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The Composition and intensity-driven sign reversal of the nonlinear optical response of nanoparticle-doped liquid crystal glass

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INTRODUCTION & AIM

The combination of liquid crystals and nanotechnology has resulted in a variety of tunable multifunctional materials suitable for advanced nanophotonic applications, including miniature lasers, structured light, nonlinear optics, quantum technologies, sensing, imaging, communication, and soft robotics. The development of new nanocomposites made of liquid crystals and various types of nanoparticles is critical for future progress in this rapidly evolving field. Traditionally, conventional molecular liquid crystals are used as anisotropic hosts for nanomaterials to create advanced nonlinear optical materials. Recently, we proposed using glass-forming ionic liquid crystals made of metal alkanoates to produce glass nanocomposites exhibiting long-term stability and strong third-order nonlinear optical response. In this paper, we provide a comparative analysis of the nonlinear optical response of vitrified mesogenic cadmium octanoate containing gold, carbon, or both gold and carbon nanoparticles.

METHODS & MATERIALS

We study mesomorphic glass-forming cadmium octanoate $Cd^{+2}(C_7H_{15}COO^-)_2$ (abbreviated as CdC_8) containing gold nanoparticles (4% mol.), carbon nanoparticles (2% weight), or both carbon (2% weight) and gold (4% mol.) nanoparticles simultaneously. The average diameter of spherical gold nanoparticles is 15 nm, and the average size of carbon nanoparticles is 6 nm.

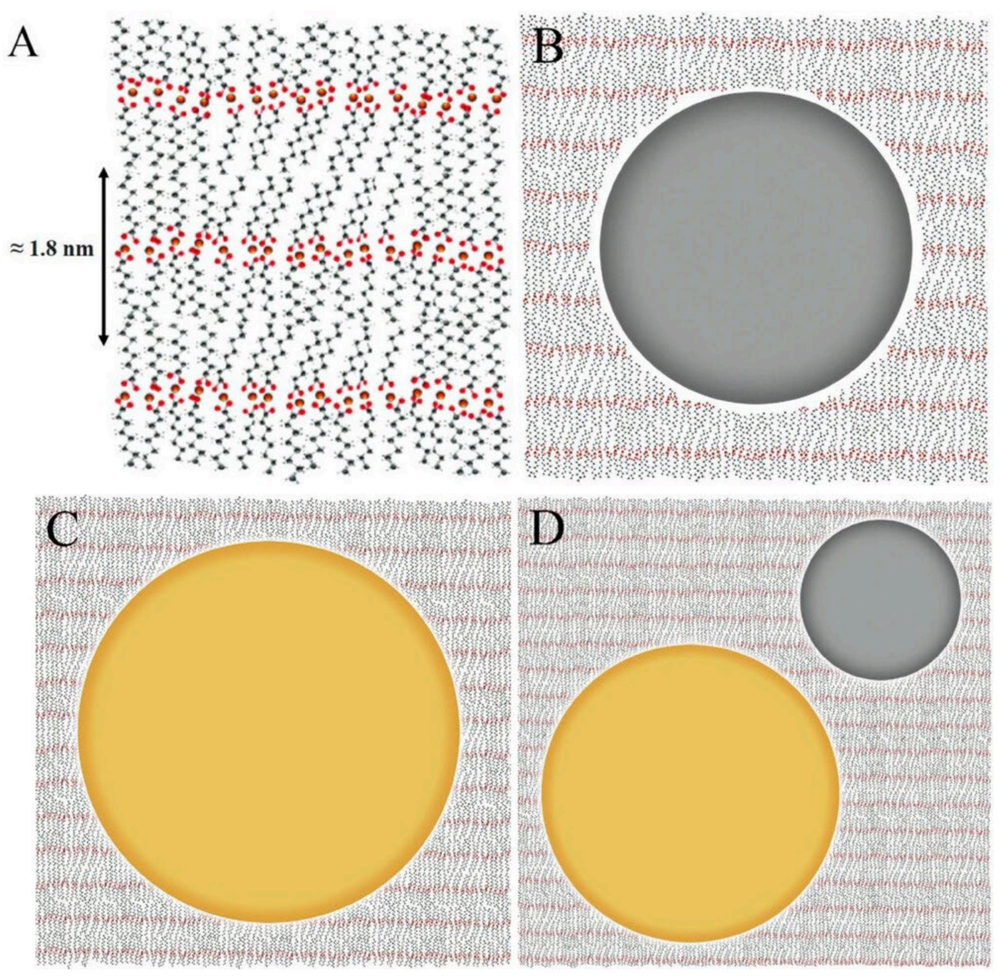

Figure 1. Schematic presentation of LC materials with characteristic relations at the nanoscale. (A) Sizes between layers matrix CdC_8. (B) Sizes of C NPs synthesized in a CdC_8 matrix. (C) Sizes Au NPs synthesized in a CdC_8 matrix. (D) C and Au NPs synthesized in a CdC_8 matrix [1].

