International Journal of Enhanced Research in Management & Computer Applications, ISSN: 2319-7471
Vol. 3 Issue 7, July-2014, pp: (29-34), Impact Factor: 1.554, Available online at: www.erpublications.com

Fiber Optics and its Applications in Optical Science and Engineering

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Abstract: This paper introduces about the fiber optics and its standards in optical communication organize. Fiber nonlinearities are limited components for optical communications frameworks, in particular for wavelength division multiplexing. Among the nonlinearities impact is four-wave blending, which is a nonlinear procedure that creates new recurrence parts from existing recurrence segments. FWM is the essential factor which at last confines the channel thickness and limit of WDM frameworks. In the ROF-WDM framework, the optical tweak method assumes a basic part in measure of fiber nonlinearity affect. Different parts of fiber optics and its related parameters as far as various components have been touched in this paper.

Keyword: Wavelength division multiplexing (WDM); Radio over fiber (ROF); Four Wave mixing (FWM)

I. INTRODUCTION

An optical fiber or optical fibre is a flexible, transparent fiber made by drawing glass (silica) or plastic to a diameter slightly thicker than that of a human hair. Optical fibres are utilized regularly as a way to transmit light between the two finishes of the fiber and find wide use in fiber-optic interchanges, where they allow transmission over longer separations and at higher transfer speeds (information rates) than wire links. Filaments are utilized rather than metal wires since signals go along them with less misfortune; also, fibres are invulnerable to electromagnetic obstruction, an issue from which metal wires endure too much.

As the quality of fiber transmission frameworks builds, the separation between wavelength division multiplexing (WDM) channels needs to drop down to make ideal and effective utilization of restricted optical low misfortune range window. Besides, high information rate communication of 10 or 20 Gb/s and long separation between intensifiers in a chain require substantial optical forces to infuse into the fiber to coordinate flag to-clamor proportion (SNR) prerequisites. The combination of high-control esteems and the nearby dispersing between channels increment nonlinear crosstalk between the channels because of the nonlinear properties of the transmission fiber. The most essential nonlinear property of fiber which can confine the information rate of the framework are Self stage tweak (SPM) Cross stage adjustment (XPM) Four wave blending (FWM), Stimulated Raman Scattering (SRS) and Stimulated Brillion scrambling (SBS) [1]. In this way, to enhance the rate of communication of any WDM optical communication framework, theories nonlinear impact of fiber should be killed. In actuality, the fiber nonlinearity exists in any communication framework which utilizes the fiber optics as a medium.

Thusly, Radio-Over-Fiber (ROF) framework is likewise influenced by this unforeseen marvel. Fiber nonlinearity is the principle dangerous marvels in high information rate optical communication frameworks. As a result of constrained low misfortune optical range, DWDM is a productive strategy to increment ghastly effectiveness. To have more directs in the low misfortune optical range, the channel dividing must abatement. As channel dividing diminishes, the fiber nonlinearity impacts increment and cause to execution corruption of optical framework [5]. This corruption even is more basic for the whole deal transmission where we have to supply abnormal state of energy to the fiber. Infusing the high volume of energy to the fiber increment the XPM and FWM impact as well as cause to initiate the impact of other fiber nonlinearity wonders like SRS and SBS. Numerous strategies have been proposed to determine and alleviate the fiber nonlinearity issues. Among these techniques we can allude to unequal channel dividing and scattering pay moved (DCS) fiber and also applying high data transfer capacity optical enhancer. In any case, the issue of fiber nonlinearity in the ROF framework is a stopped new issues and it should be researched more [6].

II. FIBER OPTICS

To further improve and explore the advantages of the high bandwidth provided by optical fiber, multiplexing is an effective solution which combines multiple numbers of wavelengths into the same fiber in the width of 1300-1600 nm spectrums [7,8,9]. With the advent of lasers with extremely narrow line widths, more channels can be multiplexed into the same fiber which provides the basis for Dense Wavelength Division Multiplexing (DWDM). As it is shown in Figure-1, the main elements of the DWDM system are the multiplexer at the transmitting end and the de-multiplexer at the receiving end. The multiplexer combines the different wavelengths and they are separated back at the receiving end with a de-multiplexer.

