# Multi-wavelength source based on SOA and EDFA in a ring cavity resonator

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A multi-wavelength source incorporating a Semiconductor Optical Amplifer (SOA) and a Erbium-doped fiber amplifier (EDFA) in a ring cavity configuration is demonstrated. The multi wavelength source is able to generate more than 12 channels at -35 dBm and above with a channel spacing of 0.8 nm at a SOA bias current of 350 mA and 980nm pump power of 92 mW. The number of wavelengths generated can be controlled by adjusting the SOA bias current and the birefringence of the ring cavity using the Polarization Controllers (PCs). The proposed laser has a channel spacing suitable for DWDM and sensing applications and shows stable operation at room temperature.

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## 1. Introduction

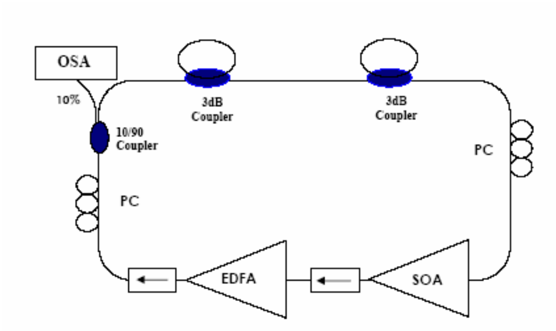
Multi-wavelength fiber lasers have recently become the focus of attention for applications in wavelength division multiplexing (WDM) systems and sensing applications. Multiwavelength sources provide a cheap and efficient alternative to the deployment of multiple laser diodes at different wavelengths, and are also more compact, consume less energy and generate less heat than multiple laser diode systems.

Simultaneous multiwavelength outputs have previously been generated by employing Brillouin/erbium fiber lasers (BEFLs) [1] or multiwavelength erbium-doped fiber laser (MWEDFL) [2, 3]. However, both these systems have certain limitations. In the case of BEFLs, only a limited number of channel wavelengths can be generated with a fixed channel spacing of about 0.08 nm. The channel spacing of BEFLs is too narrow, and makes it unsuitable for WDM applications. Stable multiwavelength sources based on erbium-doped fibers (EDFs) on the other hand are difficult to obtain due to the homogeneous broadening of laser modes, which leads to strong mode competition and unstable lasing in multiwavelength fiber lasers. In order to overcome this limitation, MWEDFLs were reported either by immersing the EDF in liquid nitrogen [4] or using a specially designed twin-core EDF [5], which is either impractical or too expensive for commercial applications.

Recently, semiconductor optical amplifiers (SOAs) have garnered increasing attention for amplifying signals in optical networks [6]. SOAs have many advantages compared to conventional optical amplifiers such as compactness, lightness, lower power consumption as well as being mass producible (due to their semiconductor nature). Crucially, SOAs allow for multi-wavelength generation at room temperature as the inhomogeneous gain medium of the SOA reduces the mode competition [7-8]. In this paper, a multi-wavelength ring cavity laser is proposed using a hybrid gain media of SOA and EDFA. Two loop mirrors are used to form an interference comb filter, which functions to slice an amplified spontaneous emission into multiple wavelengths.

## 2. Experimental set-up

The experimental setup for the multi-wavelength ring laser is shown in Figure 1. The ring cavity comprises an SOA, an EDFA, two polarization controllers (PCs), two 3dB couplers and a 90:10 output coupler. The EDFA is constructed using a 9m length EDF with erbium ion concentration of 950ppm. The EDF is pumped by a 980-nm pump laser at pump power of 92 mW. An SOA is incorporated in the ring cavity to suppress the homogeneous line broadening. By connecting together two ports of 3dB coupler as shown in the set up, both coupler ends now act as a reflector to form a resonating linear cavity, which functions as an interference filter. As the amplified spontaneous emission (ASE) generated by both SOA and EDFA enters the filter, it will be sliced into multiple wavelengths. These wavelengths will oscillate in the ring cavity to form a multi-wavelength laser comb. Polarization Controllers (PCs) is used to control the birefringence of the ring cavity so that the power of the laser and the number of wavelengths generated can be controlled. A 90:10 output coupler is used to tap the output of the ring cavity laser.




