isrjournals

International Journal of Advanced Research in Electronics, Communication & Instrumentation Engineering and Development

Volume: 3 Issue: 1 Apr,2021,ISSN_NO: 2347 -7210

Investigation of Ytterbium Doped Fiber Amplifier Region in 1µm Region for High Gain Enhancement

Reena Roslin Raj I[1],Srinivasan P[2],Vasanth R[3],Vignesh V[4]

Assistant Professor[1],Department of ECE, DMI College Of Engineering,

UG Scholar[2 3 4], Department of ECE, DMI College Of Engineering.

reenaroslinraj@gmail.com[1], santhoshsrinivasan28@gmail.com[2]

r.vasanth2210@gmail.com[3] ,vignesgv152@gmail.com

Abstract: In this paper, The high power and high performance amplifiers are needed for application such as LIDAR, remote sensing and WDM transmission system. The adaptation of Ytterbium -doped amplifiers (YDFAs) can offer larger bandwidth, high dynamic range ,and multi-watt output power. The Non -linear effects of optical channel can be minimized by optimal selections of signal wavelength with proper channel spacing. Multiple numbers of channels are combined using CWDM and DWDM based multiplexing techniques .The signal wave length selected to be in the range [1020nm -1055nm].The input power were dynamically adjusted and based on channel condition These optimal selected signal wavelengths are amplified using YDFA based amplifier and distributed over fibers. The length and doping concentration in YDFA were optimized for larger OSNR. The pumping wave lengths are chosen in such way the excitation of Ytterbium ions takes places which can amplifier the input wavelength accordingly. The triple pumping method is utilized with pumping wavelength namely 900nm,940nm,and960nm to provide peak gain over bandwidth. The operating power of input and pump signal are kept at optimum levels. The data transmitted over distributed networks can be done to transports data between end points. Direct optical amplification is performed rather electrical conversions. The new set of optical generated carrier signals were generated for transmission with help of frequency offset and distributed to various optical network units. the optical switches are used to direct the channels to proper receiver end system.

Keywords- Ytterbium, Amplifier Region

I. INTODUCTION

Communication is transmission of information from one place to another through one medium. Mankind has been using many mediums for the data transmission. One of these mediums that really had a big impact on data transmission was coaxial-cable system. The first coaxial-cable system, deployed in 1940 [2], was a 3MHz system which could transmit 300 voice channels. But these coaxial-cables, they mostly suffer from high cable losses and repeater spacing is also very limited and is costly for a longer transmission length. And these shortcomings led to the development of microwave communication system.

Microwave communication system uses electromagnetic carrier waves in the range of GHz to transmit signals with different techniques to modulate the carrier waves. The microwave communication system allowed larger repeater spacing but suffered from limited bit rate.

Then Optical fiber was first developed in the 1970s, which revolutionized the telecommunications industry and played a major role in the Information era. Because of its advantages over electrical transmission, optical fibers have largely replaced copper wire communications in core networks in the developed world.

Optical communication system use high carrier frequency (~100 THz) in the visible or near-infrared region of the electromagnetic spectrum. Because of its low loss, high capacity and bit rate it became more popular.

An optical fiber communication system has three basic components, transmitter, receiver and the transmission path as shown in the figure.

isrjournals

International Journal of Advanced Research in Electronics, Communication & Instrumentation Engineering and Development

Volume: 3 Issue: 1 Apr,2021,ISSN_NO: 2347 -7210

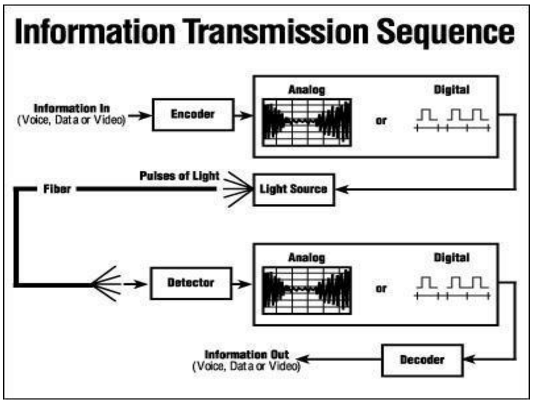


Figure 1.1

Block diagram of Optical fiber communication system

In the transmitter side the input signal is generated by a data source. The optical source is a laser source which generates optical light signal at a certain wavelength. The data source and the optical signal are fed to the modulator and then the resulting modulated pulse signal propagates through the transmission path which is an optical fiber.

