Generation and Detection of Ultra Short Pulses

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Abstract— Data traffic is expected to grow rapidly because of the emergence of high-band width consuming services and application .The rapid growth of various technologies, for example, video streaming, the expansion of major telecommunication infrastructure, etc., has raised the demand for high network capacity to deliver data traffic .Various technologies have emerged to fulfill the demands of increased data capacity .Ultra short pulse is an electromagnetic pulse having a time period in picoseconds or even less than that .Ultra short pulses offer high capacity for transmission of data traffic .The research focused on the generation of Ultra short pulses using fiber lasers which include active optical modulators of amplitude or phase types .Along with this, the research would first review various techniques to generate Ultra short pulses .The overall experimental model includes fiber laser that is based on the mode locking to generate Ultra short pulses by employing saturable absorber .The proposed system will compose of some components which are optical fiber amplifier, DC components, and an undoped fiber .The main component is the Saturable absorber which is used to generate the optical pulse and to achieve mode locking.

IndexTerms— Ultra short pulse, optical fiber, pulse generation, fiber laser, , mode-lock lasers.

I.INTRODUCTION

With the advancement in technology and even in 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 has brought quickness in everything, also in communication as well]3.[

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 .

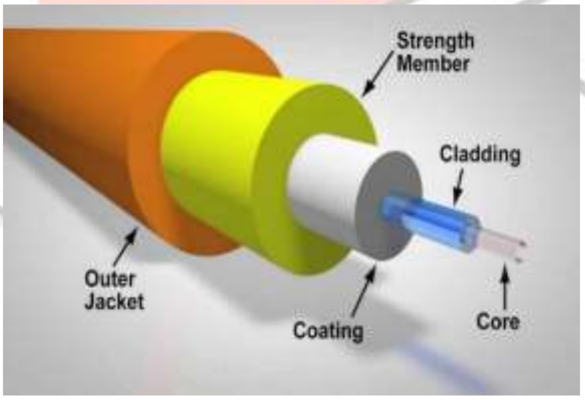

Figure 1: *Optical Fiber*

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.[

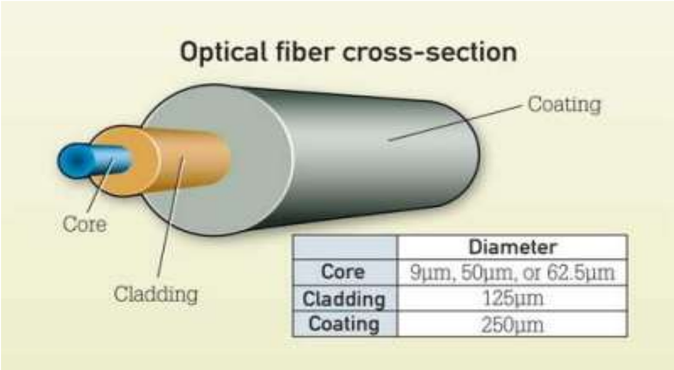

Figure 2:*Optical fiber*

1.2 Types of Light Sources in Optical Fiber Communication

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

1. LED (Light Emitting Diode)
2. Laser (Light Amplification by the Stimulated Emission of Radiation(

1.2.1 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 componentsare employed in the direct contact of each other, and it also forms the region called the P-N junction]13 .[LED and IRED (Infrared Emitting Diode) is a transparent package which allows the passage of visible energy through it .The LED and the IRED consist of the large P-N junction which helps them to pass the light which is visible to us.

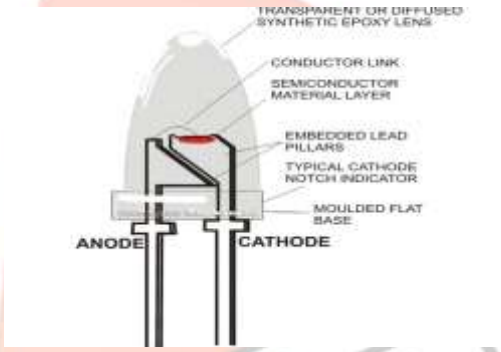

Figure 3: Internal composition of a LED [2]

