Time Domain Characteristic of Dual-mode Whispering-gallery Mode Lasers

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***Abstract*—We studied the time domain characteristic in whispering-gallery mode laser and whispering-gallery Fabry-Perot hybrid laser. In the hybrid cavity laser, mode competition at mode hopping position is intense, and the time domain signals of the competition modes oscillate alternately and complementarily. However, the time domain signals of whispering-gallery mode laser are relatively stable.**

Keywords—semiconductor laser, arced-square microcavity, mode competition

I. Introduction

Semiconductor lasers with dual-mode competition are of great significant in the fields of optical high-speed communication [1], random number generation [2]. Alternating jumping between two or more modes in a competitive laser leads to additional mode-partition noise [3-5] and enhancement of lasing linewidth, which greatly affecting the optical communication speed. The time-domain oscillation characteristic in Fabry-Perot (FP) type laser diode [6-9] and vertical-cavity surface-emitting laser [10] have been investigated.

In this paper, the time domain characteristics of a dual-mode whispering-gallery mode (WGM) laser and a hybrid square/rhombus-rectangular laser (HSRRL) described in [11] are investigated and analyzed.

II. Experimental Results

As shown in Fig.1(a), an HSRRL consists of a vertex-deformed square-rhombus microcavity (SRM) and a FP cavity. The SRM is as a reflecting surface of the FP cavity to improve its mode field distributions pattern. The lasing mode is the coupling of the two cavity modes based on the vernier effect. The side length α of the square cavity is 15 μm with a deformation amplitude δ of 0.25 μm at the vertex connected to the FP cavity, which is designed to enhanced the equivalent reflectivity of SRM. The length L and the width d of the FP cavity are 300 μm and 2 μm, respectively. Figure 1(b) shows the typical time averaged spectra as a function of I_{SRM} with I_{FP} fixed at 57 mA. At I_{SRM} of 1.50 mA and I_{FP} of 57 mA, the intensity difference and the mode interval are 1.5 dB and 1 nm respectively. We filtered out the longer and shorter wavelength side modes respectively to monitor the changes in time domain. The time domain series in I_{SRM} of 1.5 mA and I_{FP} of 57 mA is also shown in Fig. 1(c). The time domain signal of the two mode is interlaced and complementary due to a force mode competition. The mode hopping time is 3 ns, which is defined to be duration of rising or falling edge. It indicates that the intensity of one mode in the competitive dual mode is stable in a long-time range and fluctuates in a short-time range, and the mode intensity ratio is essentially the time

