© 2017 IJEDR | Volume 5, Issue 4 | ISSN: 2321-9939

Generation Of Ultra Short Pulses

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***Abstract*— Data traffic is predicted to grow further exponentially as a result of the emergence of high-bandwidth consuming applications and services. ,The fast deployment of different technologies such as video streamingthe expansion of major telecommunications infrastructure, etc. has increased the demand for network capacity for delivering the data traffic . Various technologies emerged to meet the requirement of increased data capacity. Ultrashort pulse is an electromagnetic pulse having time duration in picoseconds or even less. Ultrashort pulses offer high capacity. In this paper, we reviewed the principle of the generation ofultra-short pulses employing fiber ring lasers which include active optical modulators of amplitude or phase types.Also.various techniques to generate the Ultrashort pulses have been reviewed ,**

***IndexTerms*— Communication, capacity, bandwidth, Ultra-short pulses, Laser.**

I.INTRODUCTION

Communication is one of the essential parts of human lives. People communicate with each other to share their opinions, ideas, and feelings. Thus, communication is the exchange of information from one place to another [1].
With the advancement in technology and every sector of life, an enormous change in the way how people communicate with each other has been seen [11]. Previously horses and pigeons were the messengers to transmit information from one place to another. Technology brought quickness in everything, in communication as well [3].

Figure 1: *The Communication Process*

The main purpose of every communication is to send the information over a long distance while ensuring no damage to it. Thus all the communication system have only one motive to deliver the accurate information from the sender to the receiver. There is always some medium through which information is transformed from the sender to the receiver [4].

1.1 Optical Fiber Communication

Optical Fiber Communication is emerged as one of the fine technique to send information at high data rate with maximum long distance possible .It is one of the most secure ways to communicate .It uses light as a source of communication .The light propagates through the glass fiber from the sender to the receiver while following the principle of total internal reflection .

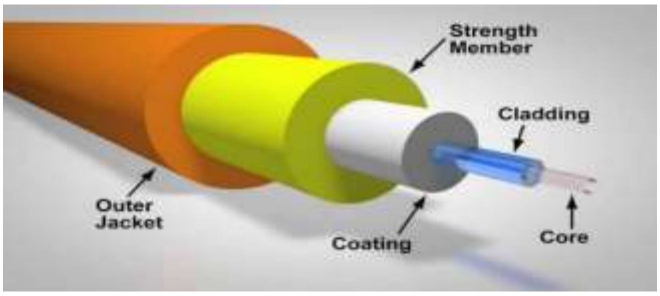

Figure 2: *Optical Fiber*

Optical fibers are very thin and have a diameter similar to human hair .It is made up of two cylindrical glasses .The inner core is the one through which the light signal propagates] 7 .[Next is the cladding surrounded by the core which has a lower refractive index .The light propagates depending on the principle of total internal reflection that occurs in the cladding-core interface]11.[

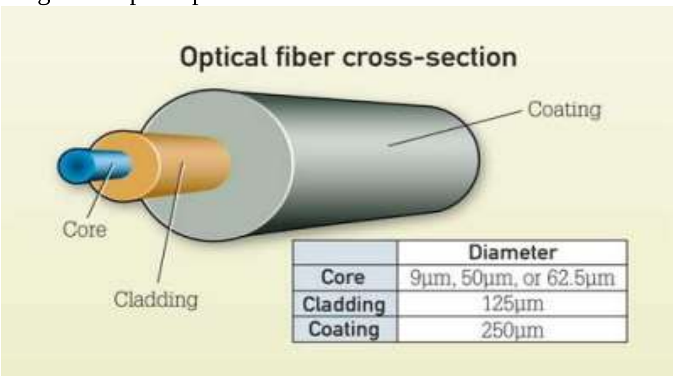

Figure 3:*Optical fiber*

There is mainly three type of light sources used in the optical fiber communication. These include:

