High Spontaneous Emission Coupling Factor in Photonic Crystal Nanolasers

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ABSTRACT: We have demonstrated high spontaneous emission coupling factor ~ 0.1 from photonic crystal nanolasers with quantum dots. This high coupling resulted from narrow homogenous broadening of the quantum dots and the small number of resonances.

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Photon localization is key to fabricating photonic devices such as lasers, optical traps, and waveguides. As resonator dimensions get smaller, the structures support the smaller number of modes in emission range. Spontaneous emission coupling (β) factors ($0<=\beta<=1$) are defined as radiation energy coupled to the lasing mode divided by total radiation energy. The small cavities such as photonic crystal nanocavities inherently have high β factors [1]. In this report, we show high β factors ~ 0.1 from our photonic crystal nanolasers with quantum dots (QDs).

Epitaxial layers including five stacked self-assembled InAs QDs were grown by molecular beam epitaxy. The QD density in our samples is $1\times10^{10}/(cm^2$ layer), and 30nm GaAs layers separated the QD layers. $Al_{0.2}Ga_{0.8}As$ is used for cladding layers to form 200nm thin slab waveguides, which are grown on an 800nm $Al_{0.94}Ga_{0.06}As$ sacrificial layer on a top of GaAs substrate. In order to define 200nm-thick 2D-PC slab cavities, electron-beam lithography, chemically assisted ion-beam etching with Cl_2/Ar gases, oxidation of $Al_{0.94}Ga_{0.04}As$ layer, and wet etching of AlO_x layer were performed. We fabricated single-, two-, and four-defect coupled cavities of two-dimensional square lattice of holes. 20nsec-pumping pulses with 3% duty cycle from a 780nm semiconductor laser were used to measure emission at room temperature.

Figure 2 shows collected peak output power of lasing mode from two- and four-defect coupled cavities. Threshold pump powers of 120µW and 370µW are measured for two- and four-defect coupled cavities, respectively [2]. Each of these cavities exhibits soft thresholds, which indicate high β factors. To see approximate values of β factor, we show the log-log plot of output power dependence on input power in figure 1 (b), and β factors are ~ 0.1. This high β factors resulted from a combination of the narrow homogeneous emission of quantum dot and the small number of modes for the quantum dots contributed to the lasing.

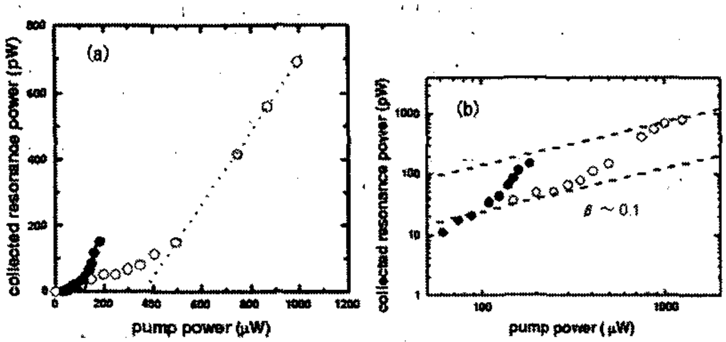

Fig. 1. Collected resonance power as a function of peak pump power. Panels (a) and (b) show the linear-linear plot and the log-log plot. Filled circles and open circles are data from two-defect coupled cavity and four-defect coupled cavity.

References

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