SOA-Based Triple-Wavelength Ring Laser

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Abstract: We propose and experimentally demonstrate a triple-wavelength fiber ring laser using a semiconductor optical amplifier (SOA) in conjunction with an array waveguide grating (AWG). The experimental results show three lasing lines with an adjustable wavelength separation and a large optical signal-to-noise ratio under room temperature. The three channels operate at 1531.5 nm, 1532.3 nm and 1533.1 nm with a peak power above -23 dBm and optical signal to noise ratio above 30 dB at SOA drive current of 350 mA. By changing the ports of the AWG, the center wavelengths of the triple lasing lines can be changed and the wavelength separation between the lasing lines can also be changed. The proposed laser configuration has the advantages of a simple and compact structure, quad-wavelength operation and the system can be upgraded to generate more wavelengths.

INTRODUCTION

Multi-wavelength fibre laser sources are becoming an increasingly attractive solution in fulfilling the role of a laser source for a wide range of applications that includes the generation of high-bit-rate soliton pulses, optical fiber sensors, differential absorption measurement of trace gases and also for dense wavelength division multiplexing (DWDM) communications applications [1]. Typically, erbium-doped fibers (EDF) ring lasers were an attractive candidate in generating a multi-wavelength laser output as the EDF provided a large gain, a high saturation power, and a relatively low noise figure. However, a significant drawback of the EDF ring laser is the number of laser mode is generally limited due to the mode competition between the channels [2], thus inhibiting multi-wavelength lasing at room temperature. In overcoming this problem, many approaches such as the cooling of the EDF in liquid-nitrogen [3] and the use of a twin core EDF [4] have been suggested, but while successful, these techniques are not viable as they are either not well suited for practical applications or are very costly.

Recently, semiconductor optical amplifiers (SOAs) have received much attention for signal amplification in optical networks [5]. Compared to conventional optical amplifiers SOAs have many advantages such as compactness, lightness, lower power consumption as well as mass producible. Additionally, the SOA is a gain medium with a dominant inhomogeneous broadening property and thus can generate multiple lasing wavelengths at room temperature. In this letter, a new and simple triple-wavelength fiber laser configuration is proposed and demonstrated using a SOA as a gain medium, array waveguide grating (AWG) as a wavelength selective filter and 3 dB couplers as a signal combiner. The AWG is chosen as the wavelength selective filter due to the extremely narrow wavelength spacing allowed by the AWG and also due to the low losses exhibited by the planar waveguide based AWG. This is the first time an AWG has been used in this context based on our knowledge. This configuration is able to minimize the mode competition in the laser cavity and therefore, increases the probabilities of getting more simultaneous lasers at a narrower wavelength spacing. The triple-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. The setup is also very compact, making it suitable for use in field applications.

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EXPERIMENTAL SET-UP

Fig. (**1**) shows the configuration of the proposed quad-wavelength SOA-based ring fiber laser. It consists of a SOA as the gain medium, an AWG as a wavelength selective filter, three 3 dB couplers to combine the four AWG output signals and a 90:10 tap output coupler. The SOA is driven by various bias current settings and the temperature of the SOA is set at 30^{o}C using a laser diode controller. The current flow through the SOA generates spontaneous emission of photons from the semiconductor gain medium due to the recombination of electron-hole pairs. The generated amplified spontaneous emission (ASE) signal of the SOA is then filtered out by the AWG, allowing only the ASE signal spectrum that falls within the filter pass-band to pass through the AWG. The four selected output signals of the AWG are recombined using three 3 dB couplers which are then looped back to the SOA. The signals will then complete the loop and passed through the SOA to be amplified. This process continues until an equilibrium state is achieved and the four selected wavelengths experience lasing. A 90:10 tap output coupler is also added to the loop.

