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# WAWELENGHT TUNABLE SEMICONDUCTOR FIBER RING LASER THROUGH ELECTRO-OPTICAL POLARIZATION CONTROL

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A narrow-linewidth wavelength tunable semiconductor fiber ring laser is demonstrated. Tunability is achieved through computer-based electro-optical polarization control. Fine rapid tunability of 30 nm in the 1550 nm region is shown. The tuning properties and working principles are also discussed.

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## 1 Introduction

Wide range wavelength tunable lasers will play an important role in many future networks and systems. Recently, wavelength tunable semiconductor fiber lasers based on a semiconductor optical amplifier (SOA) and a spectral filter, such as Fabry-Perot filters, fiber gratings, or Lyot filters, have attracted attention because of their wide wavelength tunable range and potentially fast tuning speed [1-3]. The tuning mechanism for most of these fiber lasers is done through mechanical control. However, for practical implementation it is preferable to have faster, non-mechanical wavelength tuning control. In this paper we demonstrate electro-optical polarization control for wavelength selection in a fiber ring laser that incorporates a SOA and a Lyot filter [3]. With this control, the laser demonstrates very fine tuning, repeatable wavelength selection with a range of 30 nm from 1550 nm to 1580 nm. The different laser output wavelengths can be selected very quickly by applying the appropriate set of voltages to the electro-optical polarization controller through a computer-based interface. Furthermore, the tuning characteristics of the laser for different SOA injection currents are investigated and the working principle is explained.

## 2 Experiments and results

The schematic diagram of the fiber ring laser is shown in figure 1. The laser consists of a SOA, optical isolator, 55 cm of polarization maintaining (PM) fiber, polarizer, wavelength selector and output coupler. The polarization-insensitive isolator maintains unidirectional transmission in the laser cavity. The output coupler couples out 10 percent of the light in the cavity. The 1.55 $\mu$m SOA used in the experiment has a gain difference of 1.2 dB between TE and TM polarization states under 100 mA of bias current. The SOA temperature is stabilized at 20 $^\circ$C. The wavelength selector is based on a computer-controlled electro-optical polarization controller (Optellios PC1000). This polarization controller is a small fiber-pigtailed device based on liquid

  

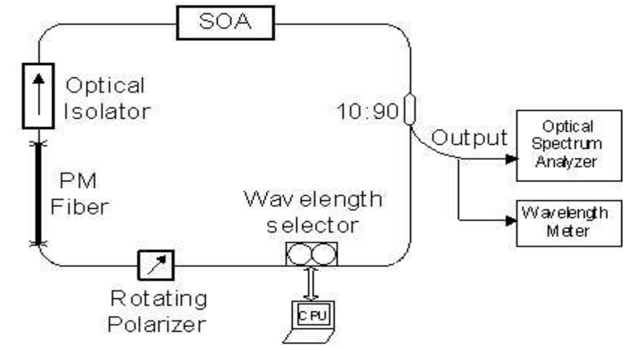


Fig. 1. Experimental setup of the semiconductor fiber ring laser.

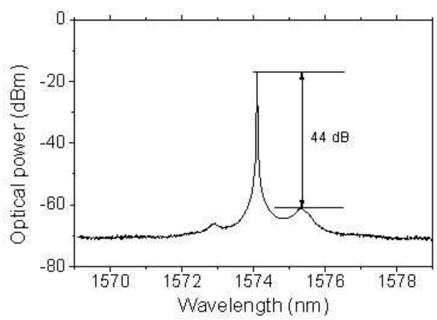


Fig. 2. The optical spectrum of the laser output. The control voltages of the electro-optical polarization controller were: (0.949, 2.847, 0.474, 3.504, 1.204, 3.814) V.

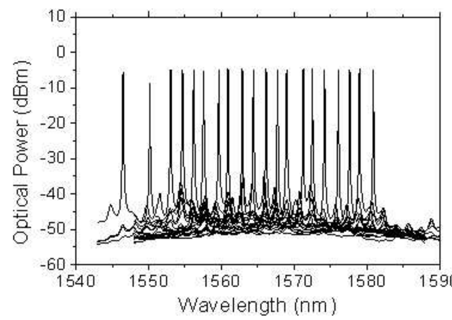


Fig. 3. Wavelength tunability of the semiconductor fiber ring laser when $I_{SOA}$ = 100 mA.

crystal technology, capable of converting any input polarization to any output polarization. It has an insertion loss of less than 1.8 dB. Its operation requires simultaneous application of six independently controlled voltages, which are automatically provided through the computer interface. The output of the laser is monitored by an optical spectrum analyzer (Advantest Q8384) with a minimum resolution of 0.01 nm. The output wavelength is accurately measured using a wavelength meter (Advantest Q8326).