Nonlinear-optical measurements were carried out using a Z-scan method. A nanosecond Nd:YAG laser generating Gaussian beams (the pulse repetition rate was 0.5 Hz; the pulse duration was 9 ns; the laser wavelength was 532 nm) was utilized in experiments. Femtosecond Z-scan experiments were performed using a Gaussian laser beam generated by femtosecond laser Mira-900F with a Legend HE optical amplifier, at wavelengths of 800 nm and 600 nm, with a repetition rate of 1 kHz and pulse durations of 176 fs and 100 fs, respectively. Z-scan measurements were conducted using both closed-aperture (CA) and open-aperture (OA) schemes.

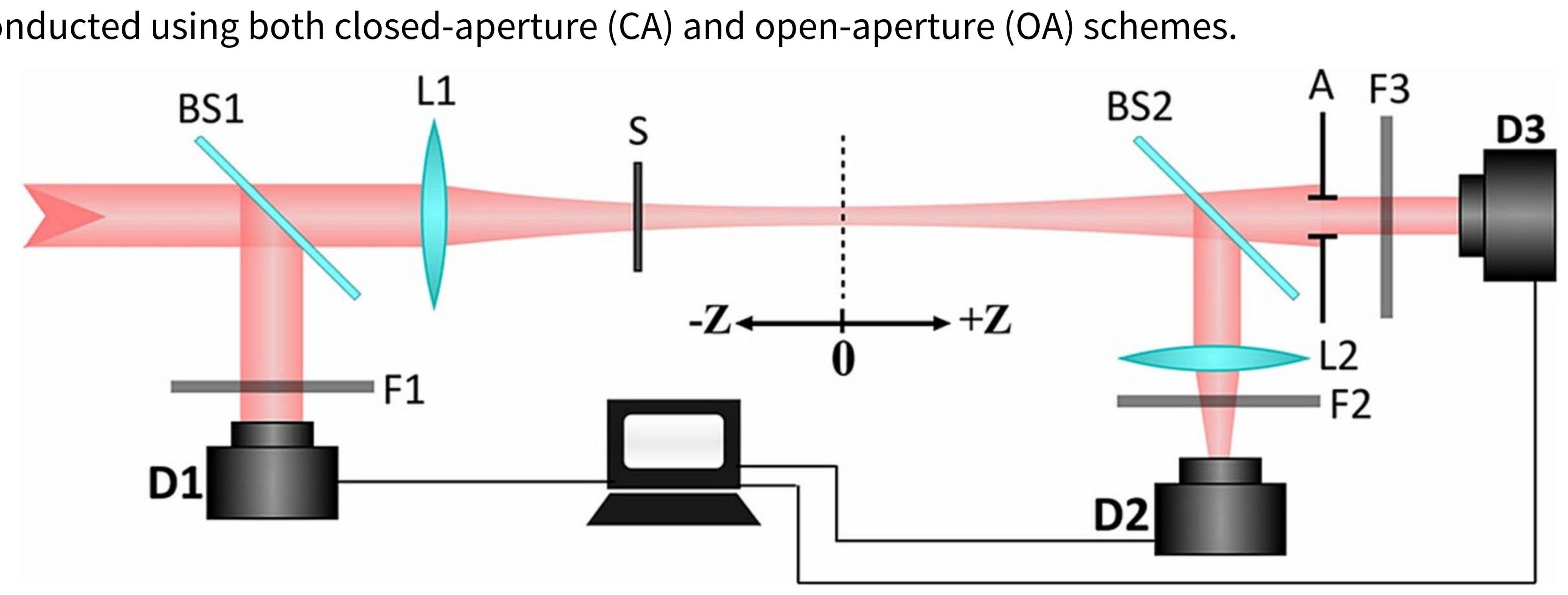

Figure 2. Schematic illustration of Z-scan measurements [2].

