콜레스테릭 액정의 광결정 가장자리에서의 펨토초 비선형 광학 이동

Femtosecond nonlinear optical shift in photonic bandgap edges of a cholesteric liquid crystal

Jisoo Hwang, N. Y. Ha, H. J. Chang, Byoungchoo Park* and J. W. Wu
Department of Physics, Ewha Womans University
*Quantum Photonic Science Research Center & Department of Physics, Hanyang University
js9279@ewha.ac.kr

A cholesteric liquid crystal (CLC) system exhibits one-dimensional (1-D) photonic bandgap (PBG) characteristics in the transmission spectrum through a selective Bragg reflection(1). Related to the nonlinear optical (NLO) processes in a PBG structure of CLC, the inherent periodicity has been exploited to phase-match the fundamental and the harmonic waves through the umklapp processes(2). Near bandgap edges of a CLC, harmonic generations have been shown to be enhanced significantly through the field localization(3). In this connection, it is important to investigate how the intensity-dependent NLO refractive index change will be manifested near bandgap edges of a CLC PBG structure. Since CLC is a naturally formed 1-D PBG chiral structure consisting of helically twisted nematics, upon irradiation of an intense optical field an ultrafast Kerr nonlinearity coming from the cubic hyperpolarizability of mesogenes composing nematics will give rise to an intensity-dependent refractive index change. It is expected that the Kerr nonlinearity should be strongly enhanced near PBG edges of CLC through a high electromagnetic DOM(4).

From the analysis of dispersion relation $\omega(k)$, it is found that the signs of the 3rd order NLO coefficients of the refractive indices parallel and perpendicular to nematic directors forming the CLC determine the profile of transmission spectrum changes in the PBG structure. A red (blue) shift of bandgap position for positive (negative) signs for the both ones was predicted, while an increase (decrease) in bandgap width for the positive (negative) sign for parallel one and the negative (positive) sign for perpendicular one was predicted.

For the experimental measurement of NLO changes in CLC bandgap edges, CLC cell with the gap size of 7.0 μm is fabricated in a left-handed helical structure from the mixture of nematics (ZLI-2293, Merck) with a chiral center (S-811, Merck). With the 18.9 % wt. concentration of S-811, a CLC cell with the stopband centered at 785 nm with 50 nm width was obtained. The linear optical parameters of the fabricated CLC cell was determined through the Berreman 4×4 matrix. A Ti:Sapphire femtosecond mode-locked laser with 130-fs pulse width (Spectra-Physics, Tsunami) was employed for a NLO transmission measurement. With the pulse repetition rate fixed at 400 kHz, a typical laser power was on the order of 100 μW with the maximum up to 0.5 mW. With a microscope objective ×10, the beam was focused to a spot size of 7.5 μm beam waist providing the high peak intensity of ~5.0 GW/cm^2 easily. By use of a Fresnel rhomb, the polarization of Ti:Sapphire output was controlled to provide the right-circularly polarized (RCP) and left-circularly polarized (LCP) as well as linearly polarized lights in the whole range of the measurement wavelength. Fig. 1 shows the experimental data of nonlinear transmission dispersion measured from 730 nm to 850 nm at 10 nm intervals for RCP and LCP lights. At the high intensity, we find that there occur NLO changes in the transmission for LCP light near the bandgap edges, while no change is observed in the whole range of PBG for RCP light. At the LCP light intensity of 4.3 GW/cm^2, the change of normalized transmission amounted to 14 % for 740 nm, the high frequency PBG edge, and 13 % for 800 nm, the low frequency PBG edge. We find that PBG shifted toward to the shorter wavelength as the incident light intensity increased, hence, a blue shift of PBG via NLO process in the nematics forming CLC. Next, in order to determine the Kerr coefficients, the nonlinear transmission measurement was carried out as a function of the incident LCP light intensity at the fixed wavelengths of 740 nm and 800 nm (Fig. 2). The obtained Kerr coefficients were $n_{parallel}^{(2)}$ = -2.8×10^{-13} (cm^2/W) and $n_{perp}^{(2)}$ = -3.9×10^{-13} (cm^2/W), corresponding to an effective Kerr nonlinear susceptibility $(\chi_{perp}^{(3)})_{eff}$ = -2.0×10^{-11} (esu) and $(\chi_{parallel}^{(3)})_{eff}$ = -1.6×10^{-11} (esu). When compared with the literature values of third harmonic generation (THG) $\chi^{(3)}$ reported for generic nematics such as MBBA and E7[5,6], we find that the enhancement factors are in the range of 7 and 60. This work is supported by KRF-2002-042-C00024

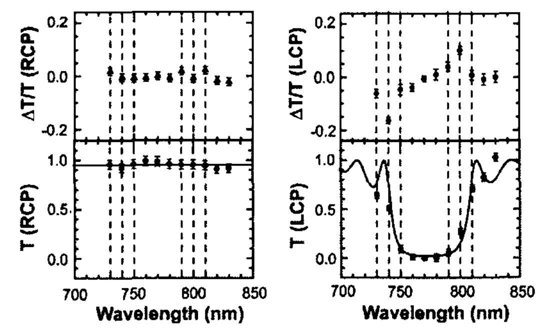

Fig. 1 Normalized nonlinear transmission changes at the high intensity of 4.3GW/cm^2 are plotted along with the low intensity (10MW/cm^2) measurement.

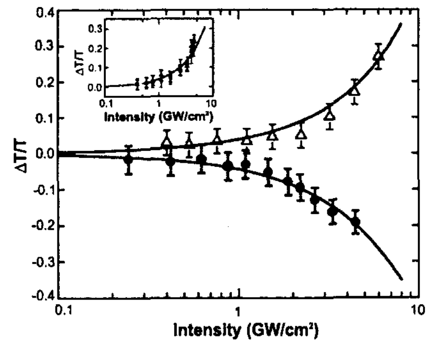

Fig. 2 Normalized nonlinear transmission changes are measured as a function of the incident laser intensity. Open triangle and closed circle correspond to the measurements for the wavelength of 800 nm and 740 nm, respectively.

1. V. I. Kopp and A. Z. Genack, Phys. Rev. Lett. 89, 033901 (2002).
2. J. W. Shelton and Y. R. Shen, Phys. Rev. Lett. 25, 23 (1970).
3. H. Hoshi *et al*, Phys. Rev. E 63, 056610 (2001)
4. Y. Dumeige, *et al.* Appl. Phys. Lett. 78, 3021 (2001).
5. K.Y. Wong and A.F. Garito, Phys. Rev. A 34, 5051 (1986).
6. D. Yellin *et al.* Phys. Rev. Lett. 82, 3046 (1999).