“RECENT PROGRESS IN FIBER-OPTIC COMMUNICATION”

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1. INTRODUCTION

1.1 What is fiber-optic communication?

The latest and most advanced mode of data communication which involves, transmitting information from one place to another by flashing/sending pulses of light through an optical fiber can be termed as fiber optic communication. The light (the media of transmission) forms an electromagnetic carrier wave, modulated according to the carrier needs.

The optical fibers have revolutionized the data comm. Industry by attaining higher data bit rate of communication speeds over 100 peta-bits per second using these modes of fiber optic communication only

(Fiber-Optic Communication flow diagram)

(Optical Fiber Construction)

1.2 Conclusion

The fiber is constituent of two layers selectively core and cladding (as depicted in figures), selected for the total internal reflection (the basic principle of fiber-optic communication).

Practical Fibers – Consists of cladding coated with a layer of acrylate polymer or polyimide.

Individual Coated Fibers – Fibers formed in ribbons and buffer bundles have a tough resin buffer layer or a core tube extended around them for protective sheathing.

Jacket Material

Material	Halogen-free	UV Resistance	Remark
LSFH Polymer	Yes	Good	Good for indoor use
Polyvinyl chloride (PVC)	No	Good	Being replaced by LSFH Polymer
Polyethylene (PE)	Yes	Poor	Good for outdoor applications
Polyurethane (PUR)	Yes	?	Highly flexible cables
Polybutylene terephthalate (PBT)	Yes	Fair?	Good for indoor use
Polyamide (PA)	Yes	Good Poor	Indoor and outdoor use

1.3 Capacity

September 2012, there was a demonstration by NTT JAPAN of a single fiber cable that was able to transfer 1 petabit per second (10^5 bits/second) over a distance ranging from 50-60 kilometers.

Optical fiber vs. copper: the choice is clear		
	Optical Fiber	Copper
Capex Cost (2,000-user optical LAN)	< \$300,000	> \$1,000,000
Lifecycle	30-50 years	5 years
Distance	12 miles	300 feet
Weight (per 1,000 ft.)	4 lbs.	39 lbs.
Energy Consumed	2 watts per user	more than 10 watts per user
Maximum Bandwidth	69 Tbps	10 Gbps
Security	Hard to tap, easy to alarm	Emits EMI

1.4 Propagation Speed and Delay

Propagation Speed – Speed of light in glass (slower than vacuum).

180,000 to 200,000 kilometers

Latency – 5.0 to 5.5 microseconds of latency per kilometer

Delay - For every 1000 kilometers round trip there can be a delay of 11 milliseconds

1.5 Safety

Infrared rays as used in this form of communication can damage the eyes, particularly in lens or micro-scopic inspection by technicians due to high power levels which are inadvertently radiating invisible IR.

There is also a possible change of slipping of glass clavers and fragments under the skin because of their minute and diminished size as compared to other equipment media.

So a high amount of care is needed while manufacturing and inspection of the optical fiber and the disposal of cleaving wastage should be ensured of collecting and disposing carefully.

Latest Development

Since the first announcement of low-loss fiber by Corning Glass Works in 1970, remarkable progress has been made in glass fibers for optical communication both in fabrication techniques and in fiber transmission characteristics. Various fabrication methods have been proposed and examined; the outside vapor-phase oxidation (OVPO) method, the modified chemical vapor deposition (MCVD) method, and the vapor-phase axial deposition (VAD) method, to name typical examples. These processes have enabled us to obtain graded-index multi-mode fibers with low loss and broad bandwidth, as well as low-loss single-mode fibers. In particular, the development of low transmission-loss fibers in the long-wavelength band opened up a new low-loss window in the wavelength bands of 1.3 μm and 1.55 μm .

This review paper describes recent progress in the fabrication methods and transmission characteristics of optical fibers, together with future trends and items for research in the field of optical communications.

2. Latest Development

Since the first announcement of low-loss fiber by Corning Glass Works in 1970, remarkable progress has been made in glass fibers for optical communication both in fabrication techniques and in fiber transmission characteristics. Various fabrication methods have been proposed and examined; the outside vapor-phase oxidation (OVPO) method, the modified chemical vapor deposition (MCVD) method, and the vapor-phase axial deposition (VAD) method, to name typical examples. These processes have enabled us to obtain graded-index multi-mode fibers with low loss and broad bandwidth, as well as low-loss single-mode fibers. In particular, the development of low transmission-loss fibers in the long-wavelength band opened up a new low-loss window in the wavelength bands of 1.3 μm and 1.55 μm .