RESULTS & DISCUSSION

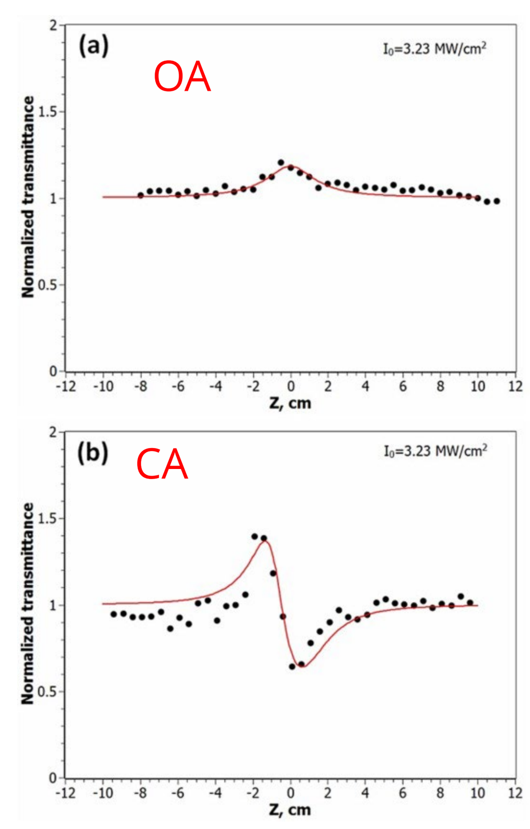

Figure 3. Z-scan curves for CdC_8 with gold nanoparticles [2].

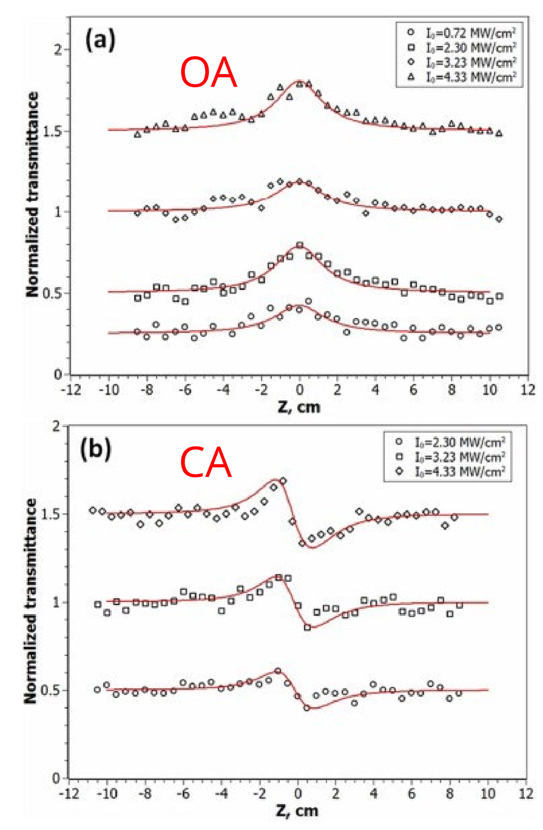

Figure 4. Z-scan curves for CdC_8 with carbon nanoparticles [2].

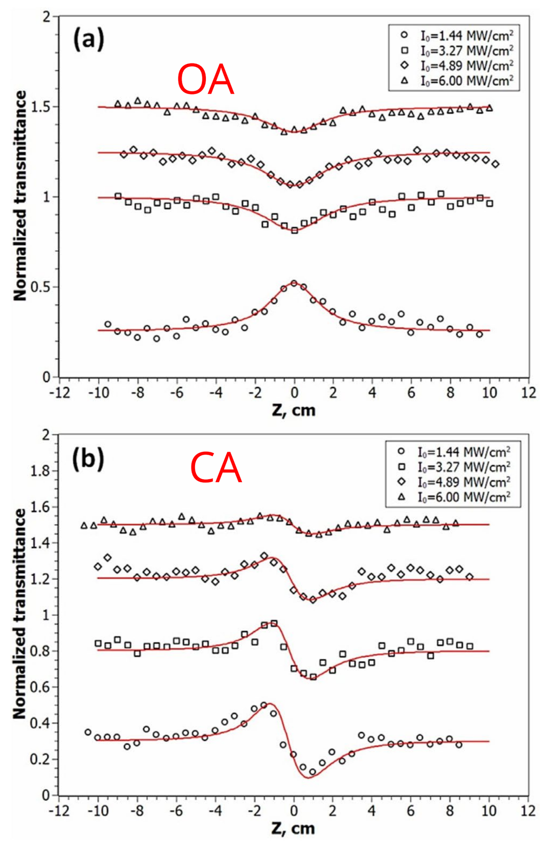

Figure 5. Z-scan curves for CdC_8 containing both gold and carbon nanoparticles [2].