At the receiver side the optical signal is detected through an optical detector. The detected signal then passes through the demodulator to get the desired output signal. An optical fiber is a flexible thin filament of silica glass that accepts electrical signals as input and converts them to optical signal. It carries the optical signal along the fiber length and re converts the optical signal to electrical signal at the receiver side.

As depicted above, information (voice, data, or video) is encoded into electrical signals. At the light source,these electrical signals are converted into light signals.

It is important to note that fiber has the capability to carry either analog or digital signals. Many people believe that fiber can transmit only digital signals due to the on/off binary characteristic of the light source. The intensity of the light and the frequency at which the intensity changes can be used for AM and FM analog transmission.

Once the signals are converted to light, they travel down the fiber until they reach a detector, which changes the light signals back into electrical signals. This area from light source to detector constitutes the passive transmission subsystem; i.e. that part of the system manufactured and sold by Corning Cable Systems.

Finally, the electrical signals are decoded into information in the form of voice, data, or video.

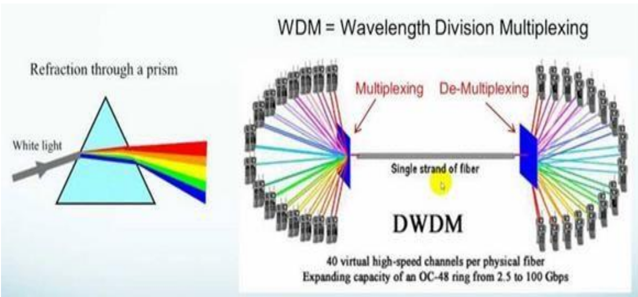
II. WDM TECHNOLOGY

WAVELENGTH DIVISION MULTIPLEXING

Wavelength division multiplexing (WDM) is a technique modulating various data streams, i.e. optical carrier signals of varying wavelengths in terms of colours of laser light onto a single optical fiber. Wavelength division multiplexing WDM is similar to frequency-division multiplexing (FDM) but referencing the wavelength of light to the frequency of light. WDM is done in the IR portion of the electromagnetic spectrum instead of taking place at radio frequencies (RF). Each IR channel carries several RF signals combined with frequency-division multiplexing (FDM) or time-division multiplexing (TDM).

Each multiplexed infrared channel is separated or demultiplexed into the original signals at final point. Data in different formats and at different speeds can be transmitted simultaneously on a single fiber by using FDM or TDM in each IR channel in combination with WDM. It allows network capacity to be gradually and cost effectively increase.

1.2 WDM



WDM enables bi-directional communication and multiplies signal capacity. Each laser beam is modulated by separate set of signals. Since wavelength and frequency have an inverse relationship (shorter wavelength means higher frequency), the WDM and FDM both contains the same technology in them.

At the receiving end, Wavelength- sensitive filters, IR analog of visible-light color filters are used.The first WDM technique was conceptualized in the early 1970s. Later, Wave division multiplexing (WDM) systems were able to handle 160 signals that will expand a 10 Gbit/second system with a single fiber optic pair of conductors to more than 1.6 Tbit/second (i.e. 1,600 Gbit/s).

The first WDM systems were two-channel systems that used 1310nm and 1550nm wavelengths. Shortly afterwards came multi-channel systems that used the 1550nm region – where the fiber attenuation is lowest.

Wavelength division multiplexing systems can combine signals with multiplexing and split them apart with a de-multiplexer. WDM systems are popular with telecommunications companies because they allow them to expand the capacity of the network without laying more fiber by using WDM and optical amplifiers.

These two devices work as drop multiplexer (ADM), i.e. simultaneously adding light beams while dropping other light beams and rerouting them to other destinations and devices and this type of filtering of light beams were made possible with e talons, devices called Fabry- Perot interferometers using thin-film-coated optical glass. In general, WDM systems use single-mode optical fiber (SMF) in which only a single ray of light having a core diameter of 9 millionths of a meter (9 µm).

Other systems with multi-mode fiber cables (MM Fiber) which are also called as premises cables have core diameters of about 50 µm. Present modern systems can handle up to128 signals and can expand a basic 9.6 Gbps fibre system to a capacity of over 1000 Gbps. It is mostly used for optical fiber communications to transmit data in several channels with slight variation in wavelengths. WDM can increase the total bit rate of point-to-point systems.