When the output coupler (see Fig. 1) is 10:90, the laser has a lasing threshold current of 45 mA. Figure 2 shows the output of the laser at 1574.09 nm when the SOA current is 100 mA. The lasing output wavelength has a very narrow linewidth of less than 0.01 nm, and the suppression ratio of the main mode to the side mode is larger than 40 dB. The optical power of the output is -4.7 dBm. The wavelength of the lasing light is directly related to the control signal sent to the electro-optical polarization controller. When the control voltages are changed and reset back,

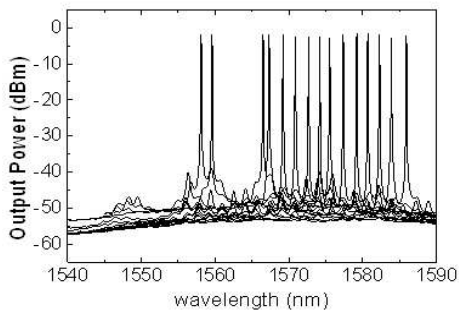


Fig. 4. Wavelength tunability of the semiconductor fiber ring laser when $I_{SOA}$ = 180 mA.

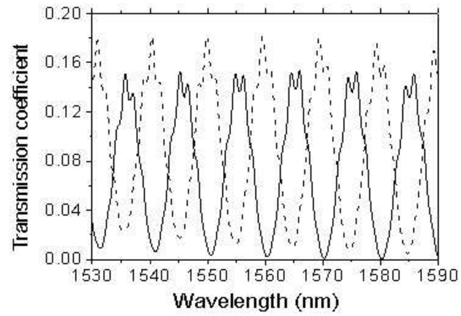


Fig. 5. Transmission spectrum of the filter in the laser cavity: two curves correspond to two different settings of polarizers.

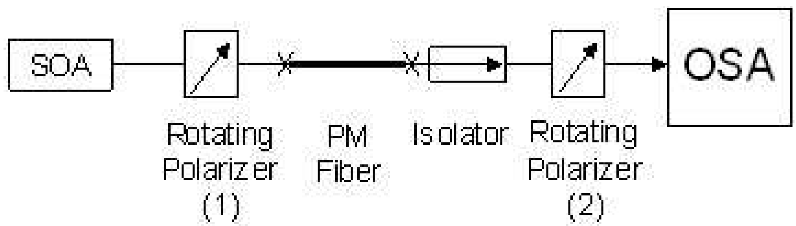


Fig. 6. Measurement of the transmission spectrum of the Lyot filter in the laser cavity.

the central wavelength of the lasing light is within 0.05nm, which makes this technique a very consistent tuning method for wavelength selection.

Two different wavelength tuning ranges for the laser at SOA injection currents of 100 mA and 180 mA are shown in figures 3 and 4, respectively. At 100 mA, the laser has a wavelength tuning range of 30 nm, from 1550 nm to 1580 nm. The output wavelength range can be moved to longer wavelength by increasing the SOA current.

## 3 Working principles

The polarizer and polarization-maintaining fiber in the laser cavity (see figure 1) form a fiber-based Lyot filter, which provides the wavelength selection mechanism. Wavelength tuning of the laser can be achieved by rotating the polarizer and the polarization controller. To analyze the spectral characteristics of the Lyot filter and to understand the wavelength selection mechanism in the laser cavity, we opened the laser ring and measured the output spectrum of the amplifier and the Lyot filter, without feedback. Figure 6 shows the setup, where an additional polarizer was added to compensate for the second pass through a polarizer that the light would otherwise see in a fiber loop. Changing the polarization direction of either one of the polarizers in the Lyot filter changes the optical output spectrum. After taking into account the spectral shape of the ASE from the SOA, the transmission spectrum of the filter can be found from the output spectrum. Figure 5 shows the transmission spectra thus obtained for two different polarizations.

## 4 Conclusion

We have demonstrated a rapidly tunable semiconductor fiber ring laser. Wavelength tunability in the 1550 nm region is achieved by using a computer-controlled liquid crystal based electro-optical polarization controller. The tuning range, characteristics and the working principles of the laser were demonstrated and discussed. In practical applications, any desired lasing wavelength can be easily selected through a computer-controlled interface. The demonstrated laser has a 30 nm tuning, very narrow linewidth (less than 0.01 nm), 40 dB side mode suppression, and -4.7dBm output power. Long term tuning accuracy was better than 0.05 nm.

## References

[1] M. J. Chawki, ”All fiber, 1.5um widely tunable single frequency and narrow linewidth semiconductor ring laser with fiber Fabry Perot filter”, *Electronics Letters* **29**, 2034-2035 (1993).

[2] J. M. Oh, H. B. Choi, D. Lee, and S. J. Ahn, ”Efficient tunable fiber ring laser for 1580nm band with a fiber Bragg grating”, in OSA *Trends in Optics and Photonics (TOPS) Vol. 5. Optical Fiber Communication Conference*, Technical Digest, Postconference Edition (Optical Society of America, Washington DC, 2001), pp. WA6-1 – WA6-3.

[3] D. Zhou, P. R. Prucnal, and I. Glesk, ”A widely tunable narrow linewidth semiconductor fiber ring laser”, *IEEE Photonics Technology Letters* **10**, 781-783 (1998).

[4] D. Senderáková, A. Štrba, and J. Chlpík, The polarizing element based on a holographic grating, Proc. SPIE, Vol. 4016, pp. 425-429, 2000.