カプセル型波長スケール金属共振器レーザの試作と室温パルス発振

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Wavelength-scale metallic cavity lasers have drawn increasing attention for ultra-dense photonic integrated circuits and on-chip interconnects applications [1]. Here, we fabricate a capsule-shaped wavelength-scale laser with metallic cladding and demonstrate its room-temperature lasing operation at 1550nm under pulsed optical pumping. We compare it with a rectangular laser of similar size and show improved slope efficiency and side-mode suppression ratio (SMSR) by using the capsule shape.

Fig. 1(a) shows the scanning-electron microscope (SEM) image of the fabricated capsule-shaped cavity before metal deposition. By introducing an optimized curvature with radius R at both ends of a conventional rectangular metal-clad cavity, optical mode is pushed effectively inside the mesa, resulting in drastic reduction of metallic loss especially for the transverse-electric (TE) mode [2]. After fabricating the mesa by inductively coupled plasma (ICP) reactive-ion-etching (RIE) process, the entire mesa was coated with a thin (40 nm) SiO_2 passivation layer and finally by a thick (1 μm) silver layer [3]. The device was mounted top-side down on a silicon carrier and optically pumped from the InP substrate side by using a 1030-nm pulsed laser for characterization.

Figure 2 shows the emission spectra from a rectangular laser with W = 1 μm and L = 1.6 μm observed under increasing excitation pump power. The device has two clear lasing peaks at 1551 nm (Mode 1) and 1545nm (Mode 2). The insert shows the optical intensity of each mode as a function of excitation pump power, which accounts for the total power of the entire beam spot (spot width ~5 μm). There is clear evidence of mode competition between the two lasing modes, which limits the SMSR to be <5 dB.

Figure 3 shows the emission spectra from a capsule-shaped laser with W = 1 μm, L = 1.6 μm, and L/R = 1.25 to maximize the Q factor [2]. Similar to rectangular cavities, two peaks of competing modes are observed; however shorter-wavelength mode (Mode 2) quickly becomes the dominant lasing mode at increased pump power with a SMSR as large as ~10 dB. Figure 3(b) shows the optical intensity of each mode as a function of excitation pump power. We clearly observe suppression of Mode 2 as well as increase in the slope efficiency by factor of 1.69 for Mode 1.

From finite-difference time-domain (FDTD) simulation, we confirm that the lasing mode (Mode 1) in Fig. 3(a) corresponds indeed to the TE mode, which has the dominant electric field oriented in width direction of the mesa. We therefore attribute the observed enhancement of SMSR to be the reduction of metallic losses for the TE mode induced by the curvature. It is also worth noting that the capsule device has a smaller area than the square cavity as is clear from Fig. 1(c). Thus, we expect reduced lasing threshold for the capsule-shaped lasers.

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Reference

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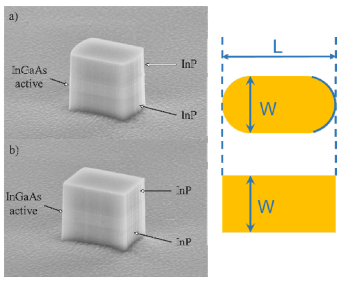

Figure 1. SEM images of capsule (a) and rectangular (b) metal-clad laser. With parameters defined in (c), L=1.6μm W=1μm, and L/R=1.25.

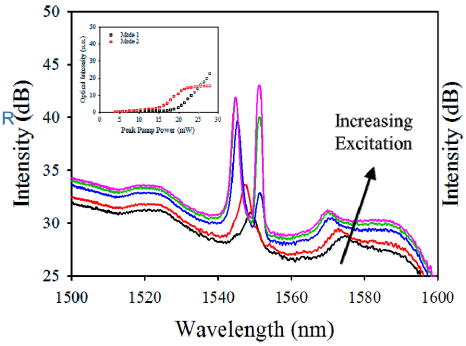

Figure 2. Emission spectra from a rectangular cavity (L=1.6μm W=1μm). Insert shows the intensity of the respective modes as a function of peak pump power.

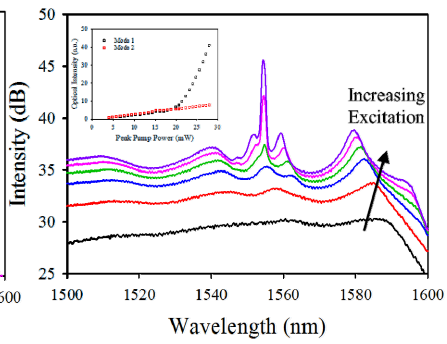

Figure 3. Emission spectra from a capsule-shaped cavity (L=1.6μm, W=1μm, L/R=1.25). Insert shows the intensity of the respective modes as a function of peak pump power.