1.2.2 Laser *(*Light Amplification by stimulated emission of radiation*)*

Light Amplification by the Stimulated Emission of Radiation) LASER (is a device which emits a low-divergent and narrow beam of coherent light by the process of optical amplification which is based on the stimulated electromagnetic radiation emission .Most light sources produce incoherent light that has a phase which changes randomly with time and position .The optical electronic device generates a narrow beam of monochromatic light with amplifying photons through more energy by impacts with other photons] .3[

1.2.2.1 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

1.2.2.2 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 .[

1.3 Ultrahigh Capacity Demands and Short Pulse Lasers

Data traffic is predicted to grow further exponentially as a result of the emergence of high-band width consuming applications and services such as Internet protocol television) IPTV(, file sharing, high-definition television)HDTV (and image transmission whose compressed bit rate is on the order of Gbps .Apart from it, the expansion of major telecommunications infrastructure in developing countries also results in huge data traffic .In addition, societies live in an age of trend of using video transmission in global communities has risen tremendously indicating that the bit rate or capacity of the backbone networks must be increased significantly to respond to these demands .The rapid deployment further pushes the demand for network capacity for delivering the data traffic . This development is considered as the digital economy of the twenty-first century .The delivery of information at this rate is unheard in the history of human communication, and this would not be possible if optical fibers, especially the single-mode fibers, were not invented and exploited over the last three decades] .4[

Optical Time Domain Multiplexing

In Optical Time Domain Multiplexing)OTDM (multiple data channels are transmitted in the duration optical pulses in the form of ultra-short thatare inserted into a particular high-speed data stream throughexactcontrol of their qualified delay in the time domain . sed at the receiving end for subsequent processing toAn optical gate is uget one base rate stream from the total data stream .The otdm operating principle is illustrated in below figure- :

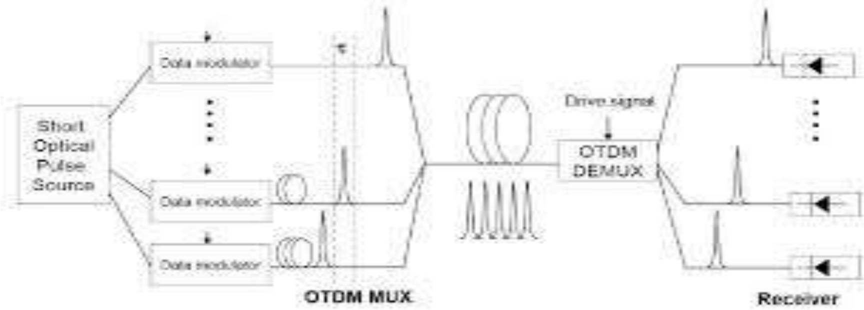

Figure 4: *Operating Principle of OTDM [1]*

Mode-locked lasers

A fundamental schematic mode-locked lasers consists of a nonlinear waveguide section, an amplifying device to compensate for the energy loss as well as to provide sufficient gain to induce the nonlinear effects, a tuning section to generate the locking condition of the light wave energy to a particular harmonic, an input and output coupling section for tapping the laser source, and an optical modulator to generate the repetition rate in association with the locking mechanism.All these optical components are interconnected by a ring of single-mode optical fiber] .4[

The pulse repetition rate generated by the above convention technique is often limited by the operating frequency of theoptical modulator embedded in the ring resonator which can be outstripped by using the nonlinear parametric amplification and the degenerate four-wave mixing)FWM (phenomenon in a special optical waveguide and the mechanism of rational frequency detuning, as well as the interference between the modulated pump signals via an optical modulator.Amplifying Resonance ring is basic of fiber ring laser.

There are certain discrete energy levels in a particle that electrons can occupy. When electrons receive energy from other sources such as an electronic or optical source, they jump from a lower level to higher levels .The electrons at high-level states E_i are excited electrons, and they can randomly jump back to a lower energy state E_j without any stimulating source .When this happens the electrons release the energy in the form of a photon and this random jumping process is called spontaneous emission, and the phases of the released photons are random .Frequency can be calculated from:

Where v is the released photon's frequency

h is Planck's constant

E_i and E_j are the energies of the electron at level i and j, respectively

υ) = E2 –E1 / (h

By contrast, when a photon enters a medium with excited electrons, it will cause a stimulated emission as the electron transits to a lower level and releases a new photon .The photons released through this emission have the same energy and phase as those of the stimulating photon .They then stimulate new emission and hence more, and more photons are generated .Therefore, the optical signal is amplified, and the medium with electrons pumped into excited states is called an amplifying medium.