III. YDFA

Though the first Ytterbium-doped fiber laser was demonstrated as early as 1988 , Yb-doped fibers were not commonly used in the beginning. The main reason for this, was the popularity of Neodymium and Erbium doped fibers. Neodymium doped fibers exhibit a four-level behavior with highly efficient emission at 1060 nm wavelength for pumping at 800 nm. Erbium doped fibers have the advantage that their emission wavelength (1520 to 1600 nm) lies in the telecommunication wavelength region and they can be pumped at a number of wavelengths from 510 to 1480 nm. However, these systems have certain disadvantages, for example, excited state absorption in Erbium-doped fibers and limited emission bandwidth in Neodymiumdoped fibers, which limits the gain and applications of such fibers. Therefore the attention turns to other rare-earth-doped fibers. A detailed study of various advantages of Ytterbium-doped fibers was presented by Paschotta et al., in 1997 and this served as a door to renewed interest in these fibers.

The key characteristics of Ytterbium-doped gain medium which results in its numerous advantages are discussed in this subsection. Electronic level structure of Yb3+ ions The electronic structure of Yb3+ ions is shown in Fig. 2.7 [38], with only the two main energy levels involved in light amplification, the ground level manifold (2F7/2) and a higher excited manifold (2F5/2).

isrjournals

International Journal of Advanced Research in Electronics, Communication & Instrumentation Engineering and Development

Volume: 3 Issue: 1 Apr,2021,ISSN_NO: 2347 -7210

These energy levels are split into sub-energy levels by the Stark effect and pump and laser transitions occur between various subenergy levels as indicated in Fig. 2.7, by red and green arrows, respectively. The main advantages of Ytterbium-doped gain media arise from the fact that only one excited state manifold is involved in the laser transition.

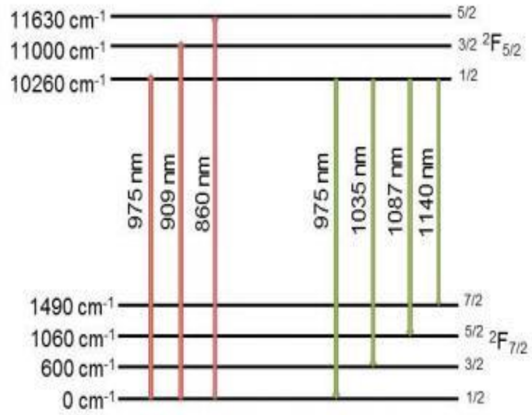
The relatively small energy gap between the ground and excited-state results in extremely low quantum defects. Consequently high power efficiency is possible, and many detrimental effects such as thermal effects, quenching and excited state absorption are significantly reduced [39].

The low quantum defect also results in some disadvantages such as a pronounced quasi-3-level behavior.

Yb-doped fibers exhibit quasi-3-level or 4-level behaviors depending on the pump and seed wavelengths. For emission wavelengths less than 1080 nm, the lower laser transition state is located very close to the ground level (see Fig. 2.7) similar to a quasi-3-level system.

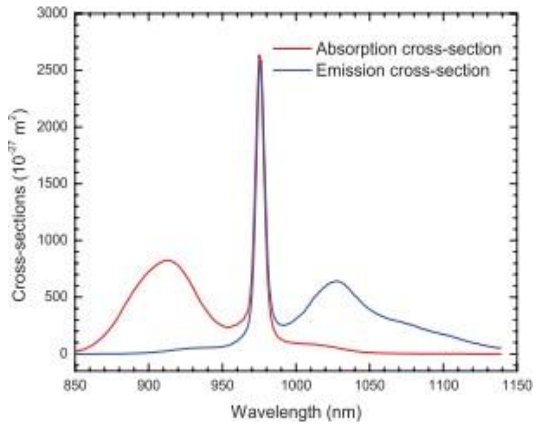
There is significant population in this level at thermal equilibrium, which causes re- absorption losses [39] in the un-pumped gain medium and consequently, higher laser thresholds are required compared, for instance, to Nddoped fibers [40].

Beyond 1080 nm, the laser transitions occur at energy levels 11 considerably higher than ground-level and hence the system exhibits a 4-level behavior. Due to the large energy gap between the ground level and lower laser level, population inversion is easily achieved and the laser threshold is reduced in this regime.



