelength of 1.3 μm;

0.24 – attenuation coefficient, dB/km, at a wavelength of 1.55 μm;

H - wavelength 1.55 μm;

18 - specific chromatic dispersion, at a wavelength of 1.55 μm;

LG - swaddle twist;

One of the most promising companies in the production of DWDM is Huawei Technologies Co., Ltd.

Huawei Technologies offers a wide selection of equipment and network solutions. These are C&C08 digital switching systems, narrowband and broadband optical subscriber access networks with integration of SONET services, SDH/DWDM

Optix optical systems, GSM/GPRS mobile communication equipment, broadband equipment for ATM/IP/MPLS networks, data transmission and Internet access equipment Quidway series, Tellin intellectual networks, signaling and synchronization systems, videoconferencing and interactive television systems. Among the innovative developments is the U-SYS solution for the next-generation NGN network.

Another important company producing DWDM equipment is the European company Alcatel–Lucent, which supplies communication solutions that allow telecommunications operators, service providers and corporate users to support services related to voice, data and video transmission.

Alcatel-Lucent's activity in the global telecommunications market is carried out today in three main segments, through three business groups of the company: Fixed Communications Group (a group of fixed communication systems), Mobile Communication Group (a group of mobile communication systems) and Private Communication Group (a group of corporate communication systems).

Cisco Systems is a world leader in the field of network technologies that change the way people communicate, communicate and work together. The company's activity is focused on five main technological directions: highway routing, switching and services; solutions for joint work; virtualization of data processing centers and cloud computing; video technologies; architecture for business transformation.

3.3 Selection of DWDM equipment

Today, there are many solutions for the organization of trunk networks. A large number of foreign companies provide such an opportunity.

Today, three manufacturers of DWDM equipment are the most competitive. Let's consider the general characteristics of the parameters of each of them and make a choice in favor of the most suitable one.

OptiX OSN 8800 is one of the most powerful trunk nodes of HuaweiTechnologies. Basically, it is used in trunk networks (for example, television broadcasting networks, networks of electric supply companies), regional and regional trunk networks, central nodes of the urban network. In addition to high capacity and the ability to transmit WDM signals over long distances, the system includes the functions of a reconfigurable optical input/output multiplexer (ROADM), the possibility of T-bit cross-switching, full cross-switching in the range from 100M to 40G/100G, the possibility of 40G/100G transmission and many protection and control functions. With such capabilities, OptiX OSN 8800 provides users with a comprehensive OTN/WDM backbone solution for multi-service, high-performance, and fully transparent transmission. The appearance of OptiX OSN 8800 is presented in Figure 3.4.

Figure 3.4. Appearance of OptiX OSN 8800

OptiX OSN 8800 supports cross-connections of optical and electrical type, which allows you to implement switching at the level of optical channels and at the level of individual spectral subchannels, allows you to quickly introduce services, thereby reducing capital costs (CAPEX). It is possible to make the topology of the network more flat, which facilitates planning, commissioning and expansion of the network. This shortens the terms of service provision.

OptiX OSN 8800 can allocate bandwidth on request, which also guarantees high efficiency of bandwidth usage. The architecture with the separation of the tributary and linear part increases the return on investment and reduces the need for spare parts

40G technology has been successfully used in commercial networks. Huawei has experience in 40G projects in the USA, Europe and the Asia-Pacific region. OptiX OSN 8800 has good compatibility of 100G and 10G/40G transmission systems, and guarantees a smooth transition from 10G/40G to 100G.

ASON technology on both levels, optical and electrical, for the first time in the industry, a synergy model of optical and electrical transmission is used, reliability up to 99.999% is ensured.

The use of integrated optics technology achieves a high degree of equipment integration. Dozens of optical components are placed on one chip and implement 12x10G transmission. Thanks to the high degree of integration, the OptiX OSN 8800 takes up 80% less space, the commissioning time is reduced by 50%, and the design process is radically simplified.

OptiX OSN 8800 cards can work in different modes. Thanks to this, it is possible to flexibly configure services, easily design, expand and maintain the network. The need for spare parts is significantly reduced.

Without the use of regenerator stations (REG), OptiX OSN 8800 can transmit 10 Gbit/s signals over a separate spectral channel over a distance of 5,000 km, 40 Gbit/s signals over a distance of 2,000 km, and 100 Gbit/s signals over a distance of 2,000 km.

