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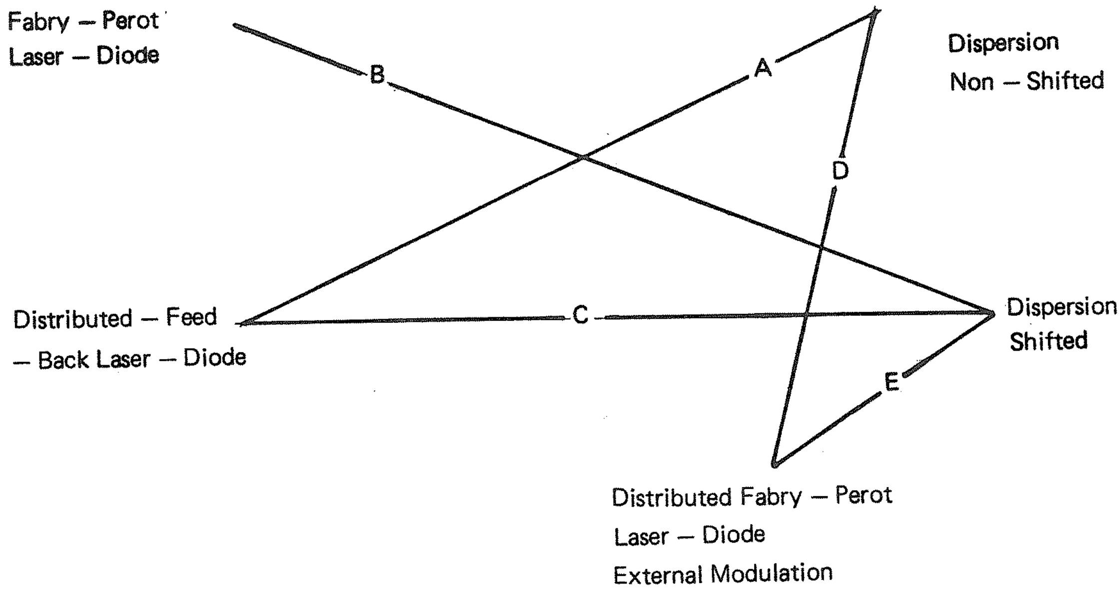
Table 2, Five possible Design Options in 1550 mm Wavelength Itnestity Modulation and Direct Detection Systems.



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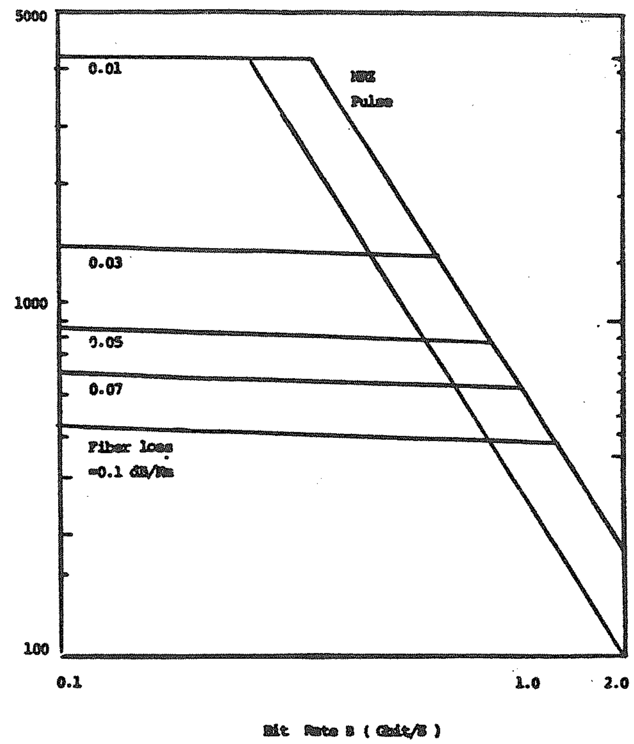

Fig 4. Transmission Distance vs. Bit Rate

Stage	Repeater Spacing km	Wave length m	Optical Fiber				Light Source				Bit Rate		Application
			Multi mode	Signal Mode: Zero Disperion 1.3μ	Signal Mode: Zero Disperion 1.55μ	Signal Mode: Polari zation	LED	LD	DFB	Frequency Stabilization	Gb/S		
I	10	85		O			⟶	⟶			O		short haul
II	50	1.3		O			⟶	⟶	⟶		O	O	Long haul
III	100	1.55			O		⟶	⟶	⟶		O		Long-haul Submarine
IV	100	1.55			O		⟶	⟶	⟶			O	Large Capacity
V	500	1.55		O	O	O			⟶	⟶	O	O	Very — large capacity
VI	5000	2-10		Fluoride Fiber						O	O	O	Non-repeatere Submarine