The amplifying medium is now put inside a cavity formed by two mirrors to form a typical laser .One of the mirrors totally reflects the light, while the other reflects part of the light and transmits the rest to the output .The photons initially emitted from the spontaneous emission process are amplified when traveling through the amplifying mediumvia the stimulated emission .The photons are reflected back and forthbetween the mirrors and grow exponentially if their frequencies or wave lengths satisfy the phase condition .

ω= N πc /nL

where,

L is the cavity length

N is an integer number; c=3×108 m/s is the speed of light in vacuum

n is the refractive index of the medium or the effective refractive index of the guided mode if the medium is an optical waveguide

The schematic diagram in Figure 5 shows the experimental setup according to which the modulation of the pump source can be implemented using a step recovery diode)SRD (which would produce a very short pulse and a low repetition rate to modulate the amplitude of the pump lightwave via an optical modulator of moderately wide bandwidth .That is, the bandwidth limitation of the modulator in conventional mode-locked lasers can be overcome.

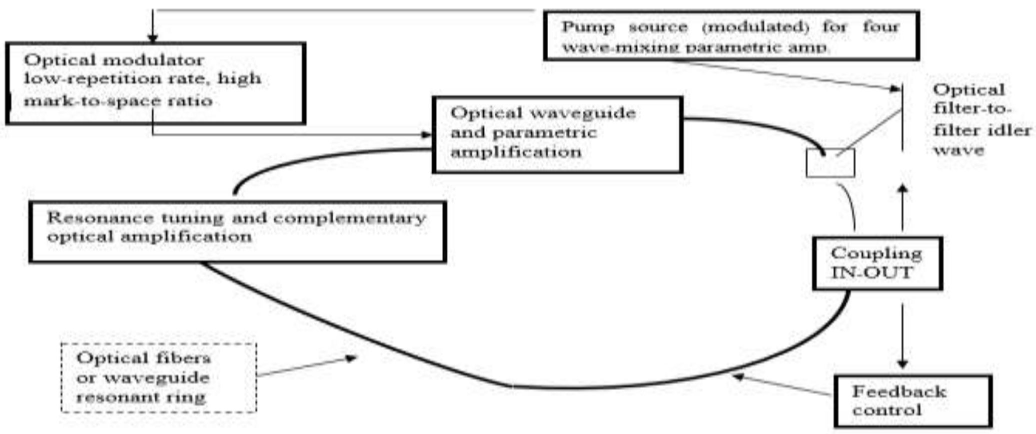

Figure 5: *Structure of a mode-locked laser using parametric amplification [4]*

As picosecond pulse generation in the bulk laser can frequently be reliable in a concentrated absorber action, so we cannot be ignored the dispersive and nonlinear effects in a fiber laser, even in the multipicosecond domain .Logically, the simplest and the easiest method that leads to the soliton fiber laser, where the current pulse also known as circulating pulses are quasi-soliton pulses.

In the passive mode-locking, the artificially concentrated absorbers are worked on the Kerr nonlinearity, are used mostly .One solution is to manipulate the non linear polarization rotation .In polarization rotation, the device is polarized by rotating it about ad ifferent axis through the laser beam .Polarization method in some length of fiber undergoes a complex rotation, which depends on the optical power due to self-phase and cross-phase modulation .In the end, the pulses are passedthrough a polarizing element that changes the polarization to power transmission.

The scope of the present research is to deliver the high power and repetition rates with the combination of the high pulse energies . The other scope of ultrashort pulses is to fulfill the demand of the applications of high capacity and high processing speed .Another scope is to determine the fundamental principles of generation of the ultrashort pulses using the fiber ring lasers .The objective of this is to analyze the ultrashort pulse sequence and then generate the ultra-short pulses .