Lambda Xtreme Transport is a next-generation DWDM optical network solution from Alcatel-Lucent, which implements a unique combination on one platform: ultra-high capacity up to 2.56 Tbit/s and ultra-high range — up to 4,000 km without electrical signal regeneration.

The Lambda Xtrem Transport platform, developed for use in regional and high-density highway networks, uses common amplifiers, controller units and control systems. The choice of the desired configuration — long-range (LH), ultra-long-range (ULH) or high-capacity (UHC) — is carried out by choosing the appropriate transponders that support speeds of 2.5 Gbit/s, 10 Gbit/s or 40 Gbit/s on the client side.

By seamlessly integrating various hardware — a high-capacity optical I/O multiplexer, a Lambda Router All Optical Switch, and a next-generation 10/40 Gbit/s Lucent Lambda Unite Multi Service Switch — the Lambda Xtreme Transport platform provides a complete set of solutions that support control and control at the wavelength level.

Lambda Xtreme Transport works in the Ultra Band range (extended L-band only). Because at the same time, unlike multi-band C+L systems, adders and splitters are not used, the system is characterized by smaller dimensions, ease of expansion and management, which in total reduces overall system costs. The modular and scalable design allows modernization and expansion without interruption of service.

When creating the Lambda Xtreme Transport platform, advanced technologies developed in Bell Laboratories were used, including combination (Raman) amplifiers, soliton transmission systems, dynamic channel stabilization, and automatic power stabilization.

System management is carried out with the help of Navis optical network management complexes.

The high-capacity optical input-output multiplexer HC-OADM supports remote parameterization, which simplifies the implementation of "hot" modernization and changes in the network topology.

The joint use of long-range and ultra-long-range transponders in one system is allowed, which reduces the cost of configurations in which in the ultra-long-range system (up to 4000 km) input/output of waves is performed on intermediate multiplexers HC-OADM.

For low-cost configurations and applications with concentrated losses (as in the case of optical cross-switches), close- and intermediate-range optics are supported on client interfaces, respectively.

In various configurations, Lambda Xtreme Transport can consist of a different number of racks - from 1 to 60. Automatic stabilization of power in the channel using dynamic filters and software adjustment of pump lasers and optical amplifiers when changing the number of channels is provided.

The well-known and well-established company Cisco also presented its product - ONS 15454 MSTP. The Cisco ONS 15454 MSTP is based on a proven platform

Cisco presented the first solution for building multi-service optical networks that provide effective provision of not only traditional services based on SONET/SDH at speeds from 2 Mbit/s to 10 Gbit/s, but also new services based on Ethernet, IP and SAN. The appearance of this equipment is presented in Figure 3.5.

Figure 3.5. Appearance of the ONS 15454 MSTP equipment

To meet the ever-changing requirements of telecommunications operators and corporate customers, the platform provides a wide range of unique functions and features:

• configurable speed and type of client interfaces. For example, 10 Gbit/s transponders allow clients to programmatically select the switching speed of client equipment (STM-64, 10GE WAN, 10GE LAN PHY);

• support for a wide range of client interfaces - from 100 Mbit/s to 10 Gbit/c with the possibility of switching to 40 Gbit/c channels;

• full integration of MSPP (services based on TDM, L2 transport and transport for data storage networks) and MSTP (provision of transparent optical channels and intelligent optical transport) in one platform;

• full transparency for SDH equipment in the case of using multiplexing transponders, which allows providing transport services of optical channels in combination with multiplexing;

• management of optical channels by means of G.709 GCC, which allows operators to provide and control SLA (Service Level Agreement) for each provided service;

•certification of the platform by manufacturers of data storage systems (SAN). This is a mandatory requirement for using equipment in SAN networks.

Cisco ONS 15454 MSTP equipment provides the ability to adjust the wavelength (selection of an optical channel) on all optical transponders. Reconfigurable optical multiplexers (R-OADM) allow you to minimize the list of used devices and modules.

The platform of this equipment is universal, hence the possibility of installing any modules in any. R-OADM allows you to use modules of the same type in all nodes of the network.

Transponder cards with integrated multiplexing of data and TDM traffic allow you to optimize the use of optical channels in the system.

"Plug and play" architecture for modules, allowing maximum flexibility to configure and modernize network elements: terminal nodes, optical nodes, linear amplifiers and dispersion compensation nodes in networks with or without optical amplification.

Automatic balancing and power control for each optical channel make it possible to build "self-healing" networks.