Table 1. Stages of development of Optical fiber systems

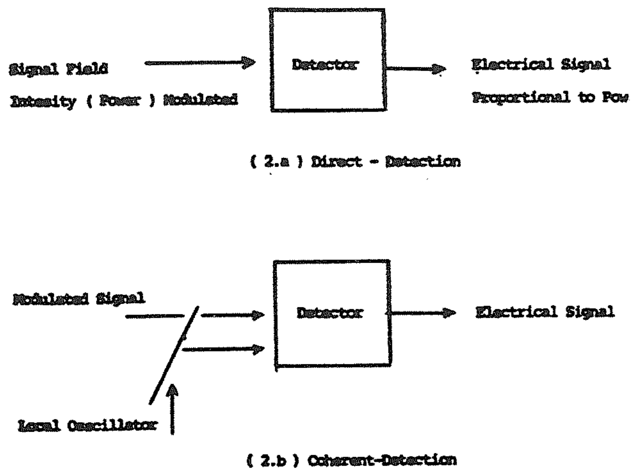

Fig. 2. Direct and Coherent Detection

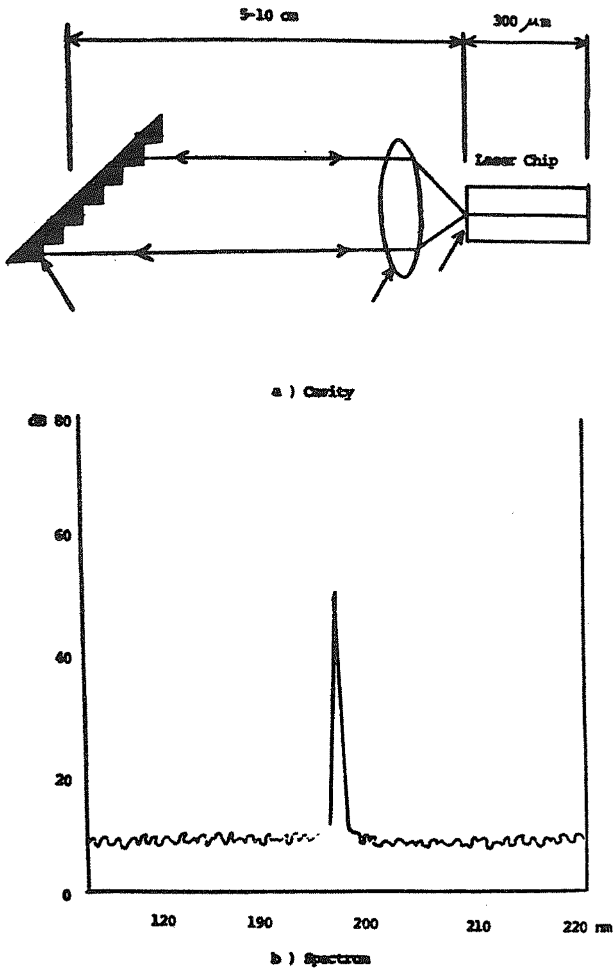

Fig 3. External cavity laser with measured spectrum

ssary, in order to have it commercially available.

As this moment it seems to be quite difficult to predict the possibility of this fiber being installed in the sea until around 2000.

Fluoride glass fibers have a high potential application to long distance repeaterless communication systems. The systems would require fibers with extremely low loss and there now an extensive worldwide research programs to attemplt to explore loss mechanism in $Zr\,F_4$ based glasses and fibers [33] They will examine both intrinsic and extrinsic losses and compare the losses in fibers that are currently being fabricated by several laborateries through the world [64]. Minimum attenuation in $Zr\,F_4$ is predicted to be around 10^{-3} dB/km at 3.44 μm [33].

In addition, new optical windows for ultra – low loss flouride fiber applications appears 2–10 μ m [34 – 43].

D. Systems Considerations:

The fluoride fiber dispersion is estimated to be around 18 PS/nm. km. Fig 4 shows the transmission distance as a function of transmission speed in case that input power of mv, receiver sensitivity – 38 dBm external modulation, 18.4 PS/km. nm. Future repeater – less optical transmission system of 4000 km and 400 Mbit/S is projected to be realized if fiber of 0.01 dB/km loss, external modulator, and 1. 6 – 8 mw input power are used [65].