II. RELATED WORK

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 the 10GHz 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] .9 .[

Jens Limpert, Fabian Roser, Thomas Schreiber, and Andreas Tunnermann)2006(reviewed the benefits of the ultrafast fiber laser systems and compared them with bulk solid-state lasers .Their high single-pass gain, heat dissipation capability, broad gain bandwidth, simplicity, robustness, and compactness make the fiber lasers more attractive for the host of applications .Rare earth doped photonic crystals fiber proposed the different properties that allow an upward scaling of performances than conventional fiber lasers .The transfer of additional functionality and their protracted optical parameter range to the fiber showed that such type of systems has the huge potential to scale the performance of next-generation laser systems through micro structuring].15]

F .Yoshino, H .Zhang and A .Arai)2009 (presented ultrashort 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 fiber laser model is designed for the medical diagnostics, imaging metrology, laser material processes, and scientific research. The study suggested 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 .A unique level of utility is proposed by ultrafast fiber lasers for advanced and commercial scientific applications of the ultrafast optics .In this research, extraordinary power levels can be produced in the spectral range from XUV to the THz region .Along with this, coherent super continuum generation has been explained in depth .At last, various techniques have been represented for controlling the phase of fiber amplifiers and fiber lasers]17.[

M .Mielke et.al)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 femto second 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 this, it has been estimated that Radiance lasers operate continuously around the clock without used by users .It needs the intervention of human only one time in approximately 27,000 hours .The applications and critical performance data associated with the Radiance ultrafast lasers has been presented.This research also presented an all-fiber erbium amplifier system which generated >100 μJ per

pulse using femtosecond class pulse width, an autonomous control system and excellent beam quality .The author presented the laser platform perform in this research and described the lifetime and reliability for ultrafast lasers]18 .[
M .M .Mielke, et .al)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 toxic 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, et .al) 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 .This research also proposed DUF fiber laser which is based on linearly chirped fiber Bragg grating in which the total cavity length is changeable .The result indicated that the total cavity length of DUF fiber laser is changeable linearly as the function of pulse wavelength] 20.[

III. RESEARCH GAPS

In 2000 ,*Nakazawa etal* demonstrated a 1.28Tbps transmission by OTDM 128 channels at 10Gbps .While were successful to do so for adistance of 70 km only.In 2002, *Gupta et al.*proposed to use a Fabry-Perot filter)FFP (inserted into the ring to equalize the pulse amplitudes in the RHMLFL .However, this method requires that the FFP's free spectral range)FSR (be equal to the repetition rate and additional circuit to stabilize the FFP.In 2005, *A .Tünnermann et al.*reviewed theefficiency and uses of high average power and high energy Ultrafast ytterbium-doped fiber laser systems. Nevertheless, the attributes that make fiber based laser systems attractive that are long interaction length still constitute the principal limitation of high peak power pulsed fiber laser systems, the nonlinear effects .Nonlinearity can lead to severe pulse distortions and can even cause damage to the fiber.In 2015,*Xueming Liu et al.*established a DUF fiber laser based on a linearly chirped fiber Bragg grating .Though it is simple, stable, has low-cost .Still, it also leads to a large amount of dispersion.
The development of optical communications after the invention of the optical fiber has fulfilled the demand in the past .But to keep up with the exponential growth of data traffic in the near and not-so-near future, more and more hardware components and transmission technologies have to be developed. The proposed model of generating Ultrashort pulsed using fiber laser attempted to overcome the restrictions of ultra-short fiber laser system to deliver high power and repetition rates in future with a combination of high pulse energies .This model could meet the demand of applications which require high processing speed and high capacity.

IV. RESEARCH METHODOLOGY

The overall work was done in the MATLAB and the OptiSystem Software .In this project, basically, the co-simulation of MATLAB is done which means that Optisystem is calledfrom the MATLAB Software .After the Co-Simulation, the plots of Optical-time domain visualizer and optical Spectrum analyzer were shown through the MATLAB Software.
The overall Optisystem Model is as shown below