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Non-Linear Effects in Optical Fibers

Major Nonlinear Effects

- Stimulated Raman Scattering (SRS)
- Stimulated Brillouin Scattering (SBS)
- Self-Phase Modulation (SPM)

- Cross-Phase Modulation (XPM)
- Four-Wave Mixing (FWM)

Stimulated Raman Scattering (SRS)

- Scattering of light from vibrating silica molecules
- Amorphous nature of silica turns vibrational state into band
- Raman gain spectrum extends over 40 THz or so.
- Raman gain is maximum near 13 THz.
- Scattered light red-shifted by 100 nm in the 1.5 μm region

SRS: Good or Bad?

- Raman gain introduces interchannel crosstalk in WDM systems.
- Crosstalk can be reduced by lowering channel powers but it limits the number of channels. On the other hand.
- Raman amplifiers are a boon for WDM systems.
- Can be used in the entire 1300–1650 nm range.
- Erbium-doped fiber amplifiers limited to ~ 40 nm.
- Distributed nature of amplification lowers noise.
- Likely to open new transmission bands.

Stimulated Brillouin Scattering (SBS)

- Scattering of light from acoustic waves.
- Becomes a stimulated process when input power exceeds a threshold level.
- Low threshold power for long fibers (~ 5 mW). Transmitted Reflected
- Most of the power reflected backward after SBS threshold is reached.

Self-Phase Modulation (SPM)

- Refractive index depends on optical intensity as
- Leads to nonlinear Phase shift
- An optical field modifies its own phase (SPM).
- Phase shift varies with time for pulses.
- Each optical pulse becomes chirped.
- As a pulse propagates along the fiber, its spectrum changes because of SPM.

SPM: Good or Bad?

- SPM-induced spectral broadening can degrade performance of a lightwave system.
- Modulation instability often enhances system noise.

On the positive side . . .

- Modulation instability can be used to produce ultrashort pulses at high repetition rates.
- SPM can be used for fast optical switching.
- It has been used for passive mode locking.
- Responsible for the formation of optical solitons.

Cross-Phase Modulation (XPM)

- Consider two optical fields propagating simultaneously.
- Nonlinear refractive index seen by one wave depends on the intensity of the other wave.
- Nonlinear phase shift:
- An optical beam modifies not only its own phase but also of other copropagating beams (XPM).
- XPM induces nonlinear coupling among overlapping optical pulses.

XPM: Good or Bad?

- XPM leads to interchannel crosstalk in WDM systems.
- It can produce amplitude and timing jitter.

On the other hand, . . .

XPM can be used beneficially for

- Nonlinear Pulse Compression
- Passive mode locking
- Ultrafast optical switching
- Demultiplexing of OTDM channels
- Wavelength conversion of WDM channels

Four-Wave Mixing (FWM)

- FWM is a nonlinear process that transfers energy of pumps to signal and idler waves.
- FWM requires conservation of Energy $\omega_1 + \omega_2 = \omega_3 + \omega_4$
- Momentum $b_1 + b_2 = b_3 + b_4$
- Degenerate FWM: Single pump ($\omega_1 = \omega_2$).

FWM: Good or Bad?

- FWM leads to interchannel crosstalk in WDM systems.
- It generates additional noise and degrades system performance.

On the other hand, . . .

FWM can be used beneficially for

- Parametric amplification
- Optical phase conjugation
- Demultiplexing of OTDM channels
- Wavelength conversion of WDM channels
- Supercontinuum generation

3. Conclusion

Optical fibers exhibit a variety of nonlinear effects. Fiber nonlinearities are feared by telecom system designers because they can affect system performance adversely. Fiber nonlinearities can be managed through proper system design. Nonlinear effects are useful for many device and system applications: optical switching, soliton formation, wavelength conversion, broadband amplification, demultiplexing, etc. New kinds of fibers have been developed for enhancing nonlinear effects.

The optical mode of communication has provided a breakthrough in the data communication industry quenching the needs of high-speed data rate transmission and development.

4. References

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