Fully automatic power control on all optical amplifiers (reliability combined with automatic gain control to quickly compensate for changes associated with adding, removing or switching channels, as well as changes in optical fiber characteristics caused by aging and environmental changes).

After conducting a detailed analysis of the properties of the DWDM trunk equipment of various companies, taking into account economic, quality indicators, authority, I made a choice in favor of the Cisco ONS 15454 MSTP equipment.

3.4 Control system selection

Such system is a critically important component necessary to maintain modern communication networks in working condition.

To succeed in a competitive environment, it is necessary to quickly allocate resources for services to provide these services on demand. In addition, preventive support is necessary to prevent failures and achieve system availability at the level of 99.99999%. These goals cannot be achieved without reliable network management tools that can monitor and log all activities that can affect network performance.

Cisco Transport Manager (CTM) is a key product for managing optical networks. CTM is the most functional optical transport network management system. STM provides service personnel and network administrators with easy and convenient access to the richest range of capabilities of the Cisco Optical Networking System (ONS) 15000 series of products.

With built-in support for SONET, SDH, DWDM, as well as IP and Ethernet technologies, STM is a truly integrated management system for optical transport networks, fully focused on multi-service optical networks. The use of products of the Cisco ONS 15000 series and STM as a system leads to a reduction in initial and operating costs.

STM was designed to ensure the highest reliability. Network support and management is a constant process of information accumulation, its storage and processing. STM is designed for uninterrupted operation and constant solution of all management tasks, fully coping with the maximum number of network elements (NE) and client workstations, even in cases of powerful alarm flows.

STM is based on industry-standard platforms such as SUN Solaris, Oracle 8 and Microsoft Windows, which are widely used in the modern Internet industry. STM allows operators to maintain a relatively low cost of hardware and software components necessary for ego operation, as well as to use specialists of a wide profile who know the technologies necessary for ego support.

STM provides extensive capabilities in such areas as inventory, configuration, problem management, performance monitoring, and security management. However, the development of STM did not stop there, and new functions and support for new devices are integrated into it.

The STM client's graphical interface provides operators with the richest set of functions without which optical network management is unthinkable. Components such as Domain Explorer, Sub-Network Explorer and NE Explorer provide easy navigation within the management domain.

Using Domain Explorer, the administrator can divide the management domain into groups of network elements.

Separate groups can then be delegated to different operators. NE Explorer graphically displays a network element, rack, shelf or module, allowing the operator to delve into the parameters describing the configuration of the module or its interface.

STM automatically recognizes chassis and modules installed in network elements. At the same time, it supports their database, constantly checking it with the real state of the device.

Remote file management functions provide significant advantages, especially on large networks. These are functions of remote backup and restoration of configurations of network elements and remote software download. At a specific moment, all these functions can be performed both with a separate device and with a group. Checking the compliance of the provided services with the agreements requires regular collection of information about all transmission parameters.

STM supports up to 500 user records. Each of the users can belong to one of three access levels: Administrator, Provisioner or Operator. To ensure the integrity of the authentication system, STM allows you to set the age of passwords, the time of inactivity of the connection, and also block individual accounts. In addition, the Administrator can terminate the connection of any operator. The logging system allows monitoring the operator's actions and, thus, determining whether his actions pose a threat to network performance.

Cisco Info Center (CIC) is a distributed monitoring system that is part of the Cisco Internet OSS portfolio. Working at the service and network levels, CIC closely interacts with other tools and supports customer-oriented monitoring and network separation for services.

Cisco enhancements include configurable mediators of network element managers, advanced automation tools, ready solutions for integration with other Cisco products, and much more.

CIC simplifies work with the help of automation and integration in a single environment of alarm signals and event data coming from devices based on different technologies and supplied by different manufacturers. The main advantages of solutions based on Cisco Info Center include:

• the well-tuned CIC event correlation mechanism allows operators to interpret data and configure actions for automatic response to certain events;

• CIC supports tools from different manufacturers based on different technologies. CIC does not depend on the technology of network elements, which allows creating a full-scale centralized failure management center;

• service-level monitoring simplifies the service monitoring process, allowing providers to monitor services based on multiple technologies and resources.

The flexible definition of sections and event filters in CIC allows telecommunications operators to monitor the state of services based on multiple technologies and resources. Thus, service monitoring includes monitoring of all network elements that make up this service. Operators can use CIC to create abstract views and provide subscribers with service status data. At the same time, the data will be provided to each customer in a standard form in accordance with the definition of the service. This function simplifies the monitoring of services provided to customers.

