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JTuC5 **11:30 am**

Optical Characterization of High Quality Two Dimensional Photonic Crystal Cavities

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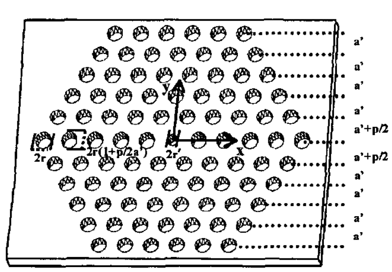
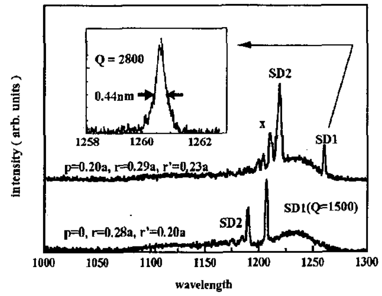
Photonic crystal nanocavities have recently attracted much attention because such cavities are predicted to provide the desired combination of both small mode volume and high Q values. However, typical well-confined donor mode cavities have small mode volumes, but also suffer from low Q values limited by vertical scattering losses. To address the problem, Vuckovic *et al.* recently predicted[1] by 3D-FDTD (finite difference time domain) calculations that single defect cavities with fractional edge dislocations can have well-localized modes with high Q values of as high as 30,000. In this presentation, we report the experimental demonstration that by using fractional edge dislocations in photonic crystal cavities, it is possible to construct microcavities with high Qs as well as small mode volumes.

Figure 1 is a schematic of our defect photonic crystal nanocavity with fractional edge dislocations. We used three stacked indium arsenide (InAs) quantum dot (QD) layers, which were clad by $Al_{0.16}Ga_{0.84}As$ layers on top of a 400 nm $Al_{0.94}Ga_{0.06}As$ layer. The cavity thickness (d) is 240 nm. The patterns of photonic crystal defect cavity were lithographically defined. Photonic crystal cavities are surrounded by twenty layers of photonic crystal for good optical confinement in plane. The lattice spacing (a) is lithographically controlled to 370 nm (d/a = 0.65). After lithography, the patterns were transferred through the active membrane by using an Ar^+ ion beam assisted with a Cl_2 jet, and the $Al_{0.94}Ga_{0.06}As$ layer under cavities was subsequently oxidized in steam, and then the AlOx layer was completely removed. We



JTuC5 Fig. 1. schematic of photonic crystal cavities with fractional edge dislocations.



JTuC5 Fig. 2. PL spectrum of samples with different elongation parameter (p/a).

fabricated samples with two different p/a values (p = 0, and 0.20a).

Figure 2 shows the p/a dependence of photoluminescence spectrum measured from two cavities with almost the same r/a and r'/a. The shallow donor (SD1 and SD2) peaks have distinct y- and x-polarizations, respectively. By considering polarization dependence and simulation results, SD1 and SD2 were found to match numerically predicted shallow donor modes. In our samples, a maximum Q was obtained at p/a = 0.20. Typical spectra taken from the nanocavities are shown in an inset of figure 2. The measured Q was as high as 2800. Therefore, by adding fractional edge dislocation, we could increase the measured Q to twice the value measured from a symmetric cavity. To compare the measured Q with our simulation results, we have carefully measured the geometries of our fabricated structures, and modelled these with 3D-FDTD method. Indeed, we find that the calculated Q values for our experimentally realized geometries (of 4400) are much closer to the measured values, and that the simulated mode volume is 0.43(λ/n).[3]

1. J. Vuckovic, M. Loncar, A. Scherer, and H. Mabuchi, "Design of photonic crystal microcavities for cavity QED", Phys. Rev. E. to be published, December 2001.

JTuC6 **11:45 am**

Light Propagation Via Coupled Defects in Photonic Crystals

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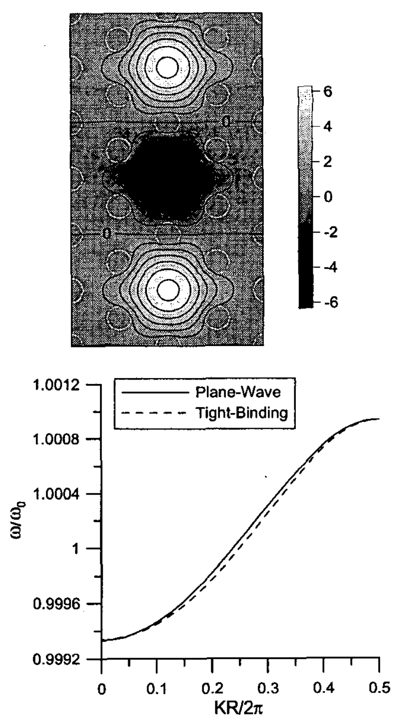
Low-loss waveguiding around sharp bends is a key task in microoptics. A coupled-defect waveguide is able to perform much better at sharp bends[3] than a channel waveguide.[2] It also can enhance considerably the efficiency of second harmonic generation due to the low effective group velocity.[4] Coupled-defect optical waveguides are a superlattice or superstructure consisting of original and modified unit cells of the underlying photonic crystal.[1] A tight-binding description of a chain of defects in a linear medium was derived in[1] leading to a dispersion relation which is quadratic with respect to the frequency. Recently the validity of the tight-binding approximation of the defects in a two-dimensional superstructure was investigated by means of direct transmission calculations using a transfer-matrix method.[5]

Here we start from a more general form of the reciprocity theorem and derive equations which are linear with respect to the frequency. The equations describe pulse propagation in an arbitrary arrangement of defects in a photonic crystal, with an additional arbitrary but weak perturbative polarization, describing, e.g., a nonlinearity. For a linear chain of uniform defects with two degenerate modes per defect Fig. 1 compares the dispersion relations of one of the two emerging minibands resulting from the tight-binding analysis and rigorous plane wave calculations.[6]

For slowly varying envelopes b_{kl} of defect l and mode k ($k = 1, 2$) the evolution equations in the time domain are

$$i\frac{\partial b_{kl}(t)}{\partial t} = -\frac{\omega_0}{2}\left[\gamma_k^0 b_{kl} + \gamma_k^1(b_{k,l-1} + b_{k,l+1})\right] - \frac{\omega_0}{2W_k}\int d^3\mathbf{r}\,\mathbf{e}_k(x, y, z - lR)\,\mathbf{p}^{\text{pert}}(\mathbf{r},t), \quad (1)$$

where ω_0 is the frequency and W_k the energy of the degenerate modes e_k, R is the separation of the defects, γ_k^0 denotes the self-interaction of a defect, γ_k^1 the overlap between nearest neighbor defects and p^{pert} is the slowly varying perturbative polar-



JTuC6 Fig. 1. Image plot of a component of the electric field of the Bloch mode of the defect chain with defect spacing R and original mode eigenfrequency ω_0 for $KR = \pi$ superimposed on the index profile (top) and corresponding dispersion relation (bottom) obtained with rigorous plane-wave technique and tight-binding approximation before slowly varying envelope approximation was applied.