A multi-wavelength fiber laser for methane gas detection

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**ABSTRACT**

We report a multi-wavelength fiber laser with a semiconductor optical amplifier. The lasing wavelength of the laser can be adjusted from 1590nm to 1645nm by adjusting the round-trip cavity loss.

**Keywords:** Fiber laser, fiber sensor, gas sensor, semiconductor amplifier, multi-wavelength laser

1. INTRODUCTION

Multi-wavelength fiber lasers have attracted considerable interest recently because of their potential applications in optical components testing, fiber optic sensors and wavelength division multiplexing transmission systems [1-3]. Both Er-doped fiber amplifiers (EDFAs) and semiconductor optical amplifiers (SOAs) have been used as gain media in building multi-wavelength fiber lasers [4,5]. Most of the lasers reported so far are lasing at wavelength shorter than 1600nm because of the gain spectra of the commercial EDFAs and SOAs. In this paper, we report the demonstration of simultaneous lasing of more than 40 wavelengths at beyond 1600nm, using a SOA with a peak amplified spontaneous emission (ASE) wavelength of ~1553nm. The SOA works in a highly saturated state by strong optical feedback provided in the ring laser system, which shifts the lasing wavelength from the normal 1553nm to up to 1645nm.

2. EXPERIMENTS AND RESULTS

Fig.1 shows the schematic of our experimental multi-wavelength fiber ring laser system. A SOA is used as the gain medium, a fiber Mach-Zehnder interferometer (MZI) as the comb filter. A Polarization Controller (PC) is used to optimize the laser operation and an isolator maintains a uni-directional traveling wave in the ring cavity.

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Fig. 2 shows the ASE spectrum of the SOA used in our experiment at 100 mA. The wavelength of its peak gain is \( \sim 1563 \) nm. SOA is an inhomogeneous gain medium which allows simultaneous multi-wavelength lasing without significant spectral power fluctuation [4]. The fiber MZI comb filter used in our experiment has a free spectral range (FSR) of 0.5 nm but can be adjusted to other values by varying the optical path difference (OPD) between the two arms of the interferometer.

![Fig. 1. Schematic of the experimental setup](image)

![Fig. 2 ASE of the SOA at 100 mA (lower curve) and 160 mA (upper curve)](image)

A 9:1 fiber directional coupler is used as the output coupler. This coupling ratio allows strong optical feedback (90% of the power) into the ring cavity and hence highly saturates the SOA. The carrier density of the SOA decreases with the magnitude of the high intensity traveling wave in the ring cavity, and hence induces gain compression of the SOA and shifts its gain peak towards longer wavelength [5]. Fig. 3 shows lasing spectra when the variable attenuator was set to 14dB, 8.5dB and 3dB. The lasing wavelength increases with a reduction in the cavity loss and varied from \( \sim 1590 \) nm to \( \sim 1635 \) nm. The number of lasing wavelength and the signal to noise ratio also are increased respectively from about 10 wavelengths and 35dB to more than 30 wavelengths and over 40dB, respectively. During the aforementioned experiment, the pump current of the SOA was kept to 100mA.

![Fig. 3 Output spectrum of the ring laser with 9:1 coupler and when the attenuator loss was set to (a) 14dB; (b) 8.5dB; and (c) 3dB](image)
To see the potential of the ring laser for multi-wavelength lasing at longer wavelength, the 9:1 coupler was replaced by a 99:1 coupler and the attenuator shown in Fig.1 was removed to further reduce the round-trip loss of the cavity. The driving current of the SOA was also increased to 160mA instead of 100mA. As shown in Fig.2, the peak wavelength of the ASE spectrum of the SOA at 160mA is shifted toward to ~1553nm from 1563nm at 100mA. The output spectrum is shown in Fig.4. Lasing at over 40 wavelengths was achieved with the longest wavelength is ~1645nm and signal to noise ratio of over 40dB. This wavelength range already covers a number of absorption lines (i.e., R10, R9, R8, R7 and R6 lines) of methane gas and hence the laser could be used as a multi-wavelength source for high sensitivity methane detection by aligning the multiple lasing wavelengths (through changing the OPD of the MZI) to that of the methane absorption lines.

![Output spectrum of the ring laser with 99:1 coupler and without attenuator in the finer ring.](image)

3. SUMMARY

In summary, a simple multi-wavelength laser using a strongly saturated SOA is demonstrated. The laser wavelength can be adjusted from ~1590nm to ~1645nm by changing the cavity loss and the coupling ratio of the fiber loop coupler. Multi-wavelength lasing of over 40 wavelengths from ~1610nm to ~1645nm was demonstrated with signal to noise ratio of over 40dB. This type of lasers may be used as light sources for further wavelength division transmission systems and for fiber sensors such as high sensitivity methane detection.

REFERENCES