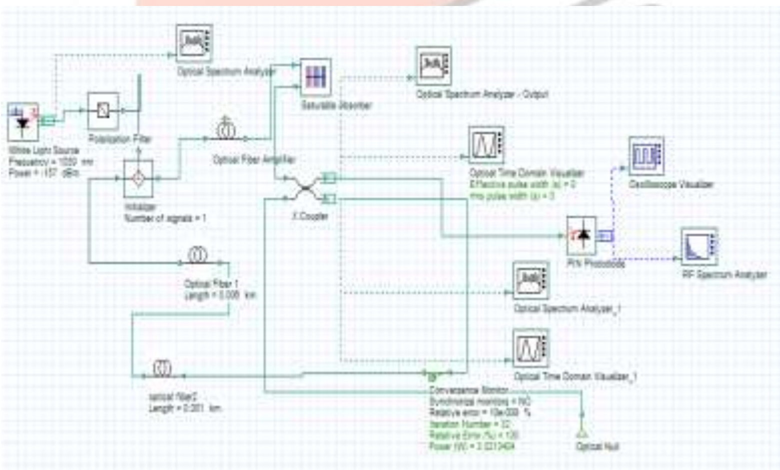

Figure 6: *OptiSystem Model*

The overall model represents the fiber laser, which is based on the mode locking and is capable of producing Ultra Short Pulses using saturable absorber .The system is composed of the optical fiber amplifier, DC components, and an undoped fiber .The main component is the Saturable absorber which is used to generate the optical pulse and to achieve mode locking .The white light source which is used in the starting of the model is to provide the noise that will initialize the pulse generation.
The various components that are used in the model include while light source, Polarization filter, Initializer, Optical Fiber Amplifier, Optical Fiber, X-Coupler, PIN Photodiode, Convergence monitor, Optical spectrum visualizer, and RF Spectrum Analyzer.

V. RESULTS

The overall model represents the fiber laser, which is based on the mode locking and is capable of producing Ultra Short Pulses using saturable absorber .The system is composed of the optical fiber amplifier, DC components, and an undoped fiber .The main component is the saturable absorber which is used to generate the optical pulse and to achieve mode locking .The white light source which is used in the starting of the model is to provide the noise that will initialize the pulse generation. Here are the plots of the final results obtained from the experimental model.

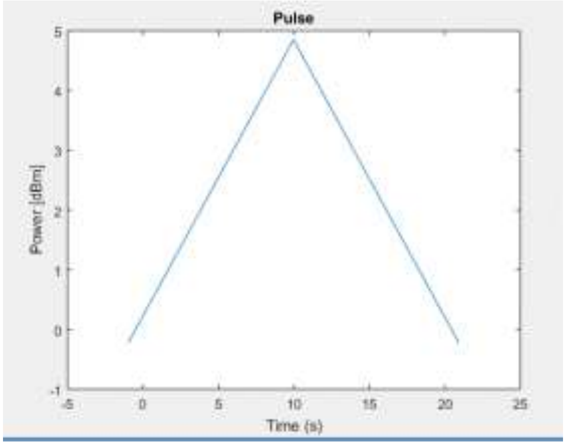

***Figure 7**: Optical-time domain visualize*

Figure 7 shows the plot of Optical time domain visualizer .The above plot was plotted through the MATLAB Software .This is the plot representing the Ultra Pulse having the Power in dBm vs .Time in seconds .This shows the highest peak point at Power 5 dBm and at time 10 seconds .Before this point, the waveform is in increasing direction, and after this point, it got decrease to the power of -0.5 dBm at 22 Seconds .

