Multiple-Wavelength Source based on SOA and Sagnac Loop Mirror

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Abstract

A simple multi-wavelength fiber laser based on a semiconductor optical amplifier (SOA) and Sagnac loop is proposed. At a 150 mA bias current, 6 lines are obtained with at least -40 dBm output power and 25 dB signal to noise ratio (SNR). The 1.49 nm channel spacing and number of lines is determined by the length of the PMF used in the loop mirror. The multi-wavelength comb output can be tuned by adjusting the operating temperature of the SOA. The source has the advantage of a simple configuration, stability at room temperature and a broad wavelength band.

Keywords: multi-wavelength fiber laser, SOA, fiber laser.

Introduction

Recently, multiwavelength fiber lasers have become the focus of most research activities due to their possible applications in wavelength-division-multiplexed (WDM) systems for communications, fiber sensor systems, optical code division multiple access (OCDMA) systems and optical test instruments [1–5]. To fulfill this role, fiber lasers developed using erbium-doped fibers (EDFs) were initially selected due to their well-know characteristics and compatibility with other optical components. However, simultaneous multi-wavelength operation in EDF lasers is difficult to achieve, as the large homogeneous line broadening of the EDF at room temperature leads to strong mode competition and subsequently loss of stability in the output power level. While multiwavelength EDF lasers were successfully reported either by immersing the EDF in liquid nitrogen [2] or using specially designed twin-core EDFs [3] to reduce the homogeneous broadening, these techniques are not viable as they are either not well suited for practical applications or very costly.

An alternative to EDF based multiwavelength fiber laser would be the development of a semiconductor optical amplifiers (SOA) based multiwavelength fiber laser. SOAs are very popular for amplifying signals in optical networks as they are compact, light and have low power consumption. As the SOA's design is based on that of a semiconductor laser, it is also cheap and mass producible. Additionally, the SOA has a dominant

inhomogeneous broadening property unlike the dominant homogeneous broadening property of the EDF. Therefore, the SOA-based multiwavelength fiber laser will be able to generate more lasing modes than EDF-based multiwavelength lasers, in which the lasing modes are generally limited to 4 [6]. In this paper, a new optical fiber ring laser configuration with an SOA gain medium and a Sagnac loop mirror as a comb filter for multiwavelength operation is proposed. The multi-wavelength source has several important advantages such as stable multi-wavelength operation at room temperature, a broad workable wavelength band and no need for optical pump lasers and has many potential applications in WDM and sensing systems.

Experimental Setup

Figure 1 shows the experimental setup of the SOA-based multi-wavelength fiber ring laser. The laser uses an SOA as the gain medium and a Sagnac loop mirror as a wavelength selective component. The forward amplified spontaneous emission (ASE) from the SOA is filtered by the loop mirror and the filtered spectrum oscillates in the ring cavity to generate a multi-wavelength laser comb. The laser comb operates at the wavelength in which the SOA exhibits the highest gain, which is at 1540 nm. Immediately before the SOA, a 10 dB fiber coupler is used to tap the output signal from laser. The output signal is characterized using an optical spectrum analyzer with resolution of 0.015nm.

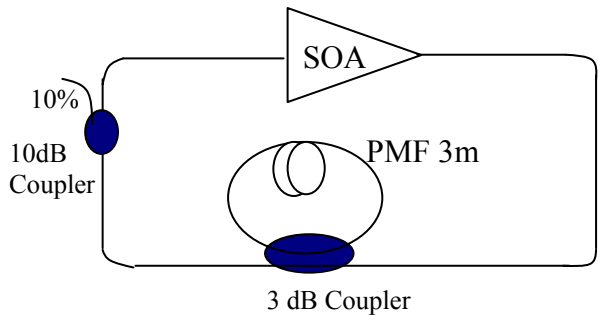

Figure 1: Configuration of SOA-based multi-wavelength fiber laser

The SOA is made from an InGaAsP-InP ridge waveguide with facets angled at 10° and is antireflection coated. It has a saturated output power of 10 dBm, the maximum bias current of 400 mW and operational temperature within 0 to 60°C. The SOA has a maximum gain of 24 dB is obtained at 1540 nm for the small signal and is flat over a wavelength range of 1532 to 1544nm and a noise figure of 10.5 to 14.6 dB. The Sagnac loop mirror is constructed using a 3-dB coupler and a pre-determined length of polarization maintaining fiber (PMF) with two ports of the coupler connected to both ends of the PMF. The ASE from the SOA gain medium is split into two beams by a 3 dB coupler, with one of the light beams travelling in a clockwise direction while the other travels in a counter-clockwise direction around the PMF. Due to the phase differences encountered when the two propagating beams meet in the loop, the beams interfere constructively and destructively. Both beams are combined at the end of fiber coupler to act as a comb filter.