Close CIC integration and CTM allows you to build a complete solution for monitoring and managing the optical network.

The composition of the trunk node previously included:

• ONS 15454E MSPP chassis - a single platform supporting both DWDM and SDH (SONET) technologies. It is used at all levels of the multiservice optical network. Figure 3.6 shows a schematic view of the CiscoONS 15454E MSPP basket. The modular design allows you to implement different functionality by simply adding new cards. New functions and services are easily added and integrated with existing ones, which makes it easy to develop and modernize the network. It should also be noted that all nodes have a single control. The chassis has 17 slots, of which 12 are universal and support various types of optical modules.

• TCC2 – synchronization, communications and control card. The appearance of this module is shown in Figure 3.7. TCC2 performs the role of the central processor of the system, provides system initialization, control, alarm indication, as well as control of the power supply and system status. To ensure redundancy, 2 TCC2 cards are installed in the system. The TCC2 card has an internal synchronization source (Stratum 3). It is possible to synchronize the system from an external source of internal synchronization or from an SDH optical signal.

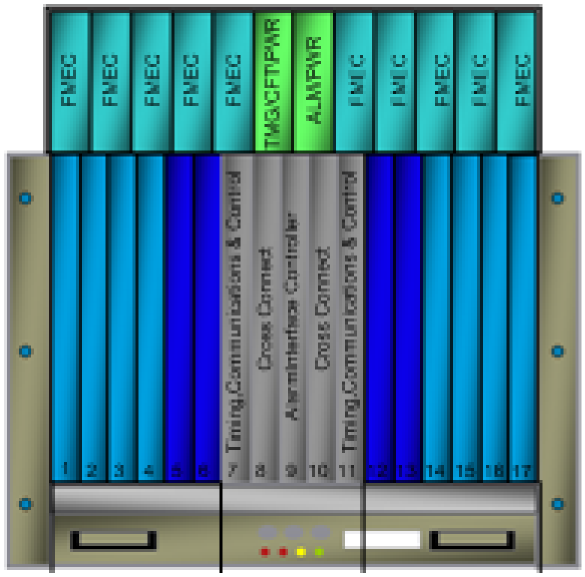


Figure 3.6. CiscoONS 15454E MSPP Chassis Appearance

Figure 3.7. TCC2 – card of synchronization, communications and control

• OSC – an optical service channel card. The appearance of the OSC optical module is presented in Figure 3.8. The service channel provides the following functions:

- supervisory data channel (SDC) for exchanging information between nodes in the network;

- propagation of the synchronization signal;

- user data channel – 100 Mbit/s.

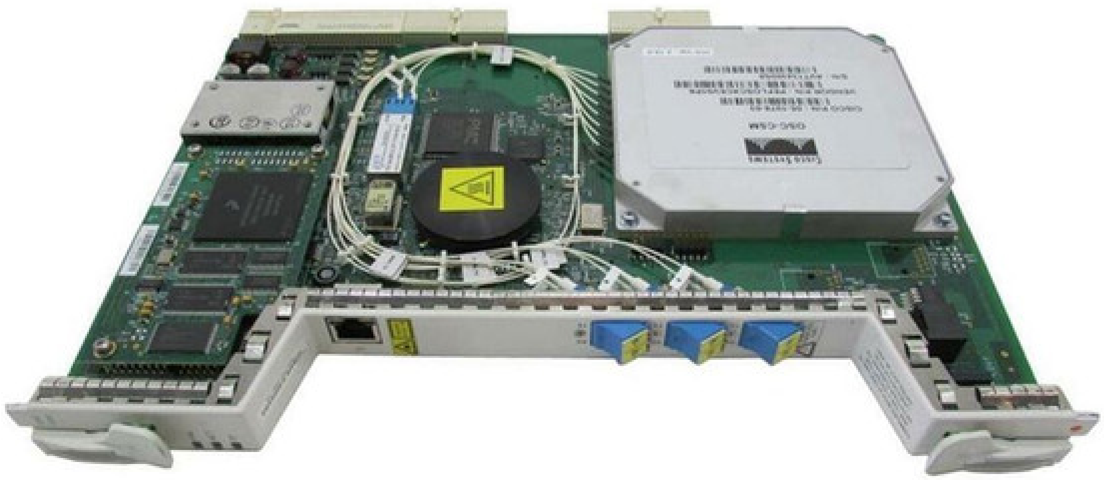


Figure 3.8. OSC map

• AIC-I (slot 9) – an alarm controller card, allows you to monitor the status of equipment by monitoring events at remote nodes. The appearance of the module is presented in Figure 3.9. The card has the following functionality:

- the ability to manage external contacts;

- organization of user data channels;

- organization of the service communication channel.