V. Conclusion

In the development of the optical fiber systems, it is very important to know the future trends in optical fiber technologies as discussed in this paper.

New optical fiber systems as high speed systems, coherent systems, optical amplifiers and ultra – low loss fluoride glass fiber were described.

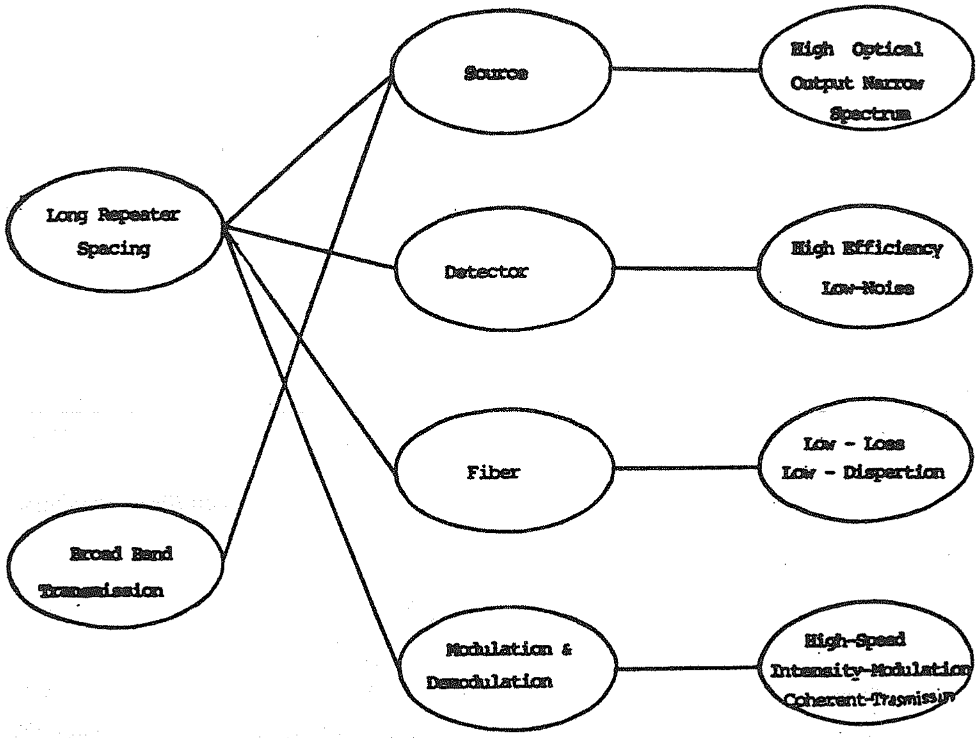

Fig. 1. Major areas of technology for advanced optical fiber.

spectral linewidth. Therefore, the spectral linewidth can only be narrowed by the other additional technique, for example, external cavity or injection locking to a master laser. As an example of that can be seen in Fig. 3[56].

3)Polarization Control Techniques

In order to improve the efficiency of heterodvene and homodyne detection, we must match the state of the polarization of the signal & the local oscillator waves at the receiving end. The polarization states travelling along the conventional single – mode fibers are subject to disturbances, compensation of polarization fluctuation or alternatives are required before heterodyne or homodyne detection.

IV. Future Optical System Technologies

A. General

Requirements for long distance and high bit rate optical fiber systems will become more complex and of higher grade in future systems to fulfill the owner's demand and also to cope with the other transmission media.

The solution may be the "all optical network" which corporates the following technologies: direct optical amplifiers and / or fluoride glass fibers as transmission media; optical splitting / combining devices; a frequency division multiplexing scheme, & coherent transmission technologies.

All of these technologies will be highly advance [57, 58, 59, 60].

In order to realize this all optical network, coherent transmission scheme will be the key technology and optical amplifiers, If ultra – low loss fluoride glass fibers are to be realized, then the optical amplifires may be eliminated and simpler network will become possible.

B. Optical Amplifier Technology

Direct optical amplification technology is of great importance for future optical fiber communication.

The promising optical amplifiers are divided into the following groups.

1)Semiconductor Laser Amplifiers:

In these amplifiers, amplification is achieved through stimulated emission in semiconductor lasers biased just below the threshold.

A Promising type of semiconductor laser amplifier is a travelling wave – amplifier. It shows a wide gain bandwidth with a good stauration performance and a low sensitivity to input signal polarization. A fiber–fiber gian of 18 dB and 8 dB is obtained in a two – channel bidirectional transmission system operating at 565 Mbit / Sec [61].