1. LED (Light Emitting Diode)
2. Solid State Lasers
3. Semiconductor Injection Lasers

1.1.1. Light Emitting Diode

A LED is abbreviatedas the light – emitting diode. LED provides visible light when the electric current is passed through it. The light emitted by the LED is not so bright.The output from the LED range from the red to blue- violet. Some LED also emits the infrared energy, and such device is called the infrared light emitting diode. LED is made up of two elements including p-type and the N- type semiconductors. These two elements are placed in the direct contact of each other, and it also forms the region called the P-N junction [13]. LED and IRED is a transparent package which allows the passage of visible energy through it. The LED and the IRED consist a large P-N junction which helps them to pass the light which is visible to us.

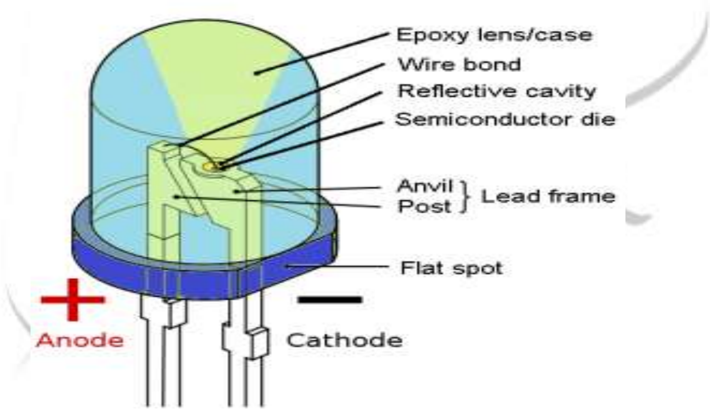

Figure 4: *Light Emitting Diode (LED)*

Benefits of the LED include the following

1. **Low power requirement-** The LED requires littlepower, as it consumes very less amount of energy.
2. **High efficiency-** The power supplied to the LED or IRED is directly converted into the radiation with the lowest amount of heat production. In this way, LED has high efficiency.
3. **Long life –** If the installation of the LED done in a better way then it remains safe and function for a long time [9].

1.1.2. LASER (Light Amplification by stimulated emission of radiation)

The LASER stands for the 'light amplification by stimulated emission of radiation. 'A laser is a focused beam of photons. It consists one wavelength and one ordinary light which dips on us in many wavelengths. The laser works on the distinct types of effect [5]. The output comes out of the laser is called the electromagnetic field. In the electromagnetic field, all the waves under the laser have the same frequency and the phase. The optical electronic device generates an arrow beam of monochromatic light by amplifying photons with more energy through collisions with other photons [23].

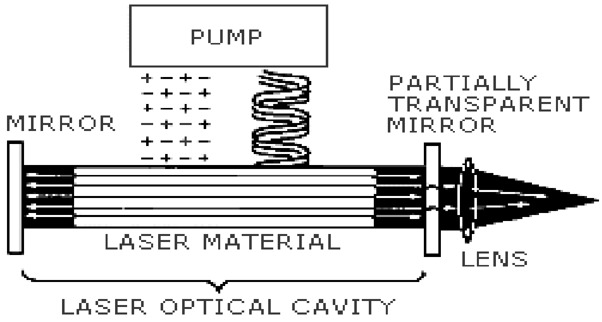

Figure 5: *LASER Components*

The cavity inside the laser contains the gasses, liquids or solids. The choice of the cavity is based on the wavelength of the output [7]. The cavity has some mirrors inside it which help to reflect or pass the light inside the cavity. The other mirror is partly reflective, and it allows only 5 percent of energy to pass into the cavity [25]. Then the energy is produced in the cavity from an external source, and this process is called pumping. When the pumping is in operation, then the electromagnetic field appears inside the cavity with the natural frequency of the particles. Lasers are one of the most significant inventions that developed in the 20th century. The use of laser technology is now common in the field of electronics, computer hardware, medicine and investigational science [8].

