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RESEARCH ARTICLE

Generation of Multiwavelength Fibre Laser based on Erbium-Doped Fibre Amplifier with Lyot Filter

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Abstract A ring cavity setup consisting of erbium-doped fibre amplifier (EDFA) as the optical pump and lyot filter aids in the production of a multiwavelength spectrum. The wavelength of EDFA pumps in photons range of 1530 nm to 1560 nm, respectively. Using maximum power of 18 dBm and a single mode fibre (SMF) of 10 km length, the number of peak lasing lines produced between 3 dB spectral range is 51. Tuning of the polarization controller (PC) to a specific angle helps provide the most stable lasing line. Stability test is done on the output multiwavelength fibre laser (MWFL) over a time period to analyze the wavelength stability.

Keywords: Multiwavelength fibre laser; Erbium-doped fibre amplifier; Lyot filter, Fibre laser.

Introduction

With the idea of building a conventional laser source that gives out a stable output and using optical fibre, this paper is focused on generating a MWFL. The generation of this multiwavelength is made possible by using an optical amplifier in the form of EDFA since it has the ability to provide optical feedback when placed inside a closed cavity [1]. The optical feedback produced will result in laser being emitted and this type of laser are known as a fibre laser. The importance of generated MWFL is that the gain medium for this laser is the optical fibre that has been doped and this results in high-quality beams being produced [1].

Using Lyot filter in the generation of the MWFL helps to aid in the production of the optical feedback because Lyot filters have a simple setup and the optical loss experienced in the cavity will be relatively low [2]. It has the ability to produce a continuous wavelength transmission that is broader compared to using FBG [3]. EDFA will function to compensate the loss and dispersion of signal which happens due to long-distance communication [4]. The compensation is done in the form of booster amplifier, in-line amplifier and pre-amplifier as illustrated in Figure 1.

MWFL today have been studied extensively by photonics research community due to its applications of in optical communication system, optical instrument testing and signal processing [5].

Lyot Filter

A Lyot filter, named after the French astronomer Bernard Lyot who invented it in the 1930s, is an optical device with a primary function of narrowband filtering of light. The key feature of a Lyot filter is its ability to transmit only a very narrow range of wavelengths, making it a valuable tool for isolating and studying specific spectral lines or features in the light spectrum.

The design of a Lyot filter is based on polarization principles, incorporating elements such as polarizers, birefringent materials (commonly quartz crystals), and analyzers. The initial polarizer sets the light into a

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polarized state, and the birefringent crystal introduces wavelength-dependent phase shifts. The analyzer compensates for these shifts, allowing only the desired narrowband of wavelengths to pass through.

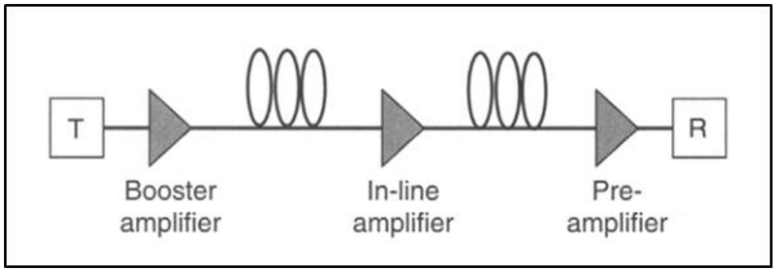

Figure 1 Booster, in-line, and pre-amplifier EDFAs used in optical transmission line [4]

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Despite their sophisticated function, Lyot filters are known for their relatively simple setup, facilitating ease of implementation, alignment, and maintenance. They exhibit low optical loss, preserving the quality of the observed signal. LLyot filters play a critical role in enabling detailed and focused observations of specific wavelengths in astronomical research.

Materials and Methods

The main active component used in the build-up of the ring cavity is the EDFA which ranges over c-band region in wavelength. The maximum power supplied by the EDFA will be 18 dBm. Since EDFA is able to work bidirectionally, both ends of the EDFA were connected to a 3-port and a 4-port optical circulator respectively. The 3-port circulator will be called Circulator 1 whereas the 4-port circulator will be known as Circulator 2. Port 3 of Circulator 1 and Port 4 of Circulator 2 come together through the 50/50 optical coupler (OC) before travelling through an 20/80 OC. 20 % of coupler output will go into the optical spectrum analyzer (OSA).

