

# A Wavelength-Tunable Monolithically Integrated Double Ring Resonator Coupled Laser

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**Abstract:** Large wavelength tuning of a double ring resonator coupled laser is demonstrated. The 20 different modes spreading in 17 nm range have a maximum output power of 1.2 mW, and a side mode suppression of about 30 dB.

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Passive ring resonator coupled lasers (RCL) are credited for their potential performances on high side mode suppression and narrow linewidth [1-2]. Double ring resonator coupled lasers (DR-RCL) can achieve large tuning range via the Vernier effect [3-4]. Experimentally, the RCLs were demonstrated with polymer or semiconductor ring resonator and an external erbium-doped fiber amplifier [5-6]. Very recently, the first monolithic GaInAsP-InP double ring resonator coupled laser has been demonstrated with single-mode operation and wavelength tunability [7]. In this paper, we report the large wavelength tuning of a DR-RCL with power output exceeding 1mW and more than 20 lasing modes.

A photograph of the DR-RCL is shown in Fig. 1. The passive double microring resonators have slightly different circumferences (ring radii of 100  $\mu\text{m}$  and 104  $\mu\text{m}$ ) so that the effective free spectral range of the double ring filter is much larger than that of single rings. The bandgap wavelength of the quaternary material used for the passive waveguide is 1.06  $\mu\text{m}$ . The waveguide ridge was deeply etched on the outer side of the ring to increase the light confinement and reduce the ring loss. The passive waveguide width is 1.8  $\mu\text{m}$ . The optical gain is provided by the 500  $\mu\text{m}$  long semiconductor optical amplifier sections SOA1 and SOA2, which use a standard gain ridge waveguide laser structure and require an additional epitaxial growth step [8]. The 300  $\mu\text{m}$  SOA sections are not biased and absorb the light of anti-resonance wavelength. The width of the SOA waveguide is 2.2  $\mu\text{m}$ .

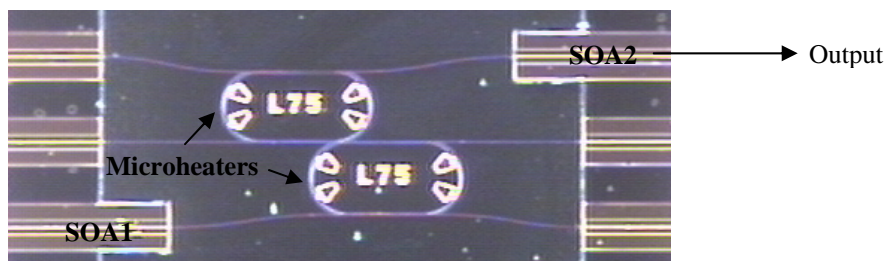


Fig. 1. A photograph of the DR-RCL.

The air gap and length of the directional coupler are 0.8  $\mu\text{m}$  and 250  $\mu\text{m}$ , respectively, which gives an estimated coupling ratio of 50%. Fig. 2 shows the dependence of the output power on bias current of SOA2 for different stage temperatures of 16, 18 and 22  $^{\circ}\text{C}$ , when bias current of SOA1 is 94 mA. The threshold currents of SOA2 at these three stage temperatures are 20, 23, and 25 mA, respectively. It can also be seen that the differential efficiency increases with the decrease of stage temperature. The laser power of around 1 mW is not as high as expected. Although it is very difficult to locate the cavity loss sources, the infrared imaging and theoretical analysis indicate that the largest loss is mainly at the transition between passive bus waveguide and SOA sections, which is much greater than 3 dB. There may be also some extra loss due to the imperfection at the narrow coupler gap.

The free spectral range of the device under test, FSR is about 0.67 nm. The 4% difference of ring radii in the double ring configuration will give 2.2% difference in free spectral range and 45 times wavelength tuning enhancement via the Vernier effect. This is corresponding to 30 nm wavelength tuning of the single-mode lasing. Four Platinum heaters are integrated on the top of microring waveguides. Varying the current of one heater can result the shift of resonance wavelength of the corresponding microring due to the thermo-optic effect and the lasing

can jump from one mode to the next one where the transmission peaks of the double ring resonators overlap the best. Fig. 3 shows a series of lasing spectrum when varying the heater current between 0-30 mA.

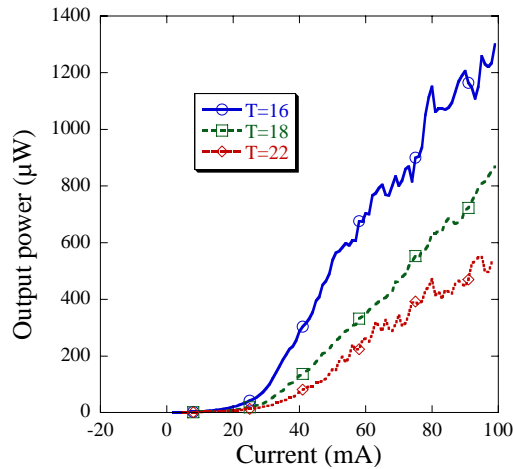


Fig. 2. Output power as a function of the bias current of SOA2 for different stage temperatures.

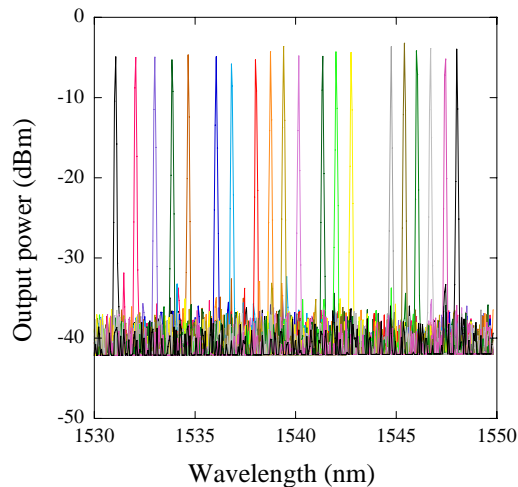


Fig. 3. Wavelength tuning by applying a current between 0-30 mA to the integrated Platinum heater.

In conclusion, we demonstrated the large wavelength tuning of a monolithically integrated GaInAsP-InP double ring resonator coupled laser. When the current of the integrated heater is changed, the laser produces 20 different modes, which spread uniformly in 17 nm wavelength range. The side mode suppression is 30 dB across the tuning range. The single-mode lasing power of 1.2 mW is achieved at stage temperature 16 °C. The lasing power and spectrum quality can be further improved if the cavity loss is reduced.

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