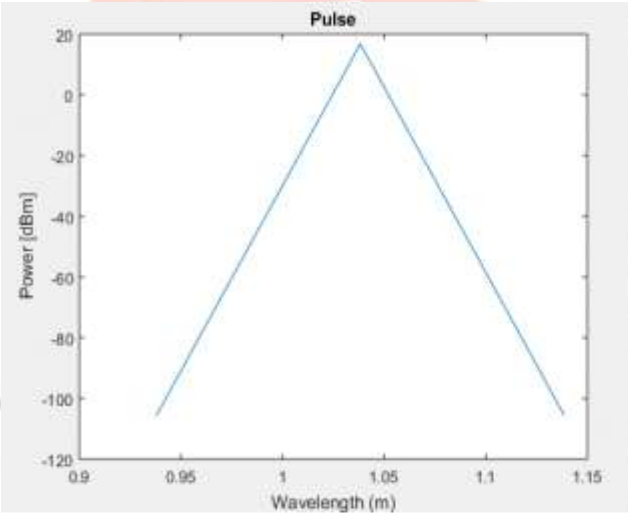

***Figure 8:** Output**:** Optical Spectrum Analyser*

Figure 8 is the plot of Optical Spectrum analyzer .The above plot was plotted through the MATLAB Software .This is the plot representing the Ultra Pulse having the Power in dBm versus.Wavelength in meters .This shows the highest peak point at Power 18 dBm and a wave length of 1.05 meters .Before this point, the waveform is in increasing direction, and after this point, it got decrease to the power of -110 dBm at 1.13 meters of wavelength .

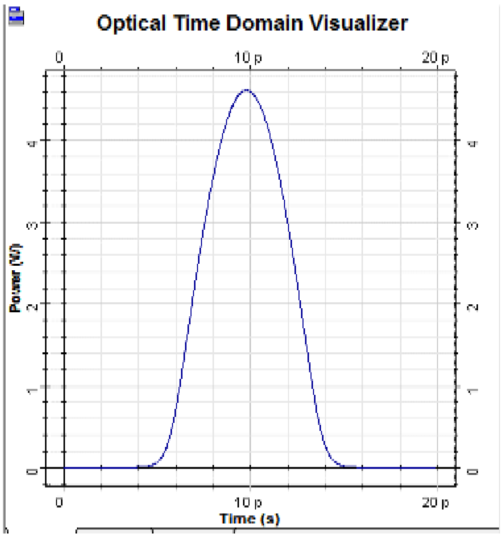

Figure 9: *Optical Time Visualizer*

Figure 9 shows the plot that is plotted through the Opti system Software .This is the plot representing the Ultra Pulse having the Power in W vs .Time in seconds .Thisshows the highest peak point at Power 4.8 W and at time 10 Pico-seconds .Before this point, the waveform is in increasing direction, and after this point, it got decrease to the power of 0 W at 15 Pico-Seconds .

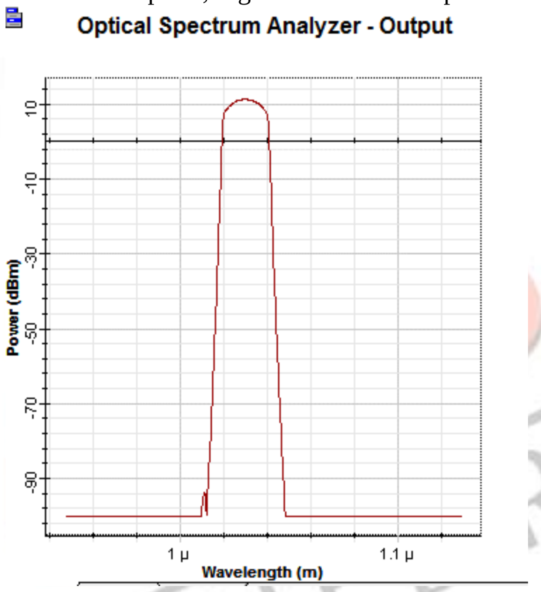

Figure 10: *Optical Spectrum Analyser*

The plot in figure 10 was plotted in the Optisystem Software .This is the plot representing the Ultra Pulse having the Power in dBm vs .wavelength in meters .This shows the highest peak point at Power 10 dBm and a wave length of 1.05 micrometers .Before this point, the waveform is in increasing direction, and after this point, it got decrease to the power of -100 dBm at 1.08 meters of wavelength .

VI. 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 .This research reviewed various sources used in the optical fiber communication .Further,the research analyzed different type of lasers along with their application areas and benefits **.**With the results of previous studies which have been done to identify the effective techniques utilized in the optical fiber communication, this research proceeded the further research on the ultrashort pulse generation and detection using fiber lasers with the mode**-**locking method **.**The research studied the fundamental principles of the generation of ultrashort pulses employing fiber lasers which include active optical modulators of amplitude or phase types. The research aimed to present experimental techniques for the generation of the ultrashort pulse sequence and to present detection methods of ultra-short pulse sequences.

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