A compact dual wavelength ring laser using a semiconductor optical amplifier and array waveguide grating

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It is demonstrated a stable dual-wavelength fiber ring laser using an SOA in conjunction with an array waveguide grating (AWG). The experimental results show stable dual lasing lines with an adjustable wavelength separation and a SNR of over 30 dB under room temperature. The first channel operates at 1530.2 nm laser wavelength with an output power of approximately -11 dBm at a saturation current of 150 mA. The second channel operates at either 1532.8 nm or 1538.8 nm with a maximum output power of more than -24 dBm. By changing the ports of the AWG, the center wavelengths of the two lasing lines and wavelength separation can be tuned under room-temperature.

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1. Introduction

Compact dual-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 [1], optical fiber sensors, the differential absorption measurement of trace gases [2] and also for dense wavelength division multiplexing (DWDM) communications applications. Typically, erbium-doped fibers (EDF) ring lasers were an attractive candidate in generating a dual-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 to generally less than 4 due to the homogenous broadening of the erbium ions as well as fluctuating an unstable lasing powers due to mode competition [3], thus inhibiting dual and furthermore multi-wavelength lasing at room temperature. In overcoming this problem, many approaches such as the cooling of the EDF in liquid-nitrogen [5] and the use of a twin core EDF [6] 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 [7]. 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 dual wavelength fiber laser configuration is proposed and demonstrated using a SOA as a gain medium and array waveguide grating (AWG) as a wavelength selective filter. The AWG is chosen as the wavelength selective filter due to the extremely narrow spacing allowed by the AWG and also due to the low losses exhibited by the planar based AWG. This configuration is able to minimize the mode competition in the laser cavity and therefore, increases the probabilities of getting two simultaneous lasers at a wider spacing. The dual-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.

2. Experimental setup

Fig. 1 shows the configuration of the proposed dual wavelength SOA-based ring fiber laser. It consists of SOA as the gain medium, an AWG as a wavelength selective filter, a 3 dB coupler to combine the two 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°C using a laser diode controller. The current flow through the SOA generates a 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 passband to pass through the AWG. The two selected output signals of the AWG are recombined using a 3 dB coupler which is 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 two selected wavelengths experience lasing. A 90:10 tap output coupler is also added to the loop.

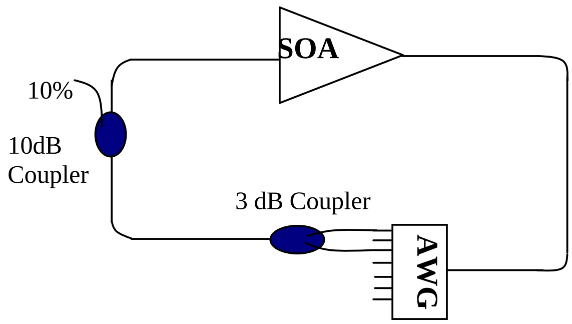

Fig. 1. Experimental setup

The SOA is made from an InGaAsP-InP ridge waveguide with anti-reflection coated facets making an angle of 10^o with respect to the optical axis. It has a saturated output power of 10 dBm and a maximum bias current of 400 mW and has a centre operating wavelength of 1534 nm with a spectral width of 40 nm. The SOA exhibits 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 for the low signal and 7 dB for the high signal. The SOA will manifest a strong resonant when it is biased at high current. Hence, the ring resonator offers the positive feedback to enhance the SOA resonant effects. 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. The two other ports of interest are ports 4 at 1532.8 nm and 12 at 1538.8 nm. The insertion loss of AWG is measured to be 3.3 dB at port 1 and reducing at ports with longer wavelength. The insertion loss at ports 4 and 12 are 3.1 and 2.5 dB, respectively.

3. Results and discussion

Fig. 2 shows the peak powers of the compact dual wavelength ring laser using ports 1 and 12 of the AWG and at different SOA drive currents. As can be seen in Fig. 2, the first laser wavelength is obtained at 1530.2 nm, which corresponds to port 1 of the AWG. The peak power of the laser at this wavelength is constant at -11 dBm for the SOA drive currents of 200, 275 and 350 mA. The second laser wavelength of the ring laser is obtained at port 12 of the AWG, which corresponds to a wavelength of 1538.7 nm. However, the peak power of the second laser wavelength is not constant. The peak power of the second laser is -48 dBm when the SOA drive current is 200 mA, and rises to -45 dB when the drive current is increased to 275 mA. It is highest at -22 dB when the drive current of the SOA is increased to 350 mA. This variation in the power of the second wavelength is due to the gain characteristics of the SOA, in which the gain increases sharply after the threshold current, thus causing the second laser power to increase only when driven above the threshold current. The first laser on the other hand does not change as the gain is fully saturated. The spacing between the two lasing wavelengths is 8.5 nm. The large optical signal-to-noise ratio (OSNR) of over 30 dB is obtained for both lasers at the maximum bias current setting under room temperature.