Figure 3.9. AIC-I – alarm controller card

- XC-VXC-10G – optical switching module. It provides a wide range of processing, aggregation and transport of low-speed and high-speed traffic over optical networks. The appearance of the XC-VXC-10G module is presented in Figure 3.10.

Other modules are added to the chassis as needed, to organize new traffic flows or expand the network.

Figure 3.10. XC-VXC-10G – Optical switching module

Using the specified equipment, it becomes possible to implement a high-speed optical fiber computer network with the possibility of connecting several dozen computers and additional equipment, depending on the subtypes of the selected equipment.

3.5 Conclusions to chapter 3

The technical side of designing a FO computer network is considered in the section. At the same time, the methods of laying optical fiber cables were considered, the type of cable for network implementation was selected, as well as the necessary equipment was selected, which implements the method of spectral compression of channels.

Using the specified equipment, it becomes possible to implement a high-speed optical fiber computer network with the possibility of connecting several dozen computers and additional equipment, depending on the subtypes of the selected equipment.

CHAPTER 4
LIFE SAFETY, BASICS OF LABOR PROTECTION

4.1 Electric current as a factor of danger

Electric injuries occur when a person is exposed to voltage as a result of touching elements of an electrical installation with different potentials, or the potential of which differs from the potential of the ground, as a result of the formation of an electric arc between the elements of the electrical installation directly, or between the electrical installation and a person who has contact with the ground, as well as in as a result of the step voltage.

Electrotraumatism as a social category is characterized by a set of electric injuries over a certain period of time, their absolute and relative indicators, distribution by severity, industries, etc.

As previously mentioned, electrical injuries account for about 1% of the total industrial injuries, and about 15-20% of fatal injuries. The latter indicates a shift in the type of electrotrauma towards severe ones, which is one of the features of electrotraumatism.

The peculiarity of electrotraumatism is that up to 70-80% of electrocutions with fatal consequences occur at electrical installations with a voltage of up to 1 kV, and up to 20-30% at electrical installations with a voltage of more than 1 kV.

The above distribution of electric injuries by the voltage of electrical installations is determined not only by the greater prevalence of electrical installations with a voltage of up to 1 kV, but to a greater extent, also by the fact that such installations are available to a larger number of workers who have insufficiently clear ideas about the dangers of electric current and safety requirements when operating electrical installations.

Installations with a voltage of more than 1 kV can be accessed by a limited number of employees who must have a sufficient level of electrical safety training in accordance with the requirements of the current standards of the electrical safety group.

In addition to the above, in comparison with other types of traumatism, electrotraumatism is characterized by the following features:

- a person is unable to remotely, without special devices, determine the presence of voltage, and therefore the action of the current is usually sudden, and the body's protective reaction is manifested only after exposure to voltage;

- the current flowing through the human body acts on tissues and organs not only in the places of contact with current-carrying parts and on the path of flow, but also reflexively, as an extremely strong stimulus, affects the entire body, which can lead to a malfunction of vital systems body — nervous, cardiovascular systems, breathing;

- electric injuries are possible without a person touching the current-carrying parts — as a result of the formation of an electric arc when the air gap between the current-carrying parts or between the current-carrying parts and a person or the ground is broken;

- investigation, recording and analysis are mainly available for severe electric injuries and electric injuries with fatal consequences, which negatively affects the prevention of electric injuries.

The path of the current through the human body significantly affects the result of the lesion. The danger of damage is especially great if the current, passing through vital organs - the heart, lungs, brain - acts directly on these organs. If the current does not pass through these organs, then its effect on them is only reflex and the probability of damage is less. The most common current path through a person, the so-called "current loop", has been established. In most cases, the current through a person flows in the direction of the right arm - legs. However, the loss of working capacity for more than three working days is caused by the flow of current along the path of hand - hand - 40%, the current path of right hand - legs - 20%, left hand - legs - 17%, the rest of the paths are less common.

