Wavelength-Tunable Optical Spectral Bistability in a Ring Laser Using a Semiconductor Optical Amplifier

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Optical bistability in semiconductor lasers has potential applications in optical signal processing, optical switching and optical computing [1-4]. Recently the wide implementation of wavelength division multiplexing (WDM) technologies for optical networking motivates the development of optical bistability at different wavelengths. Here we demonstrate the optical bistability in a fiber ring laser using a 1.55µm semiconductor optical amplifier (SOA) as the amplifier. By tuning the polarizer and the polarization controller in the laser cavity, we successfully obtain the bistable operation at different wavelengths.

The experimental setup of the ring laser is shown in Figure 1. The 1.55µm SOA in the cavity has a gain difference of 1.2dB between TE and TM polarization states under bias current of 100mA. The SOA plays a key role in producing bistable operation, in addition to providing gain in the cavity. A polarization controller, a rotating linear polarizer and 55cm of polarization maintaining (PM) fiber form a Lyot filter for wavelength selection. Ten percent of the light in the cavity is coupled out through the 10:90 coupler. The total cavity length, including the PM fiber, is about 3.7 meters.

In our experiments, we can set the laser working in either narrow-linewidth oscillation mode or bistable oscillation mode by adjusting polarization states of the light in the cavity. We obtained wide wavelength tunability in the 1.55µm region as that in the 1.3µm region described in the reference [5]. The threshold current of the laser is about 43mA. By tuning the polarization controller and the polarizer in the laser cavity, the laser can work in the condition of bistability. The operation is observed by varying the bias current of the SOA. When we increase the SOA bias current from threshold current, the laser is in state I, which has one narrow main peak at 1569.4nm (linewidth<0.1nm). When the current reaches 124mA, the laser output changes to two broad main peaks at the wavelength of 1569.8nm and 1579.5nm, which we call state II. When increasing the SOA bias current, the evolution of the output spectra of the laser is shown in figure 2 (a). When the SOA current is decreased after reaching state II, the output spectrum does not revert to state I until the SOA bias current falls below 74mA, as is shown in figure 2 (b). The linewidth of each of the two oscillations peaks in state II is dramatically broadened. The spectra of the two output states for the same SOA bias current is shown in figure 3(a) (b). For figure 3-6 we use the expression (λ1, λ2 + λ3) to denote the wavelengths of one pair of bistable states. The first value in the expression is the wavelength of the single main oscillation peak in state I, and the two values adjoined with “+” are the wavelengths of the two peaks in state II. Two states in a given pair have the same SOA bias. For figures 3-6, the horizontal scale ranges from 1557nm to 1587nm and the vertical scale is in units 10dB per division. By tuning the polarization controls of the ring cavity, we obtain optical bistability at different wavelengths. In addition to changing the SOA current, the laser can also switch from state I to state II through optical controls. [6].

In summary, optical bistability at different wavelengths in a semiconductor fiber ring laser has been demonstrated. Changing the SOA bias current shows two stable optical outputs for any given current within the operating range. The laser can also be switched from one bistable state to another using optical control methods. Different wavelengths are selected by tuning the polarizer or the polarization controller in the laser cavity. These features will make the laser very promising for all-optical wavelength routing networking applications.

Figure 1 Experimental setup of the ring laser using a SOA

Figure 2 (a) Evolution of output spectra when increasing SOA current: The five spectrum curves (from the front to the rear) correspond to SOA bias currents of 47.79mA, 64.00mA, 80.77mA, 101.00mA, 124.5mA (b) Evolution of output spectrum when decreasing SOA current: The five spectrum curves (from the rear to the front) correspond to SOA bias currents of 124.52mA, 101.00mA, 81.65mA, 66.18mA, 47.83mA

Figure 3 (a) State I (b) State II for (1569.5nm, 1569.8nm+1579.5nm), $I_{SOA}$=101mA
Figure 4 (a) State I (b) State II for (1565.7nm, 1565.9nm+1574.2), $I_{SOA}$=80mA
Figure 5 (a) State I (b) State II for (1564.3nm, 1564.4nm+1574.2), $I_{SOA}$=76mA
Figure 6 (a) State I (b) State II for (1571.2nm, 1571.1nm+1580.4), $I_{SOA}$=107mA