## 3. Results and discussion

Based on stability analysis [9], it is known that any small perturbation in the laser cavity will result in the energy distribution change of the laser modes. In an EDF-based ring laser, different modes experience different net gains, depending on the polarization state and the wavelength. Because of homogeneous gain broadening of the EDF, the fiber laser suffers from a strong mode hopping, which makes it impossible to generate stable multi-wavelength lasing at room temperature. When an SOA is incorporated into the ring laser cavity, it acts as an optical cavity buffer, producing elastic compression and expansion of the cavity length. When the rate of the cavity length shift is comparable with the relaxation time of the laser, none of oscillation modes will be temporarily dominant over others; a simultaneous multi-wavelength lasing is possible. The SOA used in this experiment is based on an InGaAsP-InP ridge waveguide with antireflection coated facets angled at $10^{o}$. It has a centre operating wavelength of 1534 nm with a spectral width of 40 nm. The gain spectrum of a hybrid amplifier, which consisting an EDFA and SOA is shown in Figure 2. A 980nm pump power of EDFA and bias current of SOA is fixed at 92 mW and 350mA, respectively. The input signal power is fixed at -10dBm. As shown in the figure, a flat-gain of 18 dB is obtained within wavelength region 1532 to 1560 nm with gain variation of less than 1 dB.

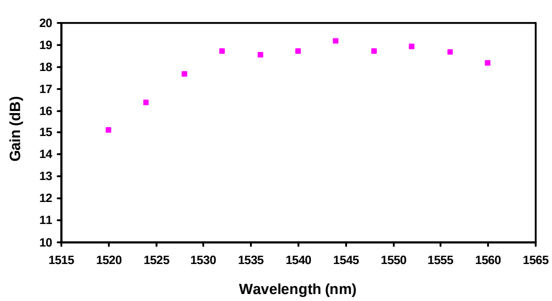



*Fig. 2. Gain spectrum of the hybrid amplifier at input signal power of -10 dBm*

The output spectrum of the ring cavity laser for different SOA drive currents is shown in Figure 3. From the figure, it can be seen that as the SOA drive current increases the number of wavelengths generated by the ring cavity laser also increases. At a bias current of 150 mA, 9 channels are obtained at a power of above -35 dBm. At 250 mA, the number of channels that can be obtained is 11, while at the drive current of 350 mA 12 channels are obtained. The multi-wavelength channels operate in wavelength region from 1540nm to 1550nm with constant channel spacing. The wavelength region is coincided with flat-gain region of the hybrid amplifier as shown in Fig. 2.

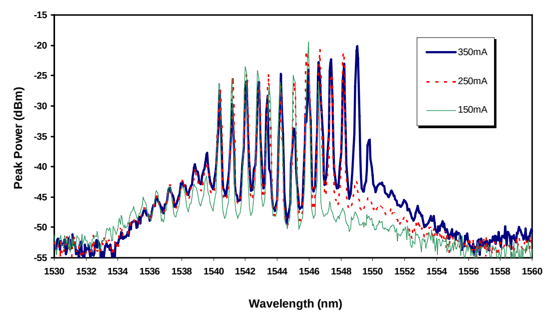



*Fig. 3. Output spectra of the proposed multi-wavelength ring laser at different SOA's drive currents*

The fluctuations of the channel powers are minima which do not exceed 5 dB at the SOA's bias current of 250 mA as shown in Figure 3. The SOA manifests a strong resonant effect when biased at high currents due to residual reflections caused by the facets of the SOA [10]. This ripple is most pronounced at the wavelength region in which the SOA exhibits the highest gain. Therefore, the fluctuation of the channel powers is highest at the highest bias current of 350 mA especially at wavelength of 1545 nm as shown in Figure 3. The four-wave mixing is also contributed to this fluctuation. Additionally, the central wavelength of the laser output spectrum can be seen to shift towards the longer wavelength as the drive current of the SOA is increased. The increase in the number of channels and the shift of the central wavelength can be attributed to the fact that the saturated gain of the SOA peaks at the relatively longer wavelength regions. The channel spacing under all three drive currents is approximately 0.8 nm, which is determined by the cavity length within both 3dB couplers used and the birefringence in the ring cavity. PCs have been used to control the number of wavelengths generated, channel spacing and the peak power. The proposed laser has many potential applications as multiwavelength sources in DWDM systems and sensor applications as compared to BEFLs and MWEDFLs due to its larger channel spacing and stable operation at room temperatures.

## 4. Conclusion

In this paper, a multi-wavelength laser is demonstrated incorporating an SOA and EDFA in a ring cavity configuration. Two 3dB couplers are used to generate a comb filter for multi-wavelength generation. The number of wavelength generated can be controlled by adjusting the SOA bias current, while the channel spacing and output spectrum bandwidth can be controlled by adjusting the birefringence inside the cavity using the 3dB couplers and the PCs. At bias current of 350mA, more than 12 channels at a spacing of 0.8 nm and power of more than -35 dBm can be achieved. The proposed laser has large channel spacing and can stably operate at room temperatures, making it suitable for DWDM and sensor applications.

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