1.3 YDFA Energy Level

Yb3+ energy level structure, consisting of two manifolds, the ground manifold (2F7/2) (with four Stark levels), and higher excited manifold (2F5/2) (with three Stark levels). Approximate energies in wave-numbers above ground energy are indicated on the left side.



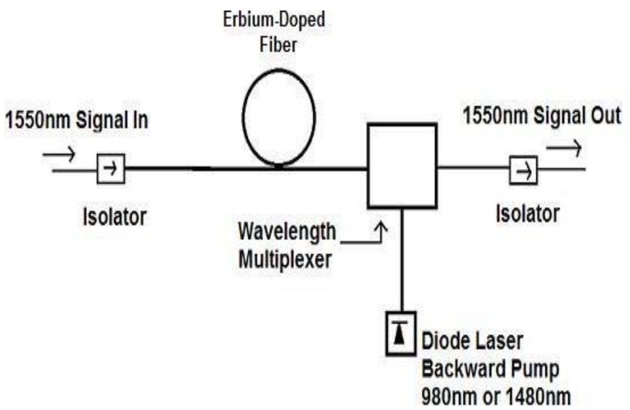
The simple electronic structure of Yb-ions leads to highly pronounced absorption and emission cross-sections, which are also strongly dependent on the host medium of the Yb3+ ions. Germanosilicate glass is the most common host medium, which is typically the material used in Yb-doped fiber cores. The corresponding absorption and emission cross-sections, as presented in [37], are shown in Fig. 2.8. The two peaks in the absorption cross-section provide the obvious choices for pump

isrjournals

International Journal of Advanced Research in Electronics, Communication & Instrumentation Engineering and Development

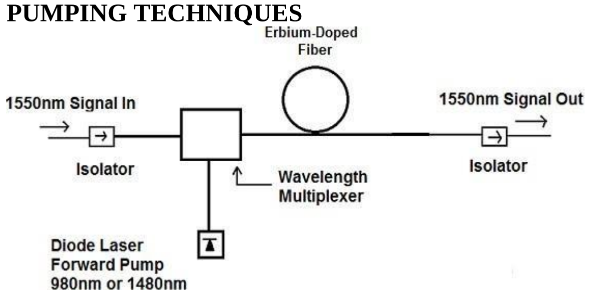
Volume: 3 Issue: 1 Apr,2021,ISSN_NO: 2347 -7210

wavelengths. At 910 nm the absorption cross-section is broad but relatively low and strong pumping is required to achieve high gain. Nearly 97 % upper state population can be achieved [37] with strong pumping. However strong pumping can lead to significant ASE at 975 nm which in turn limits the maximum gain available for amplification at longer wavelengths. The high absorption cross-section at 975 nm results in very efficient pumping at this wavelength and the problem of ASE at 975 nm can also be avoided. However, since the absorption and emission cross-sections are of almost equal magnitude at 975 nm, the maximum upper state population achievable is only 50 %. The narrow absorption peak also results in greater sensitivity to pump source parameters at this wavelength. Gain can be achieved either at the narrow 975 nm emission peak or over a broader 1000 nm to 1100 nm range. The broad amplification bandwidth is highly suitable for ultra-short pulse amplifications. Due to a strong 3-level behavior at 975 nm amplification wavelength, the re-absorption loss in an un-pumped fiber is very high and the length of the fiber has to be carefully optimized. Though it was initially believed that the low quantum defect would avoid quenching effects, strong lifetime quenching was observed in Yb-doped fibers [41].



Despite the disadvantages such as re-absorption losses and pronounced ASE, Ytterbium-doped fibers offer many advantages such as high power efficiency, low thermal effects and high gain bandwidth. These advantages make them especially attractive for high power and ultra-short pulse propagation applications.

IV. PUMPING TECHNIQUES



There are three ways to pump the Er^{3+} ions from the ground state to the upper states.

- Forward Pumping or Co-directional Pumping
- Backward Pumping or Counter-directional Pumping
- Bi-directional Pumping

Forward Pumping

In forward pumping the input signal and the pump signal propagate in the same direction inside the fiber. The input signal and pump are combined using a pump combiner or wavelength division multiplexer. Inside the fiber the pump energy is transferred to the input signal and the signal is amplified at the output of the amplifier. Isolators are used in the scheme to make sure that the signal will travel only in one direction and no feedback of signal will occur.