2)Fiber Laser Amplifiers

Optical fiber lasers, consisting of a rare earth or transition – metal – doped special silica fiber, would also be good in – line amplifiers, which are easy to splice into a fiber system. One kind which has a maximum gain at 1.536 μ m wavelength has been reported [62].

3) Fiber Raman and Brillouin Amplifiers

Using some stimulated processes of nonlinear optical phonomena in optical fibers, namely stimulated Raman scattering or stimulated Brillouin scattering we can obtain good optical amplifiers called fiber Raman amplifiers of fiber Brillouin amplifiers. One example can provide a high gain in the order of 40 dB the required power for pump light sources is only several mw with linewidth of a few MHz [63].

C. Ultra – low loss Fluoride glass fiber technologies:

Fluoride glass fibers are quite attractive for transmission media especially in submarine cable systems because it may eliminate repeaters.

Fluoride fiber having loss expeated 0.0045 dB/ km at 4 μ m [46] has not been yet attained for enough length. Therefore breath – through technology nece–

[44, 45]. In future lower dispersion in the 1550 nm region will be developed. If the dispersion values in the 1550 nm region could be decreased to one – fifth of its present value, 100 Km repeater spacing using improved optical devices would be developed[17].

The lowest loss of silica fiber which was near the theoretical limit, was obtained in 1986. Fluoride optical fiber having a loss expected 0.0045 dB/Km at 4 μ m will become most important as a future trans–mission medium[46].

B. Coherent Optical Communication Systems:

Coherent transmission systems as shown in Fig. 2. b have several features compared with conventional intensity modulation and direct detection systems. It offers 10 – 20 dB higher detection sensitivity than intensity modulation and direct detection [47]. And it offers the possibility of frequency multiplexing by tunable lasers as optical sources and tunable detector as receivers in future [48].

Current optical fiber communication systems employ intensity modulation and direct detection technique which is called IM – DD. In this method, the optical source (a semiconductor laser) blinks on and off in response to "O" and "1" electrical signals at the transmitting end. At the receiving end, the intensity of this blinking light is detected by an optical detector, which generates a corresponding electrical data flow.

Another method, which does make the most of the characteristics of optical waves and holds great promise for the future, is the coherent optical communication method. Using coherent charac – teristics of the laser light, this method can adopt a lot of modulation / demodulation techniques (amplitude, frequency and phase modulation, heterodyne and homodyne detection etc.) as electrical communica – tions [49], in comparison with IM – DD, coherent optical communications technosingals [47].

Furthermore, this new method is expected to make it possible for repeaters to be spaced well over 200 Km apart [50]. Which is an important advantage for optical fiber systems. It is also expected to offer useful applications in large capacity transmission systems[51].

In the coherent optical communication method, the key technologies are as following:

1) Development of modulation/ demodulation techniques.
2) Stabilization of oscillating frequency and narro–wing spectral linewidth of a laser diode.
3) Dealing with polarization fluctuations in optical fibers.

1) Modulaton / Detection Technologies

In the coherent systems, three modulation techniques can be used basically. The first one is ASK (amplitude shift keying) technique. In this scheme, modulation can be achieved either by directly modulating the driving current of a laser diode or by the external modulator [52]. The second one is FSK (Frequency shift keying) technique [53, 54]. In this scheme, modulation can be easily achieved by direct current modulation of a laser. The third one is PSK (Phase shift keying) technique. PSK can be achieved by external modulator or by injection locking techni-que [55]. In demodulation stage, both synchronous and asynchronous detection can be used in any one of the above three types. Asynchronous detection is easier and more practical in the presence of phase noise of a laser diode[56].

2)Leser – Diode with low spectral Linewidth

The spectral linewidth of a semiconductor laser under current conditions is not appropriate for use in coherent optical communication. However a laser chip has a cavity length of a few hundred microns, so that Q – value of the cavity is not large enough for the narrow reduction of spectral linewidth for cherent optical communication is still under investigation.[11, 12, 13]. Long – cavity laser diodes have spectral linewidth as low as a 20 KHz, may be practicable for ASK or FSK, heterodyne systems[14]. The other necessity in coherent communication system is tunability of lasing wavelength. Intense studies have been elaborated to realize ligth sources with wider – ranged and continous tuning using distributed feedback or distributed Bragg reflector lasers.[15].

High optical power output of a laser diode is also important factor to improve the system performance. Several device structures have been devised to reach high output level for Fabry – Perot and distributed feedback lasers[16, 17].