General electric injuries or electric shocks are a violation of the activity of vital organs or the entire human body as a result of the excitation of living tissues of the body by electric current, which is accompanied by involuntary convulsive contraction of muscles. The result of the negative effect on the body of this phenomenon can be different: from convulsive contraction of individual muscles to complete cessation of breathing and blood circulation. At the same time, there may be no external local damage.

Depending on the consequences of the damage, four groups of electric shocks are distinguished:

And - convulsive muscle contractions without loss of consciousness;

II- convulsive muscle contractions with loss of consciousness without breathing and blood circulation disorders;

III - loss of consciousness with impaired cardiac activity or

breathing or heart activity and breathing together;

IV - clinical death, i.e. lack of breathing and blood circulation.

Clinical death is a transitional state from life to death. IN

in the state of clinical death, there is no blood circulation and breathing, the human body is not supplied with oxygen. Signs of clinical death: lack of pulse and breathing, bluish-pale skin, pupils of the eyes are sharply dilated and do not react to light.

During the operation of the pulsed power supply unit, a dangerous voltage of 220V is used, which can lead to electric shock and injury to people, so it is necessary to take into account the features of electrocution when designing and operating the power supply unit.

4.2 Fire safety requirements for extinguishing electrical installations

Certain requirements should be observed when extinguishing fires at electrical installations.

As fire-extinguishing substances when extinguishing fires in live electrical installations, it is advisable to use compact and sprayed jets of water, gas fire-extinguishing substances - inert thinners (based on inert gases), fire-extinguishing powder.

It is prohibited to use all types of foam when extinguishing fires on live electrical installations by manual means with the participation of people.

During a fire in the research laboratory, the first person who discovered the fire must immediately call the fire brigade, the station shift chief (on-duty or station dispatcher), and the senior shift officer and start extinguishing the fire with the available fire extinguishing means, observing the safety rules.

Before the arrival of the fire brigade, the chief must perform the following tasks personally or with the involvement of personnel:

- determine the location of the source of the fire, assess the fire situation, predict the spread of the fire and the possibility of the formation of new sources of combustion on other electrical equipment;
- start fire extinguishing and cooling of building structures with the forces and means of the research laboratory;
- if possible, remove the voltage from the burning installation or electrical equipment adjacent to it, if this does not cause more serious consequences;
- check the activation of the automatic fire extinguishing system, and in case of failure - activate it in manual mode;
- organize a meeting of fire departments and determine the grounding of fire equipment and the location of fire hydrants;

- to inform the departmental fire protection about safe routes for firefighters to go to combat positions.

Fire (ignition) in electrical installations under voltage is eliminated by the personnel of the research laboratory with the help of portable and mobile fire extinguishers: powder - at a voltage of up to 1.0 kV, carbon dioxide - at a voltage of up to 10 kV.

The distance from the nozzle (bell) of the fire extinguisher to the current-conducting parts of electrical installations cannot be less than 1 m. The use of foam fire extinguishers is not allowed.

Extinguishing fires in premises on electrical installations under a voltage of up to 10 kV with all types of foam using manual means is prohibited, as foam and the solution of the foaming agent have increased electrical conductivity compared to sprayed water.

Water from water supply networks, as well as from natural and artificial reservoirs, can be used to extinguish fires in live electrical installations.

The developed power supply unit works from a 220V network, so there is a possibility of its catching fire due to a malfunction. In case of fire, the power supply unit must be extinguished with a powder fire extinguisher OP-1, which is located on the fire panel in the research laboratory.

CONCLUSIONS

In the qualifying work, the development of FO computer network based on spectral compression of channels was carried out.

An analysis of the principles of the work of FO data transmission lines was carried out. The main elements, from which such lines are formed, are analyzed. Also, the advantages and shortcomings of FO communication lines were analyzed and it was established that these lines have the best characteristics in paired with other methods of data transmission. However, it is important to ensure the high capacity and richness of such lines.

The methods of increasing the bandwidth of optical fibers are analyzed and it is established that the method based on the application of the spectral compression method is particularly promising. The peculiarities of this method were analyzed and used for the subsequent design of a FO computer network.

The technical side of designing a FO computer network is considered in the section. At the same time, the methods of laying optical fiber cables were considered, the type of cable for network implementation was selected, as well as the necessary equipment was selected, which implements the method of spectral compression of channels.

Using the specified equipment, it becomes possible to implement a high-speed optical fiber computer network with the possibility of connecting several dozen computers and additional equipment, depending on the subtypes of the selected equipment.

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