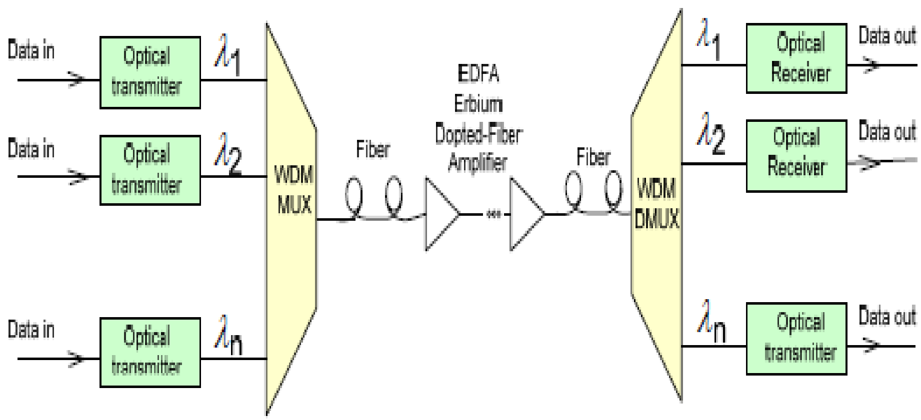

Fig.1: Optical system using WDM Technique

In the transmitter side, various light sources are modulated individually by signal. For good linkage, the frequency spectrum of individual channel should be as narrow as possible [10]. By now, laser carrier line width 4M/250 MHZ can be achieved by external / directly modulating optical wave using double feedback laser diode (DBF-LD).As it can be seen from the Figure-1, for long-haul transmission optical amplifier needed to compensate the fiber loss. Desirable optical amplifier is EDFA since it has high gain, large saturated output power and wide bandwidth. Theoretically, the number of channel within low loss window (1330nm-1580nm) is 1250, therefore, Potential capacity of WDM is

$C = 1250 \times 10 = 12.5$ Tb/s

However, many factor limits, the total number of channel in WDM including bandwidth limitation of optical amplifier and fiber nonlinearity. The existence broadband optical amplifier just has 50nm spectrum flat gain[11,12,13,14]. EDFA probably can be considered ideal amplifier since it has high gain, broad bandwidth, and also it works on population inversion principle. Gain variation of optical amplifier is detrimental because It leads to supply insufficient optical power to some WDM channel and supply too much optical power feed to other channel. Too much optical power increase the nonlinearity effect of fiber (XPM-FWM-SRS) while insufficient optical power degrade the system signal to noise ratio (SNR). Therefore, gain flattened amplifier is needed to alleviate the fiber nonlinearity effects. In this way, also we need to apply some techniques to equalize the gain of amplifier. Fiber nonlinearity is another technical challenge which limits the number of channel in WDM. The fiber nonlinearity causes to high interference and channel cross-talk between WDM channels. Therefore, Extra channel spacing is essential. In addition, the simplest approach to avoid fiber nonlinearity effects is keeping the light intensity low. This action nonetheless, is detrimental due to decreasing the system SNR.

Fiber Characteristics

The root element that makes the optical communication possible is the optical fiber. The process which guides the light along the optical fiber is the total internal reflection. It is an optical phenomenon which occurs when the incident light is completely reflected. Critical angle is the angle above which the total internal reflection occurs. In case of materials with different refractive indices, light will be reflected and refracted at the boundary surface. This will happen only from higher refractive index to a lower refractive index such as light passing from glass to air. This phenomenon benchmarks the basis of optical communication through fibers. An optical fiber is a dielectric waveguide, it is cylindrical, and mentors the light parallel to the axis [15, 16, 17].The cylindrical structure is dielectric with a radius “a” and refractive index of “n1”. This is the called the core of the fiber the fiber and the layer that encompasses this structure is called the cladding. Cladding has a refractive index “n2” which is lesser than “n1”. This helps in providing mechanical strength and helps reducing scattering losses. It also prevents the core from surface contamination. Cladding doesn’t take part in light propagation.

