Optically Tunable Photonic Crystal Reflectance Filter

D. W. Dobbs and B. T. Cunningham
University of Illinois at Urbana-Champaign, USA

We have demonstrated a photonic crystal structure whose properties are tunable with laser illumination through the incorporation of a nonlinear dye. Laser illumination causes a change in the bulk refractive index of a polymer that is doped with the dye, leading to controlled tuning of the photonic crystal reflectance spectrum.

The device, shown in Figure 1, consists of a one-dimensional periodic ($\Gamma = 550\,\text{nm}$) surface structure fabricated on a low refractive index plastic substrate that is overcoated with a layer of high refractive index TiO_2. The process is performed over large surface areas on continuous rolls of plastic film. A solution containing 95% polymethylmethacrylate (PMMA) and 5% N-Ethyl-N-(2-hydroxyethyl)-4-(4-nitrophenylazo)aniline by weight is spin-coated onto the structure, resulting in a solid film with a thickness of several microns. When the fabricated structure is illuminated with broadband light at normal incidence with the light polarization perpendicular to the grating lines, a narrow band of wavelengths ($\lambda = 891\,\text{nm}$, $FWHM = 1\,\text{nm}$) is strongly reflected. We have demonstrated that upon laser illumination, the wavelength of the reflection resonance can shift to lower wavelengths by $> 2\,\text{nm}$, and that the resonance returns to its original wavelength when the illumination is turned off. For the resonance-tuning effect to be achieved, the wavelength of the laser must be within the absorption spectrum of the dye, which is centered at a wavelength of 500 nm. As shown in Figure 3, we have characterized the switching speed and dependence of the wavelength shift with laser intensity. Because the switching behavior is independent of the polarization of the incident laser beam, the bulk refractive index change is likely caused by the trans-cis excitation of dye molecules. Numerical simulations show that the magnitude of the bulk refractive index change in the dye-doped polymer film is as large as 0.01.

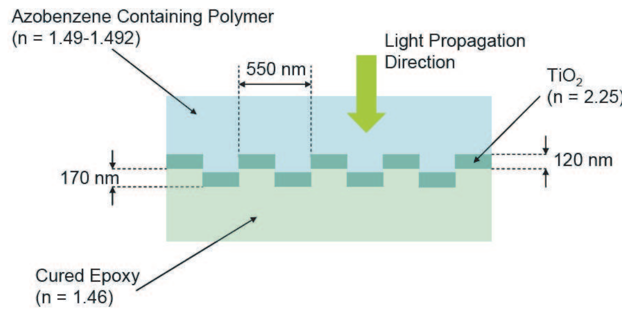

Figure 1.

Because the device structure can be fabricated inexpensively in plastic over large areas, and because a high density of independently addressable locations will be achieved due to lateral optical confinement by the photonic crystal, we expect the new device to find applications in optical computing, storage, switching, and multiplexing.

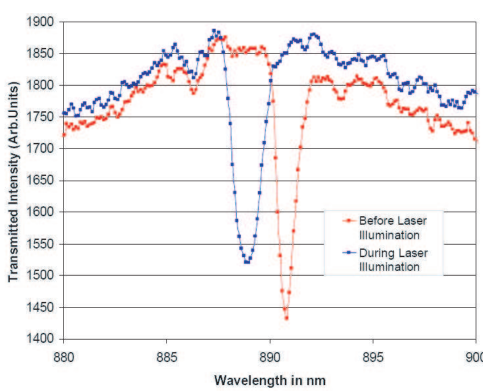

Figure 2.

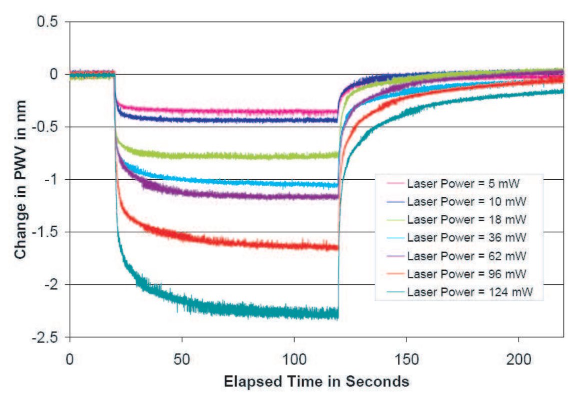

Figure 3.