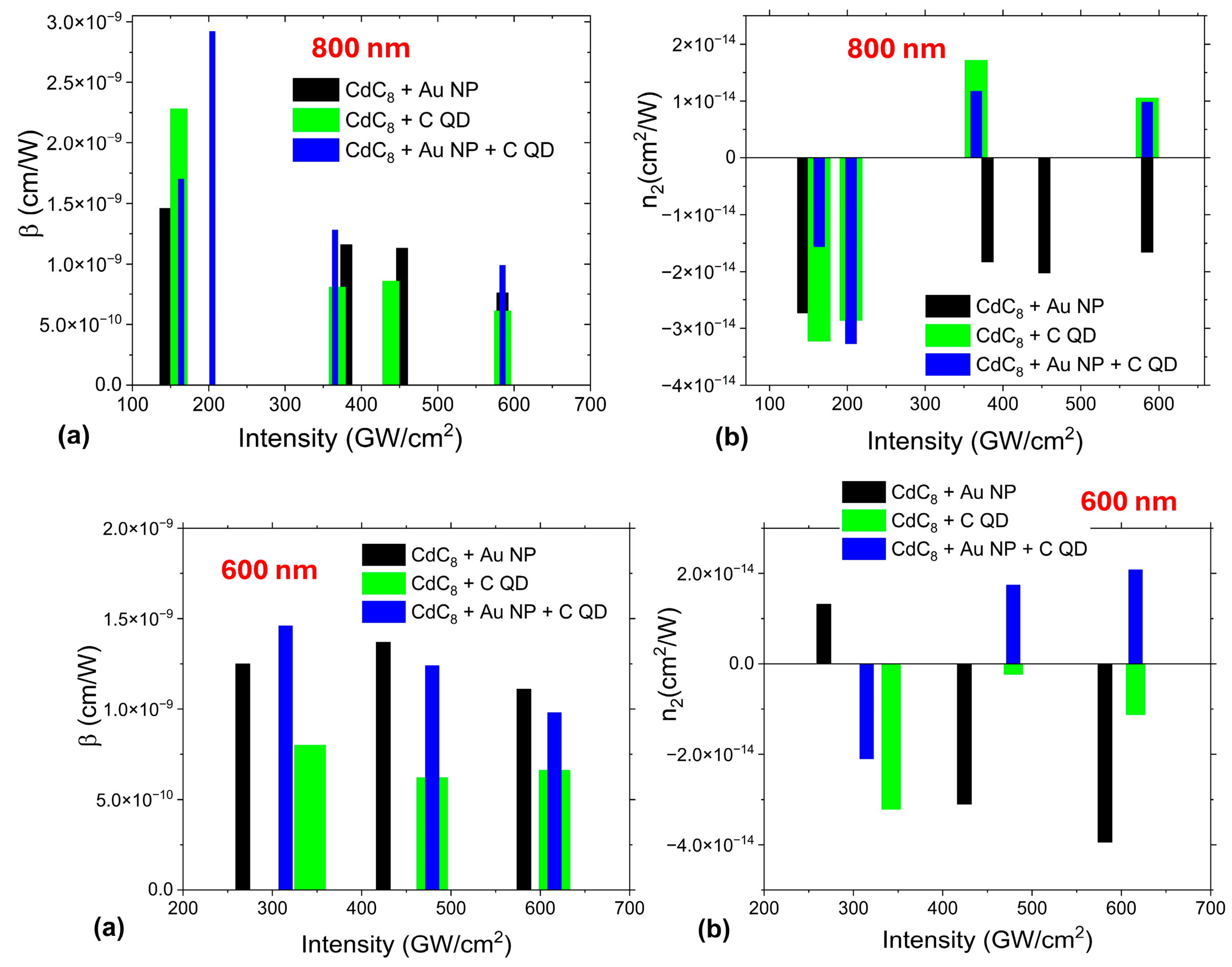

Figure 6. Nonlinear optical parameters evaluated at a wavelength of 800 nm (top) and 600 nm(bottom) [3].

CONCLUSION

Z-scan measurements, conducted using both nanosecond and femtosecond laser pulses, revealed an unusual nonlinear optical response in the studied materials. The measured values of the nonlinear absorption coefficients and nonlinear refractive indices are intensity-dependent. In addition, the excitation of the studied samples by nanosecond laser pulses can lead to the sign reversal of the nonlinear absorption coefficient, whereas the use of femtosecond laser pulses leads to sign reversal in the nonlinear refractive index. This sign reversal of nonlinear optical parameters depends on both light intensity and the composition of the studied nanocomposites. The obtained results can benefit the rapidly growing field of advanced nanophotonics, as they demonstrate different ways to control the effective nonlinear optical response of liquid crystal nanocomposites.

REFERENCES

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