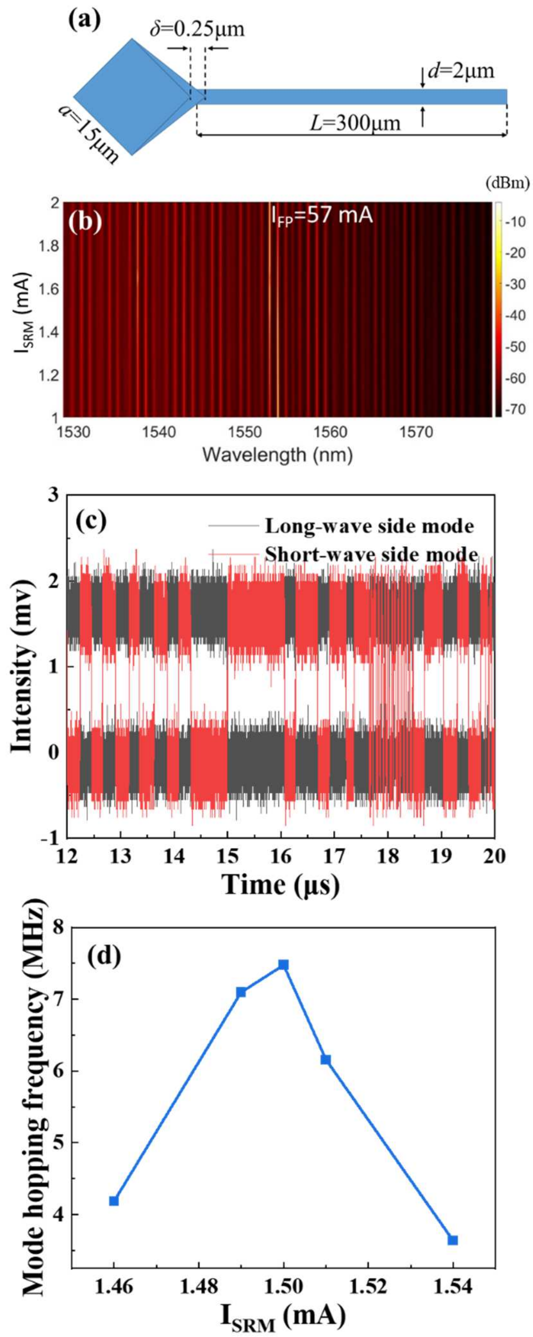

Fig. 1. (a) Diagrammatic sketch, (b) typical time averaged spectra, and (c) time domain series of the longer wavelength side (black curve) and shorter wavelength side (red curve) mode of the HSRRL. The time domain series is for the two modes around 1553 nm under 1.5 mA of I_{SRM} and 57 mA of I_{FP}. (d) Mode hopping frequency of time domain series as a function of I_{SRM}.

proportion of high level in time domain. Figure 1(d) indicates mode hopping frequency versus I_{SRM}. We define the mode hopping frequency as the number of mode jumps per unit time. The mode hopping frequency increase with the absolute value of mode intensity ratio decrease, and maximum mode hopping frequency of 7.47 MHz is at 1.5 mA I_{SRM}. Because the closer the mode intensity is, the more intense the mode competition is.

An arced-square WGM laser shown in Fig. 2(a) is used forcomparison. The arced-square microlaser has 20 μm side length, 2.17 μm deformation, 5.5 μm the center hole radius, and 1.5 μm width waveguide. The width of annular injection window is 5.5 μm. For the lasing spectra of the arced-square WGM laser in Fig. 2(b), it is dual transverse mode lasing at the longitudinal mode near 1550 nm. The intensity difference of the two modes is 7 dB and the mode interval is 0.3 nm at injecting current of 36 mA. Time domain signals of the arced-square microlaser are also monitored and measured, as shown in Fig. 2(c). The time domain signals are relatively stable without hopping and square-wave oscillation at a time scale above 100 μs. It proved that WGM laser has smaller mode-partition noise than a mode competitive WGM-FP hybrid laser.

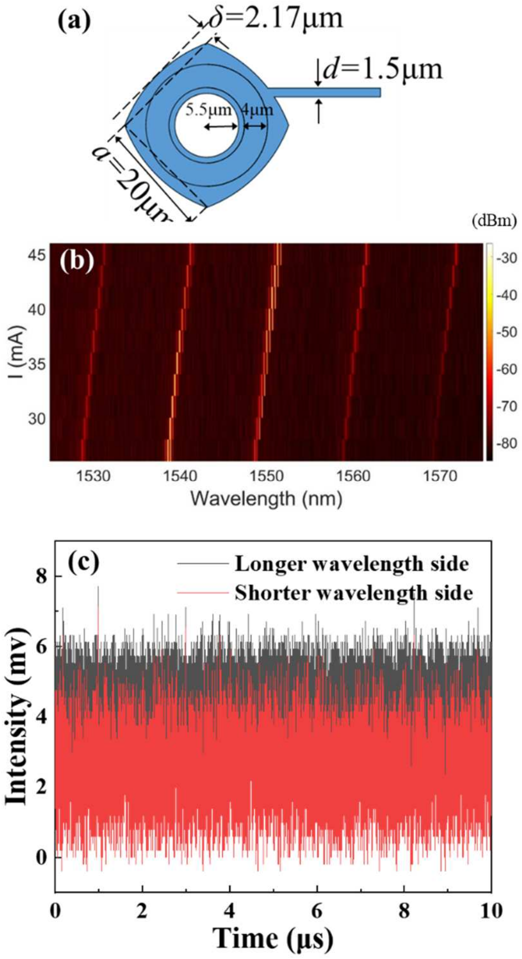

Fig. 2. (a) Diagrammatic sketch, (b) typical time averaged spectra, and (c) time domain series of the longer wavelength side (black curve) and shorter wavelength side (red curve) mode of the WGM laser. The time domain series is for the two modes around 1550 nm under the injecting current of 36 mA.

III. Conclusion

In conclusion, we studied the time domain characteristic of dual-mode WGM lasers and WGM-FP hybrid lasers. For the WGM-FP hybrid lasers, the dual-mode competition at the mode-hopping position is intense and shows alternating complementarity in the time domain. For the WGM laser, it shows a relatively weak mode competition and a stable time domain series, and has a lower mode partition noise.

IV. References

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