The remaining 80 % then travel through the highly non-linear fiber (HNLF), PC1, polarization maintaining fiber (PMF), PC2 and polarization dependent isolator (PDI) to provide a stable lasing output. Once passing through the PDI, the signal will go to a 50/50 OC whereby the signal will then be divided into two separate parts and recombine back to Port 1 of Circulator 1 and Circulator 2 respectively. Circulator 2 will be connected to the SMF and isolator and this completes the ring cavity shown in Figure 2 in generation of MWFL.

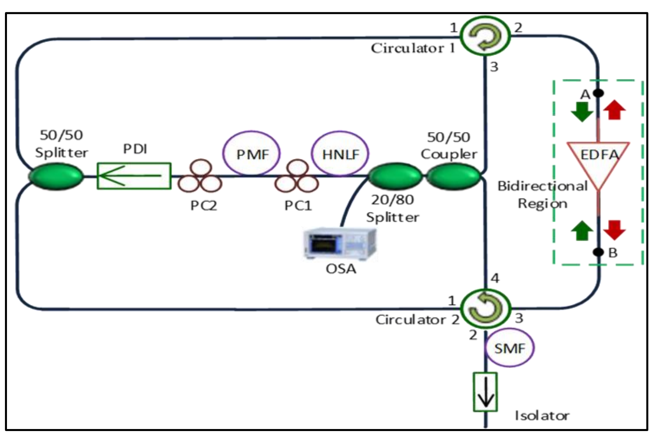


Figure 2. Generation of MWFL

Component Characterization

A technique used on passive optical components in order to determine if the components are working well without resulting in too much loss in the signal [6]. This known insertion loss that happens because the signal that travels through a component will experience a certain amount of signal loss. The lesser the signal loss, the better the component function.

Fibre Condition and Length Measurement

An assessment was conducted to ensure the operational integrity of the utilized fibres while minimizing insertion loss. The three types of fibres employed -SMF, PMF and HNLF, vary in length, and tests were performed to detect any undesired fibre breakages. This examination involved connecting one end of each fibre to an Optical Time Domain Reflectometer (OTDR).

The HNLF has a length of 1050 meters (1.05 kilometers), while the PMF spans 52.7 meters (0.0527 kilometers). In the case of the SMF, three distinct fibres were utilized with lengths of 10039 meters (10.039 km), 3016 meters (3.016 km), and 109 meters, respectively.

Results and Discussion

Generation of the Multiwavelength Fibre Laser

A multiwavelength spectrum is produced through the generation of MWFL in the ring cavity set-up. The lasing threshold plays a vital role in knowing when the optical pump will be dominated by stimulated emission rather than spontaneous emission [7]. The lasing threshold of the optical pump was measured before carrying out the experiment by manipulating the pump current power that is being sent into the ring cavity and observe the output power produced. the 20 % output ratio of the 20/80 OC will be connected to the optical power meter (OPM) and Figure 3 shows the graph of output power against the EDFA supply obtained.

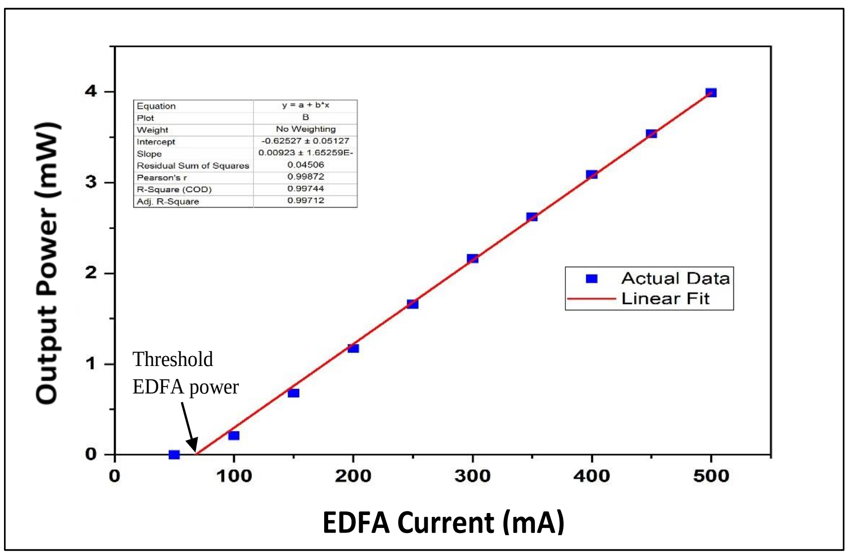


Figure 3. Graph of output power against EDFA current

Figure 3 reveals that the threshold lasing power is around 70 mA. From that point forward, the graph shows a proportionate growth, and at a maximum EDFA current power of 500 mA, the output power produced is 3.99 mW. Generating the MWFL as illustrated in Figure 4, was done by removing the OPM from the optical coupler and the 20 % output is then connected to the optical spectrum analyzer (OSA).