CLASSIFICATIONS OF OPTICAL FIBRES

i).Classification of Fiber Material:

1. Glass fiber(e.g:silicon dioxide)

2. Plastic fiber (e.g:PMMA PMMA)

ii).Classification Based On

1. Single-Mode Fiber Optic

2. Multi-Mode Fiber Optic

iii).Classification Based Index:

1. Step index fiber

2. Graded index fiber

Fibers can also be categorized as per their core’s material composition. If the refractive index of the core is uniform and changes abruptly at the cladding boundary, then it is called as Step-index fiber. In case the refractive index varies at every radial distance, then it is called as Graded-index fiber [20,21,22]. These fibers can be divided into Single mode and multi mode fibers. Single mode fibers operate in only one mode of propagation. Multimode fibers can support hundreds of modes. Both laser diodes and light emitting diodes (LED) can be used as light wave sources in fiber-optical communication systems. When compared to Laser diodes, LEDs are less expensive, less complex and have a longer lifetime, however, their optical powers are typically small and spectral line-widths are much wider than that of laser diodes. In Multimode fibers different modes travel in different speed, which is commonly referred to as inter-modal dispersion, giving room to pulse spreading. In single mode fibers, different signal frequency components travel in different speed within the fundamental mode and this result in chromatic dispersion. Since the effect of chromatic dispersion is proportional the spectral line-width of the source, laser diodes are often used in high-speed optical systems because of their narrow spectral line-width.

Fiber Losses

For optimum recovery of the received signal, the signal to noise ratio at the receiver must be considerably large. Fiber losses will affect the received power eventually reducing the signal power at the receiver. Hence optical fibers suffered heavy loss and degradation over long distances. To match these losses, optical amplifiers were discovered which significantly boosted the power in the spans in between the source and receiver. However, optical amplifiers introduce amplified spontaneous emission (ASE) noises which are proportional to the amount of optical amplifications they provide [23, 24, 25]. Low loss in optical fibers is still a critical requirement in long distance optical systems to efficiently recover the signal at the receiver. Attenuation Coefficient is a fiber-loss parameter which is expressed in the units of dB/Km.

Fiber Nonlinearities

The non-linear effects of the fibers play a important role in the light propagation [18, 19]. Nonlinear Kerr effect is the dependence of refractive index of the fiber on the power that is propagating through it. This effect is responsible for SPM, XPM and FWM. The other two important effects are stimulated SBS and SRS.

- Self Phase modulation
- Cross phase modulation
- Four wave mixing
- Stimulated Brillouin Scattering

OPTICAL FIBRES APPLICATIONS IN SCIENCE AND ENGINEERING

Optical fiber is used by many telecommunications to transmit telephone signals; Internet cable television signals. Due to much interference, optical fiber has large copper wire in long-distance applications. However, infrastructure was relatively difficult and time systems were complex and expensive Due to these difficulties, fiber-optic have primarily been installed in where they can be used to their offsetting the increased cost. Since optic communications have dropped These price for rolling out fiber become more cost-effective than that based network. The critical angle passes into telecommunications companies signals, Internet communication, and much lower attenuation and large advantages over existing distance and high-demand applications. However, infrastructure development within cities consuming and fiber-optic expensive to install and operate. optic communication systems long-distance applications, full transmission capacity, 2000, the prices for fiber dropped considerably. to the home has currently that of rolling out a copper based network.

i) TELECOMMUNICATION: Telecommunication applications are widespread, ranging from global networks to desktop computers. These involve the transmission of voice, data or video over distances of less than a meter to hundreds of kilometers, using one of a few standard fiber design in one of several cable designs.

ii) NETWORK: Carriers use optical fiber to carry plain old telephone service (POTS) across their nationwide networks. Local exchange carriers (LECS) use fiber to carry this same service between central office switches at locals levels, and sometimes as far as the neighborhood or individual home.

iii) TRANSMISSION: Optical fiber is also used effectively for transmission of data. Multinational firms need secure, reliable systems to transfer data and financial information between buildings to the desktop terminals or computer and to transfer data around the world. Cable television companies also use fiber for delivery of digital video and data services. The high bandwidth provided by fiber makes it perfect choice for transmitting broadband signals, such as high-definition television (HDTV) telecasts. Intelligent transport systems, such as smart highways with intelligent traffic lights, automated tollbooths, and changeable message signs, also use fiber-optic-based telemetry systems.