1.1.3. Gas Laser

The gas laser was the first light laser which operates on the principle of converting electrical energy into the laser light energy. The first gas laser which named as the Helium- neon laser was invented by the American scientist Ali Javan, and the William R. Bennett in 1960 Types of Gas Laser are:

1. Carbon dioxide lasers
2. Helium – neon lasers
3. Excimer laser
4. Argon Laser

1.1.4. Solid State Laser

A solid laser is a laser that uses a gain medium in a solid form rather than in a liquid form. It is used in the dye laser and gas lasers. The solid-state laser consists of the glass and the crystalline material which adds a dopant such as neodymium, chromium, erbium and the thulium [6].

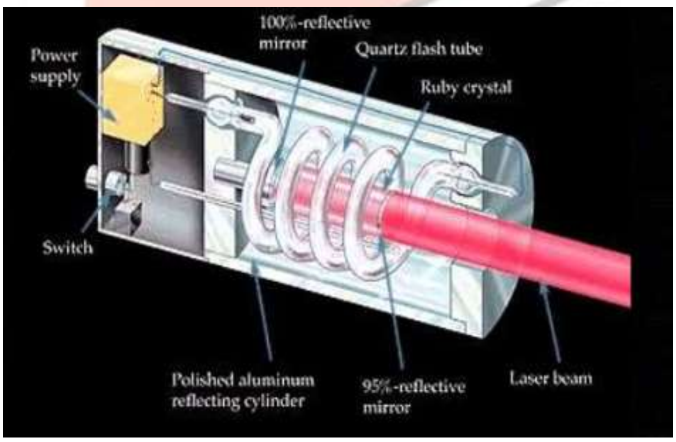

Figure 6: Ruby Laser Components

There are hundreds of the solid-state laser used in the media in which laser action has been achieved, but only a few types of solid state lasers are in use. The most common solid state lasers include the following:

1. Ruby Laser
2. Nd: YAG laser
3. Erbium doped glass lasers

1.2. Ultra-Short Pulse Lasers

To meet the increased demand for capacity, Ultra-short pulse lasers were developed. USP lasers provide a high amount of output power that can be utilized in different industrial applications. Such lasers offer pulse length from 10 picoseconds to 100 femtoseconds [9].

USP lasers can be employed in numerous applications including drilling, laser cutting, surface treatment and laser marking [12]. Major benefits of USP lasers in micromachining as it reduce collateral damage, improve dimensional accuracy, removal of post-processing steps and tighter tolerances [22].

1.2.1. Applications of USP lasers

The main application areas of USP lasers include

1. Ultrafast fiber lasers are basic building blocks of many photonic systems that used in industrial, medical as well as in the scientific application.
2. It helps to measure the fundamental constants of nature ultrahigh-speed optical communications.
3. Mode-locked fiber lasers are based on telecom components, which have been developed for reliable and long-term operation.
4. The laser output is naturally fiber-coupled. Hence, compatible with telecom systems.

1.2.2. Advantages

The Larger gain bandwidth of rare-earth-doped fibers, normally tens of nanometers that enable the generation of femtosecond pulses.Low pump powers because of the high gain efficiency of active fibers which helps to activate such lasers having flow pump powers and to allow intracavity optical components with comparatively high optical losses. Such as, specific optical filters or arrangements for dispersion compensation can not be used in bulk lasers.Fiber laser structures could be made-up with low cost and could be very condensed and uneven; mainly when free-space optics are not used [7].

1.2.3. Disadvantages

The performance of femtosecond and picoseconds mode-locked fiber lasers and amplifiers is in many cases severely limited by the strong non-linearity of fibers, and sometimes also by the chromatic dispersion.Another disadvantage is that it results from uncontrolled double refraction specifically if they are not polarization maintaining.