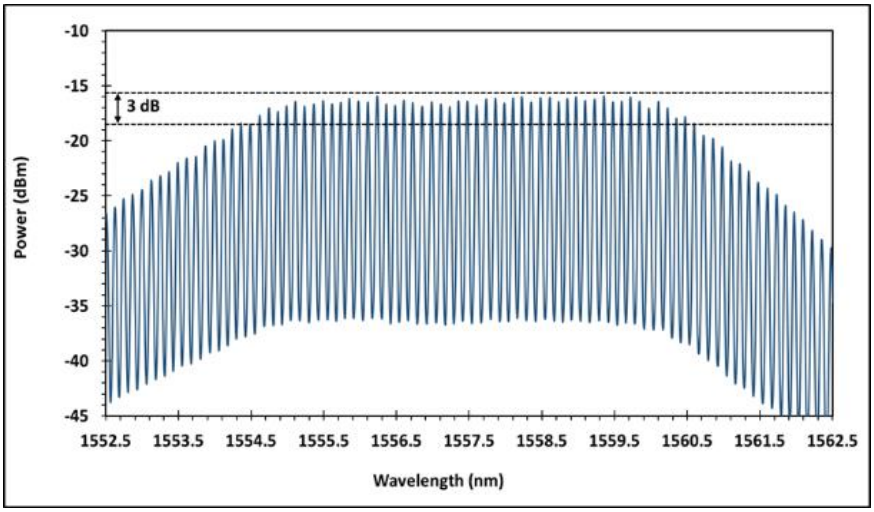


Figure 4. MWFL generated by 18 dBm EDFA using 10 km SMF

Effects of Single-Mode Fibre length on MWFL

The use of SMF in the ring cavity is modified to different lengths and the output lasing line produced was noticed. The use of 10 km SMF resulted in 51 peak lasing lines in the 3 dB spectral region. 3 dB is chosen because an increase or reduction of 3 dB results in a doubling or halving of power [7]. The EDFA's output was tuned to a maximum of 18 dBm, and the PC plates were adjusted to stabilise the laser line. Figure 5 depicts the results achieved.