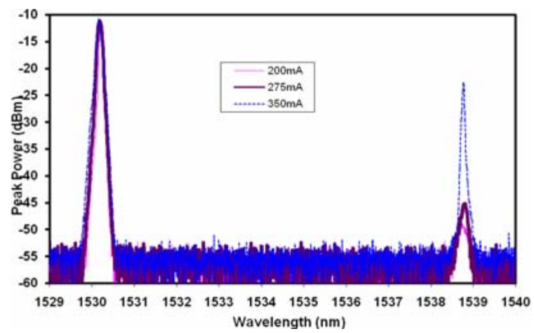

Fig. 2. Peak power of Port 1 and Port 12 lasing wavelengths at different SOA drive currents.

The experiment is then repeated by setting the SOA drive current to 350 mA but changing the ring laser outputs from the AWG from port 1 and port 12 to port 1 and port 4. Figure 3 shows the combined laser output spectrum of the two configurations. The peak laser power for the first and second wavelengths are the same at -15 dBm for ports 1 and 4, but for ports 1 and 12 the peak power of the first wavelength is higher at approximately -11 dBm, while the peak power of the second wavelength is only -22 dBm. The drop in power of the second channel as the spacing between the two wavelengths increases is due to ASE spectrum characteristics of the SOA. The ASE power of the SOA peaks at 1530 nm and reduces as the wavelength increases. Therefore, the lasing signal at the port 1 is has a higher output as compared to that of port 12, resulting in the difference in the output power as shown in Figures 2 and 3. The wavelength spacing remains constant with only slight power fluctuations throughout the experiment. This behavior can be attributed to the clamped gain in the SOA-based laser through lasing line oscillation [8].

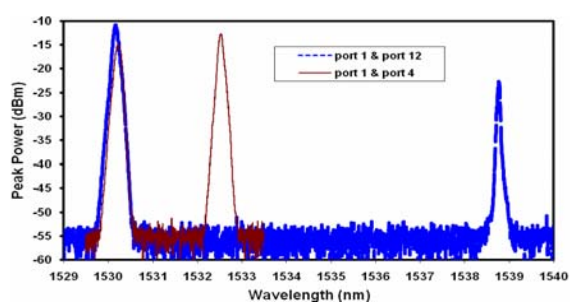

Fig. 3. Peak power of laser spectrum at port 1 and port 12 configuration and port 1 and port 4 configuration at SOA drive current of 350 mA.

Fig. 4 shows the output power of the ring laser against the SOA current. As can be seen, the 1530.2 nm laser wavelength rises sharply and reaches saturation at 150 mA when connected together with either port 4 or port 12. However, higher drive currents are required for the second laser wavelength to achieve saturation as the difference in the distance between the first and second lasing wavelengths increases. The laser wavelength obtained from port 4 only achieves saturation above 275 mA, while the laser wavelength from port 12 does not reach saturation even when the SOA is being driven at a maximum current of 350 mA. By further optimization of the cavity loss and SOA gain, it is expected that the second wavelength will be able to reach saturation, and subsequently generate a more balanced laser output form the two 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.

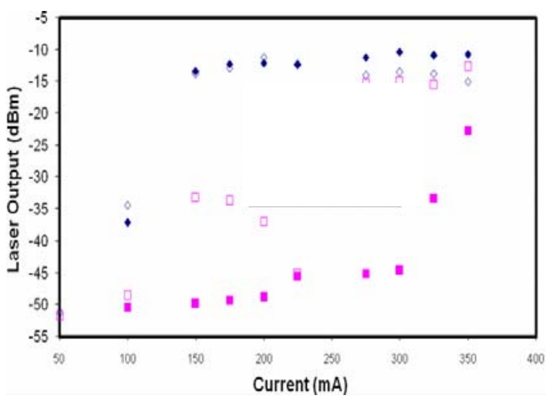

Fig. 4. Laser output for port 1 and port 12 and port 1 and port 4 configurations against different SOA drive currents.

From the experiment, it can be seen that the dual wavelength ring laser is able to generate a stable and narrow spaced laser for DWDM or sensor applications. The dual wavelength ring 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 1 × 4 or 1 × 8 coupler or even another AWG. Inserting an optical switch will allow the user to switch between the required wavelengths.

4. Conclusions

A compact dual-wavelength ring laser using an SOA and an AWG SOA-fiber ring laser has been demonstrated. The ring laser generates two laser wavelengths, at either 1530.2 nm and 1532.5 nm or 1530.2 nm and 1538.7 nm. The power of the first wavelength is constant at -11 dB, while the power of the second laser drops as the wavelength spacing between the first and second laser increases due to the dominance of the saturated first laser wavelength over the second. The laser shows stable dual lasing lines with an adjustable wavelength separation and a large optical signal-to-noise ratio of over 30 dB under room temperature. By changing the ports of the AWG, the separation of the two lasing wavelengths can be tuned over several nanometers. The proposed laser configuration has the advantage of stable dual-wavelength outputs and simple and compact structure and has many potential applications in DWDM and sensors.

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