II. LITERATURE SURVEY

M. Nakazawa, T. Yamamoto, and K.R. Tumaura (2000)proposed a method for Ultra-high-speed OTDM transmission using reverse dispersion fiber and conventional single-mode fiber. The proposed modified pulse modulation technique assisted in reducing the pulse broadening from 200fs to 20fs. The phase modulator used was extracted at the DI-NOLM while being driven at the10GHz clock. The proposed technique was helpful in diminishing the dispersion from erbium-doped. In this way, the 1.28Tbit/s signal was successfully remitted over 70 Km with optical time division multiplication technique, and single wavelength channel. Third- and fourth-order simultaneous dispersion compensation was used with a 10GHz synchronous phase modulator. The input pulse width was 380fs, and the transmitted pulse width was 400fs. But bit error rate of less than 1 was overserved with all 128 channels demultiplexed to 10Gbit/s [9].
K.K. Gupta, N. Onodera, K.S. Abedin, and M. Hyodo (2002) proposed a technique to generate optical pulses which are highly stable in timing jitter and amplitude noise. The research focused on demonstrating the repetition frequency multiplication using the optical filtering in AM mode-locked fiber ring lasers. The optical filtering was accomplished through FFP (Fabry-Perot filter). This Fabry–Perot filter is inserted into the ring to equalize the pulse amplitudes in the rational harmonic laser.A modulation signal of 869.284 MHz was used to generate a3.477-GHz optical pulse train. The generated optical pulses were highly stable with only 0.93% amplitude noise, 1.2 ps of timing jitter and large suppression of super-mode noise [10].

J. Clowes, I. Godfrey, and A. B. Grudinin, M. Rusu, M. Guina, O.G. Okhotnikov, I.A. Bufetov, E.M. Dianov, and S.E. Goncharov (2005) proposed the Nd-doped fiber laser. The laser was able to generate 170 fs pulses with with an output power of 0.8 W and spectral range of 920nm. In order to reduce the unwanted gain, the finite cut-off wavelength of the fundamental mode was obtained. It was accomplished with the use of W-type refractive index profile of the doped core. In this way, unwanted gain at 1064 nm was easily suppressed. Both the high power amplifier and master source were connected to each other using high power isolator. There was a mechanical contact between the high power isolator and then master source. In this way, low coupling loss was achieved while preserving the high reflectivity of the dichroic mirror. Though Sapphire lasers also capable of covering the same spectral range, but the proposed laser is much more efficient and compact to this conventional laser [13].
J. Limpert, F. Röser, T. Schreiber and A. Tünnermann (2005) reviewed the accomplishments, applications and scaling potential of the high energy ultrafast fiber laser systems. The power scaling is one of the major issues that occur because of the thermo-optical effects. The proposed rare-earth-doped doubleclad fiber effectively resolved this issues with its geometry. In this way, rare-earth-doped doubleclad fiber fundamental requirement for broad bandwidth short pulse amplification and very high single pass gain. It can transmit the signals at large length through the low intrinsic loss characteristics.
Along with this, a large wavelength is covered through the absorption spectrum. The long fluorescence lifetime and the small quantum defect leads to high energy storage capability and high efficiency respectively. In this way, proposed rare-earth-doped fibers are superior in comparison with other solid-state laser concepts. But the major issue was that nonlinearity could damage to the fiber because of the severe pulse distortions [14].
F. Yoshino, H. Zhang and A. Arai (2009) presented ultra short pulse fiber laser with the unique micro-marking feature, Switchable Inner Micro-Marking (Swimm), in various industrially important transparent materials. The research explained that

how ultrashort pulse lasers are capable of producing high peak power while utilizing modest average power. Thus, these ultrashort pulse lasers can be used on transparent materials and material modifications. The proposed fiberlaser model is designed for the medicaldiagnostics, laser material processes, imaging.[16] metrology and scientific research

The study suggests that adjusting various features of pulse fiber laser such as pulse energy, focusing conditions and other processing parameters, well-defined material modifications can easily be created. Also, proper control of processing conditions helps to produce features which are tough to see under normal and ambient lighting .[16]

M. E. Fermann and I. Hartl (2009) reviewed the use of fiber laser technology in different applications of ultrafast optics. The study focuses on discussing the core enabling fiber technologies. These technologies included all-fiber dispersion control, large-core fibers, highly nonlinear and fiber amplifiers.