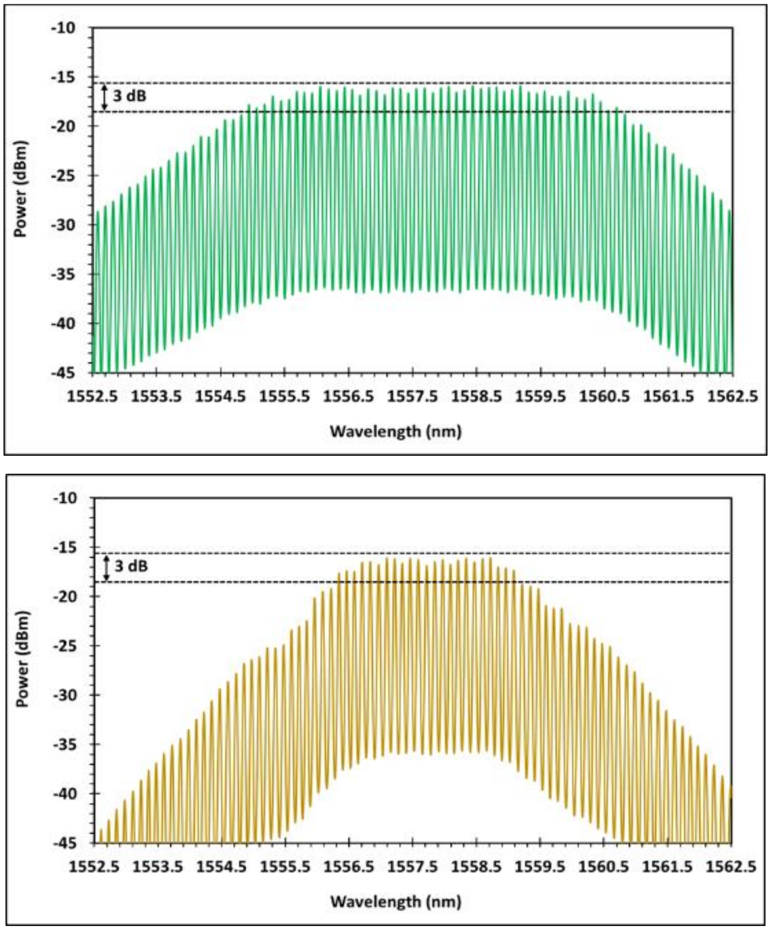
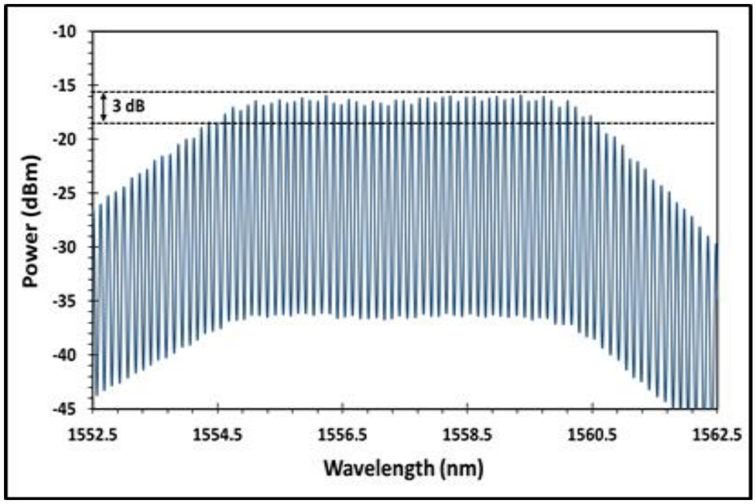


Figure 5. MWFL generated by 18 dBm EDFA using 3 km SMF and 100 m respectively

The multiwavelength spectrum depicted in Figure 5 shows 46 and 23 peak lasing lines produced within the 3-dB spectrum range employing 3 km and 100 m SMF, respectively. It proves that the stability of the MWFL is not as efficient when the length of SMF is shorter and this is due to the direct result of the Rayleigh Backscattering (RB) signal produced by the SMF [6].

Optimization of MWFL Performance

Optimization of the output wavelength spectrum is done based on the power supplied by EDFA, polarization controller tuning and the laser stability. Figure 6 shows that the flatness of the lasing line decreases as the power that is supplied by the EDFA decreases.



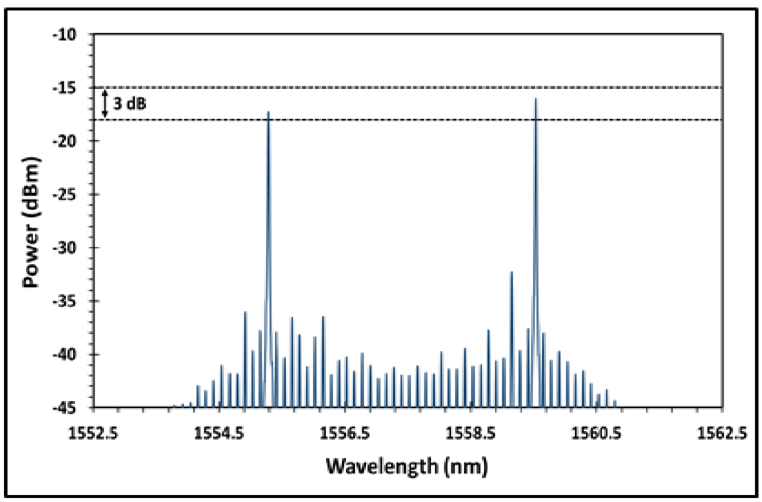


Figure 6. MWFL generated using 18 dBm and 3 dBm respectively

The manual fiber polarization controller is made up of 3 disks that will be tuned to different angles in order to study the effects on the output lasing line produced. Tuning the PC plates resulted in the fiber to be bend and rotated. Figure 7 illustrates the different angles of HWP in PC and the output lasing line produced.