Backward Pumping

In Backward pumping the input signal and the pump signal ropagate in the opposite direction to each other inside the fiber. For amplification the direction of input and pump signal is not essential. They can travel in any direction.

Bi- Directional Pumping

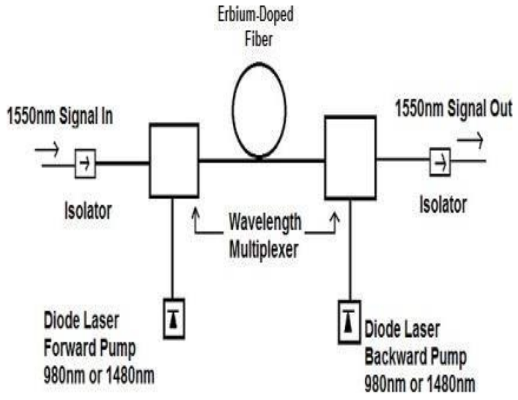
In Bi-directional pumping the input signal travels in one direction. But the there are two pump signals that travel inside the fiber. One pump signal travels in the same direction as the input signal and the other pump signal travels in the opposite direction to that of the input signal.

The different pumping configurations are shown in the figure [3.1, 3.2, 3.3].

isrjournals

International Journal of Advanced Research in Electronics, Communication & Instrumentation Engineering and Development

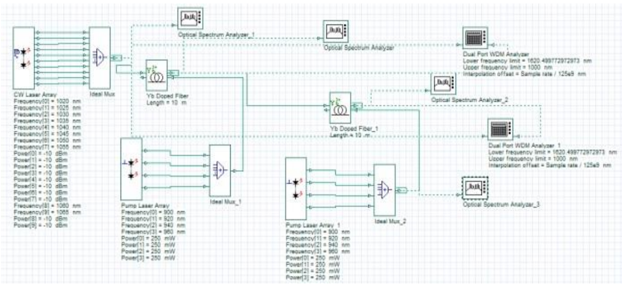
Volume: 3 Issue: 1 Apr,2021,ISSN_NO: 2347 -7210

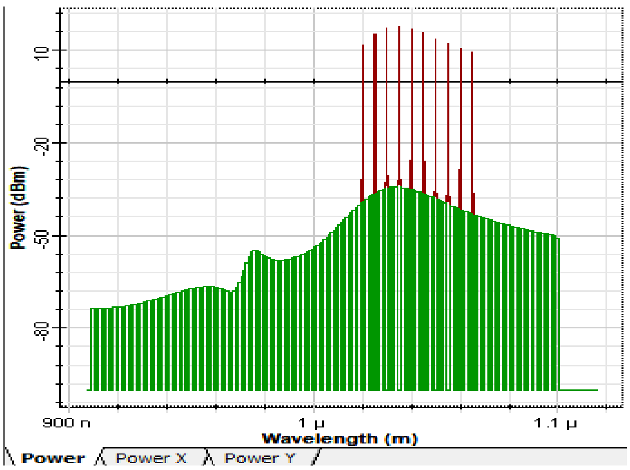


Bi-directional Pumping

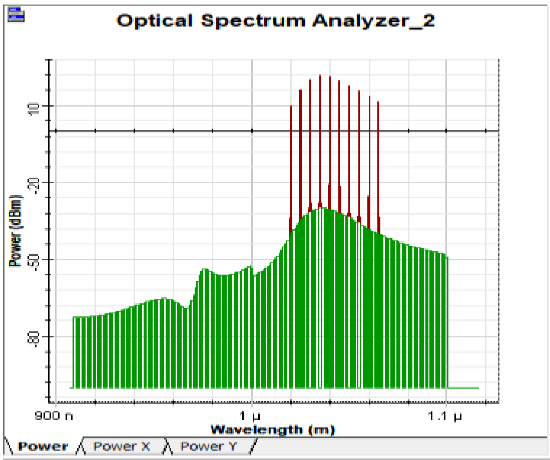
V. SIMULATION

On the transmitter side, WDM transmitter act as a source which comprises of 10 channels with starting wavelength 1020nm having frequency spacing of 5nm operated at an input power of [-10dbm,-20dBm,0dBm]. The channels are multiplexed using ideal multiplexer and amplified using cascaded ytterbium doped fiber amplifier having a length of 10m.