The study focus on a system developed about the fiber frequency combs and passively mode-locked fiber lasers. Along with this, coherent super continuum generation has been explained in depth. At last, various techniques has been represented for controlling the phase of fiber amplifiers and fiber lasers [17].

M. Mielke, D. Gaudiosi, K. Kim, M. Greenberg, X. Gu, R. Cline, X. Peng,M. Slovick, N. Allen, M. Manning, M. Ferrel, N. Prachayaamorn, and S. Sapers (2010) demonstrated an all-fiber erbium amplifier system. The system is capable of producing 100 pulses with high beam quality, an autonomous control system and more significantly with only femtosecond class pulse width. The research describes the laser platform performance as well as its thermal effects on the structure through in-depth analysis. Along with his, it has been estimated that Radiance lasers operate continuously around the clock without used by users. It needs the intervention of human only one times in approximately 27,000 hours. The applications and critical performance data associated with the Radiance ultrafast lasers has been presented [18].

M. M. Mielke, T. Booth, M. Greenberg, D. M. Gaudiosi,C. Martinez, S. P. Sapers, R. Cline and R. A. Srinivas (2013) described that compelling economics,unparalleled precision, and new materials flexibility are the three main aspects that have been validated in commercial micro fabrication. Fabrication process impact includes a dramatic reduction of post-processing requirements for metal devices since deleterious side effects, such as recast and dross can be substantially condensed. There are various materials such as brittle dielectrics and polymers whose machining and modification is very difficult. But these materials can be easily modified through the femtosecond laser methods. It helps to reduce the complexity and the direct labor. In this way, femtosecond laser materials processing is cheaper, better and fast way to fabricate parts with high precision [19].

X. Liu,Y. Cui, D. Han, X. Yao, and Z. Sun (2015) proposed a distributed ultrafast fiber laser which was based on a linearly chirped fiber. The proposed laser is highly stable and simple. The DUF lasers provide the ultrafast pulsed source with changeable and controllable cavity frequency, stable operation and low cost [20].

J. M. D. Cruz, V. V.Lozovoy and M.Dantus (2006) reviewed the issues of ultrashort pulses while applying to biological tissue. The Research found that ultrashort pulses are difficult to manipulate when use with biological tissue. They proposed a method to attain full benefits of ultrashort pulses. The proposed method is based on the coherent control that assists in correcting the phase distortions that emerge as a result of high NA (numerical aperture) microscope objectives.

The research recommends various useful phase functions to gain selectivity. But it can only be accomplished if there are perfect optimization and no moving part. They also demonstrated that how phase functions can be used to minimize the damage in multiphoton excitation [21].

Ponomarenko, O(**2011)**analyzed core-electron tunneling interaction with X- ray and XAU radiations in diatomic systems. The Research described that intense X- ray fields might cause core-hole tunneling on a timescale which would result in changes of diffraction patterns of X-ray probe pulse. X-ray free electrons and HHG lasers produce ultra-short pulses for developing novel techniques. In the experiment performed it was difficult to characterize nature of core- hole state. So, crystallographic form factors are not applicable for one-shot diffraction experiment. The importance of the effects of coherently induced by intense laser field which depends on field parameters and properties of molecules. The calculation results show coherent suppression ofcore-hole delocalization dynamics using XUV laser fields [22].

Bech, H., & Leder, A (2004) analyzed the time-dependent formation of the scattered light through the numerical investigation. To analyze the difference in the time between the signals of a higher order of refraction and reflection, calculation utilized the Mie theory. Using the principles of geometrical optics, corresponding optical path lengths of light rays were computed. To take into account the single order of the scattered light, Debye series expansion was used. In this way, they demonstrated the generation of pulse-induced scattered light for the first and second order of refraction [23].