The SOA is made from an InGaAsP-InP ridge waveguide with facets angled at 10^{o} and is antireflection coated. It has a saturated output power of 10 dBm and a maximum bias current of 400 mA and has a centre operating wavelength of 1534 nm with a spectral width of 40 nm. The SOA has a small signal gain of 20 dB with a gain saturation current of 160 mA. The noise figure of the SOA is on average 10 dB

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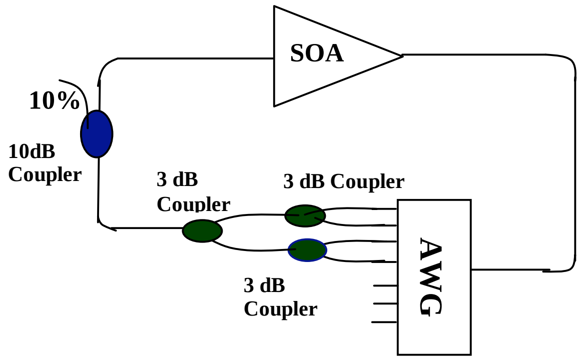

Fig. (1). Experimental setup.

for the low signal and 7 dB for the high signal. The AWG used in this experiment is a 24 channel AWG with a channel spacing of 100 GHz or 0.8 nm. Port 1 of the AWG begins at 1530.4 nm, and the last port, port 24 is at 1548.6 nm. Ports 1 to 4 of the AWG are used in the experiment. The insertion loss of AWG varies from 3.1 to 3.3 dB within ports 1 to 4.

RESULTS AND DISCUSSION

Fig. (**2**) shows the peak powers of the compact quad-wavelength ring fiber laser using ports 1~4 of the AWG at different SOA drive currents. As shown in Fig. (**2**), the lasing occurs at wavelengths of 1530.7, 1531.5, 1532.3 and 1533.1 nm, which corresponds to ports 1, 2, 3 and 4 of the AWG, respectively at SOA drive currents above 150mA. At small drive current of 150mA, the lasing wavelengths are random and do not follow the AWG center wavelengths due to the insufficient gain provided by the SOA. The peak powers for the four wavelengths increases as the current increases as shown in Fig. (**2**). At the highest SOA drive current of 350 mA, all lasing wavelengths have a peak power above -23 dBm except for the lasing wavelength on the first channel which is only -45 dBm. The wavelength separation between each channel is 0.8 nm. The variation in the power between all the channels is due to the mode competition that arises due to the narrowness of the wavelength separations but is most pronounced in the first channel. The gain characteristics of the SOA and insertion loss variation among the channels of the AWG are also contributed to the variation of peak power. Fig. (**2**) also shows that the large optical signal-to-noise ratio (OSNR) of over 30 dB is obtained for the last three channels of the ring laser at the maximum bias current setting under room temperature. By monitoring the output spectrum of Fig. (**2**) for a long time, the results indicate that the wavelength spacing keeps remains constant with only slight power fluctuations among the lasing wavelengths. This behavior can be attributed to the clamped gain in the SOA-based laser through lasing line oscillation [6].

Fig. (**3**) shows the output power of the ring laser against the SOA current. As shown in the figure, all laser wavelengths rise sharply and reach saturation at 150 mA, except for the 1530.7 nm laser wavelength. However, the peak power for both 1532.3 nm and 1533.1 nm channels is suddenly dropped at drive current of 200 mA before rises back at higher drive currents. The spectrum of Fig. (**2**) is not symmetry due to the variation of cavity loss in the ring. The laser wavelength from the first channel of 1530.7 nm does not reach saturation even when the SOA is being driven at a maximum current of 350mA. By further optimization of the cavity loss, SOA gain and channel spacing, it is expected that the first wavelength will be able to reach saturation, and subsequently generate a more balanced laser output from the four selected laser wavelengths. It is also expected that controlling the polarization of the SOA gain will be able to generate a more stable laser wavelength output power. Polarization adjustment in the cavity through polarization controller is also expected to improve power equalization.