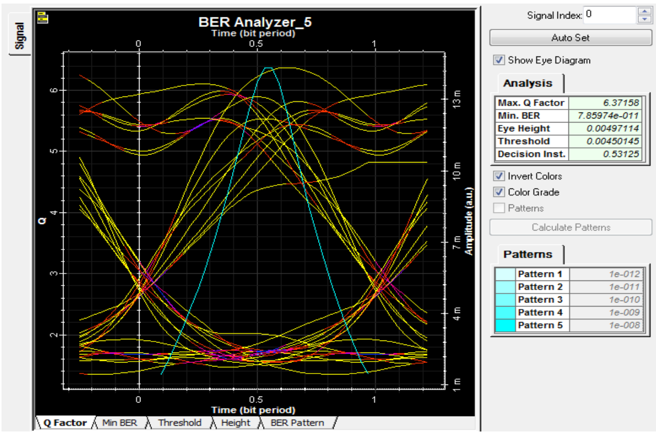




The modulated signal are amplified by YDFA and



de- multiplexed to reach separate ONU. The signal is then selected with the help of select switch with the help of PRG (Pseudo random generator) and given to the optical Bessel filter for passing out desired optical wavelength which runs through an optical fiber with specified distance to reach the endpoints of receiver and then converted into electrical signal with the help of PIN/APD diode. Then the signal is passed through low pass filter having a specific cut off frequency which converts signal into baseband level and given to 3R regenerator which tries to reshape the distorted pulse shape and then its spectral gain, quality factor are analyzed. The plots such as BER analyzer, spectrum analyzer, time domain and eye diagram Analyzer are plot.



VI . CONCLUSION

This paper represents the detailed review of different methods used for analysing the performance of optical link using YDFA and WDM technology along with application areas. The operation of YDFA is revised with different pumping configurations. Among all the techniques, the bi-directional techniques provides flat gain and low noise figure . The proper Pumped wavelength is assigned with optimal power so that it may excite the ions in YDFA to a higher energy state from lower energy state which can contribute the amplification of the input regional. The parameters such as length of the fiber (YDFA), ionic concentration and doping level are the key factor in determining the output OSNR. The need for frequency conversion is done in receiver to generate new derived frequency which are responsible for Bi-directional communications over networks . The Optical switches are implemented to direct the way of communication between the end user that are located at different optical network.

The Gain, OSNR, BISR, Noise figure property are analysed and plotted.

VI. REFERNCES

1. Sharma SR, Sood T. Gain flattening of EDFA with hybrid EDFA/ Raman amplifier with reduced channel spacing. Int J Eng Dev Res. 2015;3:1–7.
2. D. Z. Mohammed and A. H. Al-Janabi, "Passively Q-switched erbium doped fiber laser based on double walled carbon nanotubes-polyvinyl alcohol saturable absorber," Laser Phys., vol. 26, no. 11, pp.115108, 2016. DOI: 10.1088/1054-660X/26/11/115108.
3. D. Z. Mohammed and A. H. Al-Janabi, "Large diameter coreless fiber as a saturable absorber for erbium doped fiber laser cavity based on multimode interference," Opt. Fiber Technol., vol. 50, pp. 212–215, 2019. DOI: 10.1016/j.yofte.2019.04.002.
4. A. H. Al-Janabi and D. Z. Mohammed. "Stability evaluation of passively Q-switched erbium doped fiber laser based on double and multi-walled carbon nanotubes," in Frontiers in Optics, 2017, pp. FTu5A. 4. OSA Publishing/ Washington, D.C. United States.
5. W. A. Khaleel and A. H. Al-Janabi, "Erbium-doped fiber ring laser with wavelength selective filter based on nonlinear photonic crystal fiber Mach–Zehnder interferometer," Laser Phys., vol. 27, pp. 105104, 2017. DOI: 10.1088/1555-6611/aa8287.
6. S. K. M. Al-Hayali, D. Z. Mohammed, W. A. Khaleel, and A. H. Al-Janabi, "Aluminum oxide nanoparticles as saturable absorber for C-band passively Q-switched fiber laser," Appl. Opt., vol. 56, no. 16, pp.4720–4726, 2017. DOI: 10.1364/AO.56.004720.
7. K. Schuhmann, et al. "Multipass amplifiers with self-compensation of the thermal lens," Appl. Opt., vol. 57, pp. 10323–10333, 2018. DOI: 10.1364/AO.57.010323