QTuJ2 **2:45 pm**

Photonic-crystal-based resonant-cavity-enhanced detectors

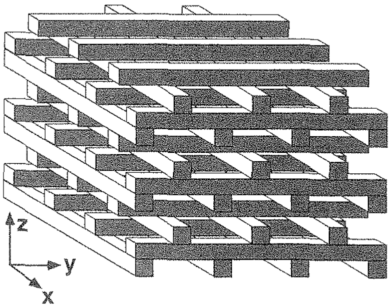
B. Temelkuran, E. Özbay, J.P. Kavanaugh,* G. Tuttle,* K.M. Ho,* *Department of Physics, Bilkent University, Bilkent Ankara 06533 Turkey*

The coherent scattering and interference of electromagnetic (EM) waves in three-dimensional ordered structures lead to formation of forbidden bands in which the propagation of photons is not allowed. These three-dimensional structures, known as photonic bandgap (PBG) crystals, have recently received both theoretical and experimental attention.[1] Recently, Ho *et al.* have proposed and demonstrated a layer-by-layer three-dimensional photonic crystal (Fig. 1), with a full PBG in all directions.[2] This structure was fabricated at smaller scales by conventional methods,[3] and defects or cavities around the same geometry was also investigated.[4] The electrical fields in such cavities are usually enhanced, and by placing active devices in such cavities, one can make the device benefit from the wavelength selectivity and the large enhancement of the resonant EM field within the cavity. This effect has already been used in optoelectronics to achieve novel devices such as resonant cavity enhanced (RCE) photodetectors and light emitting diodes.[5] In this paper, we demonstrate the RCE effect by placing microwave detectors within the localized modes of photonic crystal defect structures.

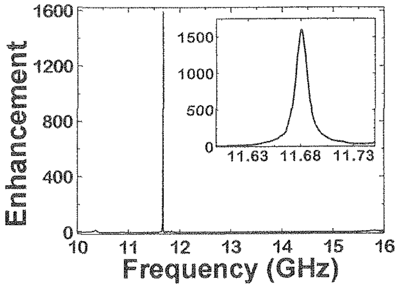
In our experiments, we used defect structures built around the layer-by-layer dielectric photonic crystal. A square law microwave detector was placed inside the defect volume of the photonic crystal, along with a monopole antenna. The DC voltage on the microwave detector was used to measure the power of the EM field within the cavity. We also measured the enhanced field by a network analyzer.

We first investigated a planar defect structure, which was built by separating a 16 layer crystal from the middle. Figure 2 shows the enhancement characteristics of this structure with a separation width of 8.5 mm. We observed a power enhancement factor of 1600 at a defect frequency of 11.68 GHz. The Q-factor (quality factor), defined as the center frequency divided by the FWHM was measured to be 900.

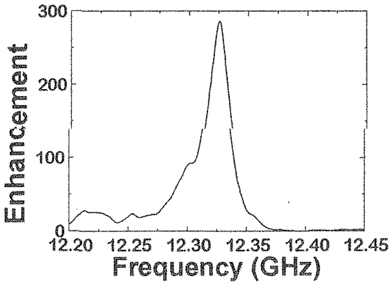
In order to obtain a defect localized in three dimensions, we modified a 16-layer



QTuJ2 Fig. 1. Schematics of the layer-by-layer photonic crystal.



QTuJ2 Fig. 2. The measured power of the EM field inside a one-dimensional defect structure.



QTuJ2 Fig. 3. The measured power of the EM field inside a localized defect structure.

crystal structure in the following manner. Part of the rods on the 8th and 9th layers were removed to obtain a rectangular prism like cavity. Figure 3 shows the power enhancement characteristics of this structure. An enhancement factor of 290, and a Q-factor of 540 were measured at a defect frequency of 12.32 GHz.

Our results suggest the possibility of using the embedded detector as an RCE detector. By using a smaller size photonic crystal and a higher-frequency detector, the effect can also be shown at millimeter and far-infrared frequencies. Such RCE detectors will have increased sensitivity and efficiency when compared to conventional detectors, and can be used for various applications where sensitivity and efficiency are important parameters.

*Ames Laboratory and Microelectronics Research Center, Iowa State University, Ames, Iowa 50011

1. E. Yablonovitch *et al.*, Phys. Rev. Lett. **63,** 1950 (1989).
2. K.M. Ho *et al.*, Solid State Comm. **89,** 413 (1994).
3. E. Ozbay *et al.*, Phys. Rev. B **51,** 13961 (1995).
4. E. Ozbay *et al.*, Appl. Phys. Lett. **76,** (1996).
5. M.S. Unlu *et al.*, J. Appl. Phys. **78,** R1-R33 (1995).