PRINCIPLE OF OPERATION

An optical fiber is a cylindrical dielectric waveguide (nonconducting waveguide) that transmits light along its axis, by the process of total internal reflection. The fiber consists of a core surrounded by a cladding layer, both of which are made of dielectric materials.[51] To confine the optical signal in the core, the refractive index of the core must be greater than that of the cladding. The boundary between the core and cladding may either be abrupt, in step-index fiber, or gradual, in graded-index fiber.

The per-channel light signals propagating in the fiber have been modulated at rates as high as 111 gigabits per second (Gbit/s) by NTT, [15] although 10 or 40 Gbit/s is typical in deployed systems.[8] In June 2013, researchers demonstrated transmission of 400 Gbit/s over a single channel using 4-mode orbital angular momentum multiplexing.[19]

Each fiber can carry many independent channels, each using a different wavelength of light (wavelength-division multiplexing (WDM)). The net data rate (data rate without overhead bytes) per fiber is the per-channel data rate reduced by the FEC overhead, multiplied by the number of channels (usually up to eighty in commercial dense WDM systems as of 2008). As of 2011 the record for bandwidth on a single core was 101 Tbit/s (370 channels at 273 Gbit/s each). The record for a multi-core fiber as of January 2013 was 1.05 petabits per second. [41] In 2009, Bell Labs broke the 100 (petabit per second)×kilometer barrier (15.5 Tbit/s over a single 7,000 km fiber).[12]

For short-distance applications, such as a network in an office building (see FTTO), fiber-optic cabling can save space in cable ducts. This is because a single fiber can carry much more data than electrical cables such as standard category 5 Ethernet cabling, which typically runs at 100 Mbit/s or 1 Gbit/s speeds. Fiber is also immune to electrical interference; there is no cross-talk between signals in different cables, and no pickup of environmental noise. Non-armored fiber cables do not conduct electricity, which makes fiber a good solution for protecting communications equipment in high voltage environments, such as power generation facilities, or metal communication structures prone to lightning strikes. They can also be used in environments where explosive fumes are present, without danger of ignition. Wiretapping (in this case, fiber tapping) is more difficult compared to electrical connections, and there are concentric dual-core fibers that are said to be tap-proof.

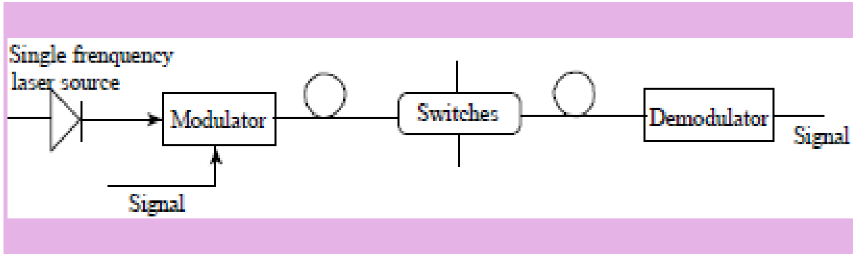

Fig. 2: Principle of Optical Communication

CONCLUSION

In this paper, distinctive parts of optical communication organize are talked about. Fiber optics situations regarding misfortunes, non-linearity have been displayed. Diverse sorts of non-direct reactions have been happened in arrange setups. High channel usage for de-multiplexing on various wavelengths ought to be accomplished. Diverse tweak methods should be produced to upgrade the execution on fiber optics in communication organize. Standard optical fibres are made by first building an expansive measurement "preform" with a deliberately controlled refractive record profile, and after that "pulling" the preform to shape the long, thin optical fiber. The preform is generally made by three synthetic vapor affidavit strategies: inside vapor statement, outside vapor testimony, and vapor pivotal affidavit.

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