As for the detectors. In Ga As/InP pin photo–detector and APD have been developed for 1300 – 1500 mm wavelength range light wave system, instead of Ge–APD. Further improvement of detectable optical power by about 5 dB can be obtained with In Ga As APD/FET type which will have application around 10 G bit/S or more [18–24].

C. Impact on Today's Decisions:

Optical fiber cable systems have several superior features to the conventional coaxial cable systems[6] These features are low transmission loss, broad transmission bandwidth, and small cable diameter. Optical fiber system is also compatable with digital radio systems [25]. Due to rapid progress of optical fiber fabrication technology, extremely low transmission loss was achieved[29].

By the way, in the decisions of selecting optical fiber system or other conventional transmission system, it is very important to know the relation among the relative estimated costs under certain assumptions.

III. New Modulation and Detection Technologies

A. High Speed IM–DD Transmission Technologies:

The first transoceanic optical fiber submarine cable system with bit rate of 280 Mbit/Sec are going to be installed both in the Atlantic and Pacific Oceans in the end of 1988. In these system 1300 nm Fabry–Perot laser diodes and optical fibers with zero dispe–sion wavelength at 1300 nm are used. Repeater spacing are 50 – 60 Km [27,28].

As shown in table I, in second stage optical fiber systems, the repeater spacing and the transmission capacity have been increased compared to 1 St generation system. To attain more economical systems, the future wavelength regions is going to shift from 1300 nm to 1550 nm called third stage [29], where the minimum loss lies.

It has been shown [1], [9] that the use of Fabry Perot laser diode at 1550 nm provides 50 Mbit/Sec in the transmission distance over 100 Km in specific single mode system.

Hence, the dispersion shifted fibers, which shifts zero dispersion wavelength at the 1550 nm wavelength region and /or the lasers with distributed feedback laser are necessary to increase the loss limited bit rate-distance product[29].

Table 2 shows five possible design options of 1550 nm intensity modulation direct detection systems. Suitable combination of optical fiber and laser diode should be slected considering bit rates, state of the arts and commercialization period [30]. Options A or B are for small / medium capacity, options C or D are for large capacity and option E is usually used for very large capacity[31].

It was mentioned that the optimized operating wavelength in the 2 nd, 3 rd stages of optical fiber systems are 1300, 1550 respectively. We may say that the 1st stage which used 800 nm wavelength region will not be largely used any more. With Fluoride fiber systems 2 $\sim$10 μ m wavelength will be used [32–43].

The lowest loss of silica fiber appears in the 1550 nm region, while zero dispersion appears at 1300 nm

REVIEW

Future Trends In Optical Fiber Communications

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ABSTRACT

Future trends in optical fiber communication systems and telecommunication systems are investigated.

I. Introduction

This paper deals with future trends in optical fiber systems which are expected to play an important role in the world wide information oriented society.

Section II deals with current advanced optical technologies of optical sources and detectors. Section III provides new modulation & new detection systems such as high speed intensity modulation and direct detection & coherent optical communication systems. Section IV indicates future optical system techno– logies such as optical amplifiers and ultra–low loss flouride glass fiber. Section V devoted to conclu– sions.

Technological progress is still accelarating and this paper reviews the technology currently available and it's trend that can possibly be realized. The stages of the development of optical fiber system technolo– gies can be shown as Table 1. Systems of stage I was first generation and have been installed around 1984 and rarely is used now [1]. Systems of stage II are second generation which are now operational [2]. Systems of stage III will become to operation at 1988 [3]. Other stages are becoming future trends[4,5].

II.Advanced Optical Technologies

A. General:

The significance of applying fiber cable techno– logy to communication fields is in establishing several broadband services and in greatly reducing trans – mission cost by having longer repeater spacings and large – capacity [6]. The technology required for advanced optical systems is shown in Fig.1. [7].

At present, the technologies for direct modulation single – mode optical fibre cable, and transmission rate 450 Mbit/S with 40 Km repeater spacing have been achieved [7].

B. Optical Sources and Detectors:

Intensity modulation and direct detection is the basic principle of all present day fiber optic trans – mission and receive system[3].

A laser of LED source is intensity modulacted, by modulating the drive current, and a photocurrent is generated at the detector which is proportional to the received power[9]. As illustrated in Fig.2.a.

Meanwhile, for multi Gbit/Sec intensity modula– tion and direct detection transmission system, various kinds of external modulators have been studied. An electro – absorption type modulator integrated with a quarter – wave – shifted distributed feedback laser is one of the promising candidates [10]. Further