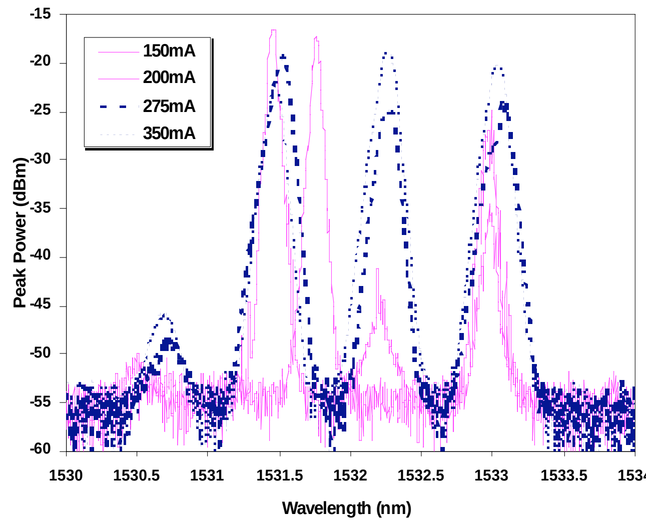

Fig. (2). Output spectra of the quad-wavelength laser at different SOA drive currents.

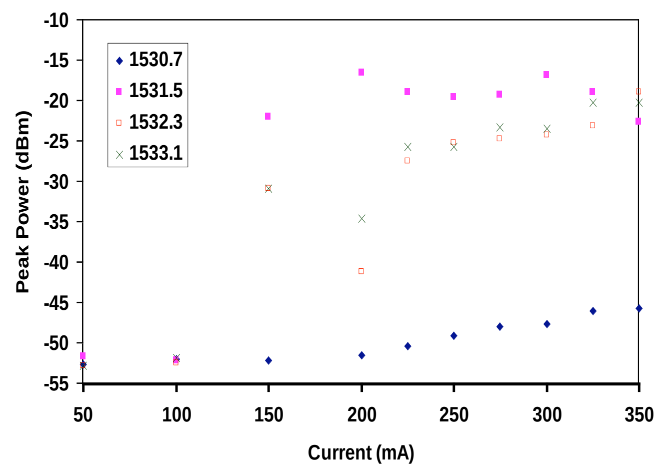

Fig. (3). Peak power against different SOA drive currents for the ring laser.

From the experiment, it can be seen that the ring fiber laser is able to generate at least triple-wavelength. The laser has a stable and narrow spacing output, which is suitable for DWDM or sensor applications. The triple-wavelength ring fiber laser design is considerably compact due to its use of the SOA and AWG. The system can also be upgraded to more lasing wavelengths by simply replacing the 3 dB coupler with a 1x8 splitter or even another AWG. Inserting an optical switch will allow the user to switch between the required wavelengths.

CONCLUSION

A compact triple-wavelength ring fiber laser using an SOA and an AWG SOA-fiber ring laser is demonstrated. The ring laser generates three laser wavelengths at 1531.5 nm, 1532.3 nm and 1533.1 nm with a peak power above -23 dBm and OSNR above 30 dB at the highest SOA drive current of 350 mA. The laser shows stable lasing lines with an adjustable wavelength separation. By changing the ports of the AWG, the wavelength separation of the two lasing wavelengths can be tuned over several nanometers. The proposed laser configuration has the advantage of stable triple-wavelength outputs at room temperature and simple and compact structure and has many potential applications in DWDM and sensor applications.

REFERENCES

[1] Chow J, Town G, Eggleton B, Ibsen M, Bennion I. Multiwavelength generation in an erbium-doped fiber laser using in fiber comb filters. IEEE Phot Tech Lett 1996; 8: 60-2.

[2] Feng X, Tam H, Liu H, Wai PKA. Multiwavelength erbium-doped fiber laser employing a nonlinear optical loop mirror. Opt Commun 2006; 268: 278-81.

[3] Yamashita S, Hotate K. Multiwavelength erbium-doped fibre laser using intracavity etalon and cooled by liquid nitrogen. Electron Lett 1996; 32: 1298-99.

[4] Graydon O, Loh WH, Laming RI, Dong L. Triple-frequency operation of an Er-doped twincore fiber loop laser. IEEE Phot Tech Lett 1996; 8: 63-5.

[5] Kelly AE, Tombling C, Michie C, Andonovic I. High performance semiconductor optical amplifiers. Optical Fiber Commun Conf 2004; 2: 3.

[6] Tiemmeijer LF, Thijs PJA, van Dongen T, Binsma JJM, Jansen EJ, van Helleputte HRJR. Reduced intermodulation distortion in 1300 nm gain-clamped MQW laser amplifiers. IEEE Phot Tech Lett 1995; 7: 284-6.

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