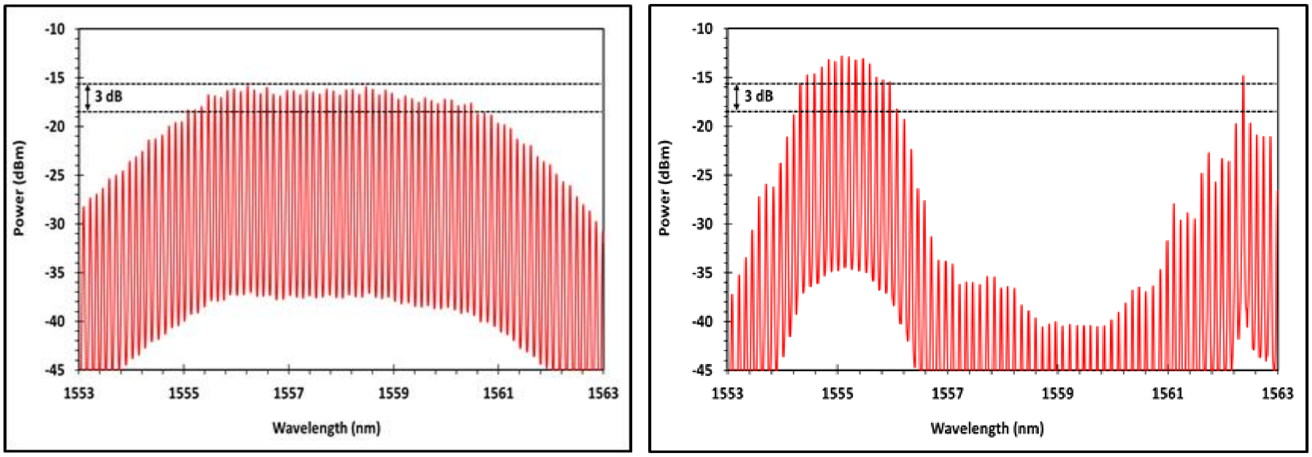


Figure 7. MWFL generated using different HWP angle of 60° and 30° respectively

Laser stability is the ability of the output laser to produce a stable MWFL over a period of time without much fluctuation. Figure 8 shows the laser stability of the output MWFL over 120 minutes time period.

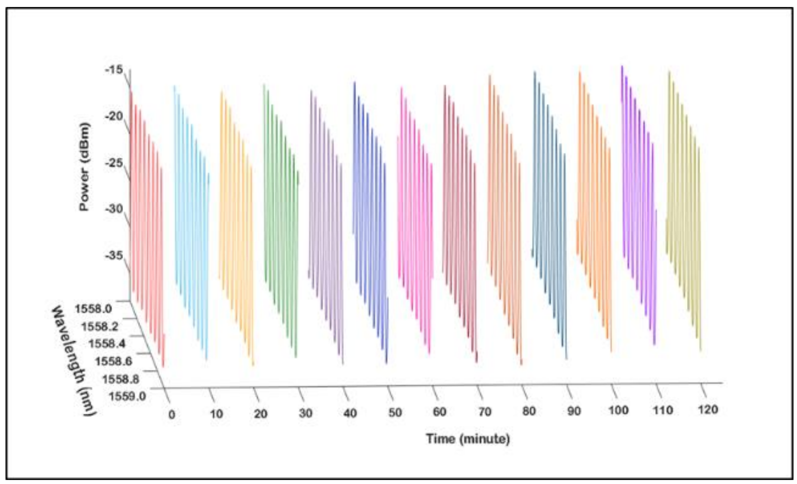


Figure 8. Laser Stability of the output MWFL

Conclusions

The generation of multiwavelength fiber laser (MWFL) based on EDFA and Lyot filter is successful due to the stable output lasing line that are produced. The threshold lasing power is approximately 70 mA before being able to provide a laser output and at maximum EDFA current power of 500 mA, the output power produce is 3.99 mW. The use of 10 km SMF in the ring cavity is able to produce 51 peak lasing line within the 3 dB spectral range and it is the most effective compared to shorter SMF length. Maximum power was able to produce the best lasing line and the flatness of the lasing line decreases as the power that is supplied by the EDFA decrease. Tuning the PC will provide the most stable lasing line. The stability test that was done on the output MWFL is able to prove the stableness of lasing line over a time period of 120 minutes at a wavelength range of 1558 nm to 1559 nm approximately.

Conflicts of Interest

The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Acknowledgement

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