Results and Discussion

Figure 2 shows the output spectrum of the fiber laser against different SOA bias currents. In this experiment, the SOA operating temperature is set constant at 30°C, while the bias current is varied between 150 mA to 300 mA. The resulting different output spectrum obtained are in Figure 2 has constant channel spacing of 1.49 nm due to the fixed length of the PMF in the Sagnac loop, which gives a constant interference pattern and hence the same channel spacing. The output power of the multiple lasing lines is observed to increases as the bias current decreases, with the effect more profound at the longer wavelength region. This behavior is attributed to the SOA characteristics, which shows a higher gain at the longer wavelengths for lower pump power. At a bias current of 150 mA, 6 lines are achieved with minimum peak power of -40 dBm and signal to noise ratio (SNR) of 25 dB. The spectrum also shows a peak power of -31.9 dBm at 1539.2 nm with a SNR of 30 dB. Because the number of lines and the channel spacing is determined by the PMF length used in the experiment, it is expected that a higher number of lines can be generated with a longer PMF.

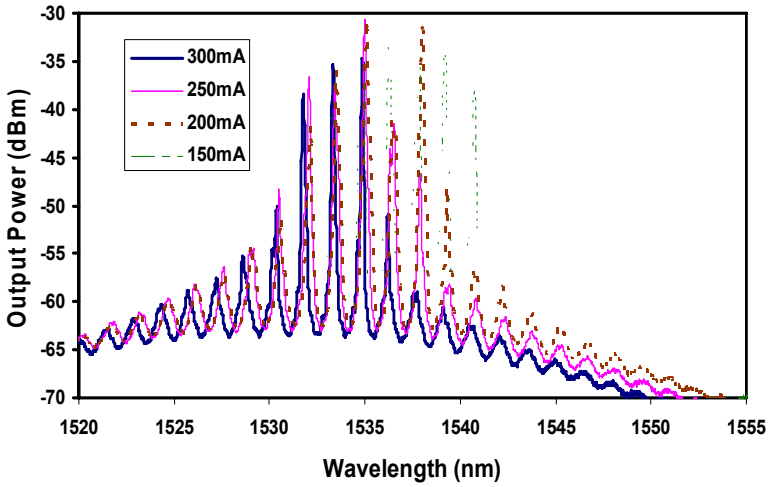

Figure 2: The output comb of the proposed laser at different bias current for the SOA. The SOA is operated at temperature of 20°C.

Figure 3 on the other hand shows the tuning of the output spectrum of the multi-wavelength laser for different temperature settings. In this experiment, temperature settings of SOA are adjusted to 20°, 25° and 30°C, while all the SOA bias current and during the experiment. It is observed during this experiment that the comb wavelength shifts by 7.7 nm as the temperature increases from 20° to 30°C. This is because the carrier density of the SOA decreases as the temperature increases, shifting the gain profile of the SOA towards the longer wavelength. This sensitivity of the SOA to the temperature thus allows the lasing spectrum of the laser to be tuned by varying only the temperature of the SOA. This provides a very simple and efficient technique to tune the comb wavelength of the proposed laser. In addition, the proposed multi-wavelength SOA-fiber ring laser is also observed to be quite stable at room temperature, and as such has a potential application in WDM systems.

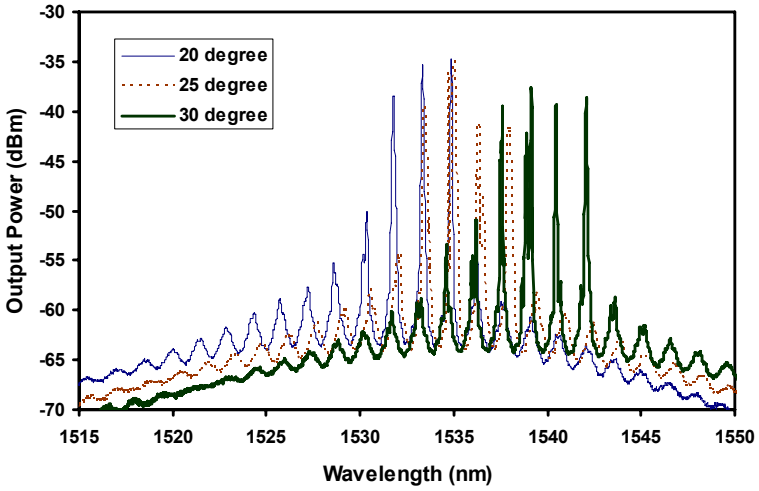

Figure 3: The output comb at different temperature setting of the SOA. The bias current of the SOA is fixed at 150mA.

Conclusion

A multi-wavelength -fiber ring laser has been demonstrated using an SOA with a small signal flat gain of about 23 dB at 1535 nm region and a Sagnac loop mirror. The loop mirror is constructed using a 3dB coupler and PMF to act as a comb filter. Multi-wavelength lasing with a channel spacing of 1.49 nm has been achieved with a 3 m PMF. 6 lines (with at least -40dBm output power and 25 dB SNR) are obtained at a bias current of 150 mA. The output of the proposed laser is quite stable at room temperature and output power can be adjusted by controlling the bias current of the SOA. The output comb can also be tuned by adjusting the operating temperature of the SOA.

References

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