Gupta, K., Onodera, N., Abedin, K., & Hyodo, M (2002) analyzed pulse repetition frequency multiplication using intracavity optical filtering in AM Mode-Locked FiberRingLaser and shows that the generated optical pulses are highly stable in amplitude noise and timing jitter. They perform the experiment in which RF modulating signals applied to Mach-Zehnder modulator that generated optical pulse trains with repetition rates equal to FSR of the FFP. The pulse generated was a high degree of pulse stability of low noise, amplitude noise, phase noise, or timing jitter [24].

Limpert, J., Röser, F., Schreiber, T., & Tünnermann, A. (2006)presented main advantages of ultrafast fiber laser systems compared to bulk solid state lasers. They prove that the fiber laser constitutes a power-scalable solid-state laser concept. To produce penetrating pulses from fiber, some limitations have to overcome. They presented the challenges, achievements, and perspectives of ultrashort pulse generation and amplification in fibers. Rare-earth doped photonic crystal fibers used by them offers several unique properties which permit an upward scaling of performance related to conventional fiber lasers.They concluded that the short pulse fiber laser systems would deliver very high average powers and high repetition rates in a group with high pulse energies .[25]

Hay, N., De Nalda, R., Halfmann, T., Mendham, K., Mason, M., Castillejo, M., & Marangos, J (2001)analyzed High-order harmonic generation from organic molecules in ultra-short pulses from the molecular system of near-infrared high-intensity laser pulses. Harmonic intensities were measured in the function of laser intensity. They used polarization method; it works on different properties like molecular properties, electronic structure, and behavior of ionization and fragmentation in larger systems. They concluded that the molecules remain integral during the interaction, high-order harmonic generation. As a result, the dependence of harmonic intensity is of laser ellipticity [26].

Feng, H., Zhao, W., Yan, S., & Xie, X. P. (2011)analyzed Generation of 10GHz Ultra-Short Pulses with Low Time Jitter in an Actively Mode-Locked Fiber Laser by using the cross-mode modulation. In this, they searched for the relationship between the line width of external modulation continuous wave source and performance of an actively mode-locked fiber laser. They resulted that the ultrashort pulse at high repetition rate with low time jitter could be generated by the optimization of the continuous wave laser source, which means it has a potential application in all optical communication networks [27].

Kuizenga, D. J (1977)analyzed the Generation of the short impulse for laser fusion in an actively mode-locked Nd: YAG LASER. It works on the principle of the prelase period. It has three main conditions that short one envelope should approach a steady state value after the number of round trips. The prelase period must also be long enough for the pulses to become transformed in a limit. Secondly, the spectrum is the factor of two from the steady states transformed limited spectrum after a few round trips. The third is, when the laser is on the threshold pulse at the start of the prelase period; there is a usual relaxation oscillation. They conclude all this by using different formulas [28].

Bradley, D., & Durrant, A. (1968)analyzed Generation of ultra-short dye laser pulses by mode-locking. The mode locking is carried out in that situation when transmitting time of ruby and dye laser cavity are equal. Organic dye laser when optically pumped by a huge pump laser pulse then it produces a high range of frequencies between 4000 Angstrom to 11000 Angstrom. Hence the output spectrum is usually of a wide range. The output of width depends on two factor. The two factors are cavity length and the pumping intensity [29].

Esirkepov, T. Z., Bulanov, S. V., Zhidkov, A. G., Pirozhkov, A. S., & Kando, M (2009) analyzed ultra-short Gamma-ray and X-ray pulses producing High-power laser-driven source. Double Doppler Effect method was used in this research. In this method, a relative mirror reflects a counter-propagating electromagnetic radiation that results in intensification and frequency multiplication. On the other hand, ultra-intense co-propagating electromagnetic wave gives its energy to the mirror [30]

III. FINDINGS

This section provides insightinto the findings of the research. The table given below is insight of the various key findings of the literature review.

Table I: *Research Findings*

Year	Researchers	Algorithm/Method	Input	Results/ Solution
2000	M. Nakazawa, T. Yamamoto, and K.R. Tumaura [9].	Modified pulse modulation technique	Single channel bandwidth, Optical time division multiplexed and polarization multiplexed signal	Successful transmission of a signal over 70 KM with bit error rate less than 1.
2002	K.K. Gupta, N. Onodera, K.S. Abedin, and M. Hyodo [10]	Pulse repetition frequency multiplication using optical filtering	a modulation signal of869.284 MHz	Successfully generated a highly stable optical pulse train.
2005	J. Clowes, I. Godfrey, and A. B. Grudinin, M. Rusu, M. Guina, O.G. Okhotnikov, I.A. Bufetov, E.M. Dianov,and S.E. Goncharov [13].	Proposed Nd-doped fiber laser with spectral range of 920nm	A modulated signal	The proposed method is effective in producing 170 fs pulses with output power of 0.8 W
2005	J. Limpert, F. Röser, T. Schreiber and A. Tünnermann [14].	Compared rare-earth-doped fibres with another solid-state laser	Various factors such as storage capability, efficiency, thermal load, etc. were analyzed.	Proposed rare-earth-doped fibres are superior in comparison with another solid-state laser
2009	F. Yoshino, H. Zhang and A. Arai [16].	Demonstrated the use of ultrashort pulse fibre	Different features such as pulse energy, focusing conditions, and	Successfully created material modifications which are difficult to see under normal lighting,

		laser in material modification	other processing parameters were adjusted.	
2009	M. E. Fermann and I. Hartl [17].	Reviewed the use of fibre laser technology in different applications of ultrafast optics	all-fibres dispersion control, large-core fibres, highly nonlinear and fibre amplifier technologies has been discussed	Described how different technologies couldbe used for the phase control in fibres.
2010	M. Mielke, D. Gaudiosi, K. Kim, M. Greenberg, X. Gu, R. Cline, X. Peng,M. Slovick, N. Allen, M. Manning, M. Ferrel, N. Prachayaamorn, and S.Sapers [18].	Examined all-fibres erbium amplifier system and Radiance Lasers	Analyzed the system through a various parameter.	The performance of both systems has been analyzed thoroughly with some descriptions about them.
2013	M. M. Mielke, T. Booth, M. Greenberg, D. M. Gaudiosi,C. Martinez, S. P. Sapers, R. Cline and R. A. Srinivas [19]	Presented the benefits of the femtosecond laser methods	Different difficult to process materials	The proposed method is effective to fabricate material in an easy, better, fast and cheaper way.
2015	X. Liu,Y. Cui, D. Han, X. Yao, and Z. Sun [20]	Reviewed the challenges and benefits of distributed ultrafast fibres laser	Various performance parameter was analyzed	The benefits of DUF lasers include simple structure, low cost, and highly stable pulse generation.
2006	J. M. D. Cruz, V. V.Loz ovoy and M.Dantus [21]	proposed method based on the coherent control to take the potential of ultrashort pulses	Various phase functions were controlled to gain selectivity	With perfect optimization and no moving part, the damage to the biomedical tissue was reduced to great extent
2011	O. Ponomarenko	Used Mie theory, principles of geometrics optics and Debye series expansion	Scattered light	Refraction of the first and second order was demonstrated for the pulse-induced generation of scattered light.

IV. CONCLUSION

With the advancement in technology, major changes in the way of communication havebeen identified. Technology decreased the time taken by the information to flow from one place to another to a great extent. Optical fiber communication is one of that technology that helps to transmit the information in few seconds while ensuring high security and reliability. LED and LASER is the major source of information transmission in the optical fiber communication.

In this paper, we reviewed the various sources used in the optical fiber communication. We analyzed different type of lasers along with their application areas and benefits. The literature has been reviewed to identify the effective techniques utilized in the optical fiber communication. The Research review will help to proceed the further research on the ultra-short pulse generation and detection.

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