行政院國家科學委員會專題研究計畫　成果報告

液晶材料研究

計畫類別：個別型計畫
計畫編號：NSC91-2113-M-032-003-
執行期間：91 年 08 月 01 日至 92 年 07 月 31 日
執行單位：淡江大學化學系

計畫主持人：余良杰

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中　華　民　國 92 年 10 月 31 日

行政院國家科學委員會補助專題研究計畫成果報告

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計畫參與人員：羅偉昱　　俞方正　　卓志鍵
簡志偉　　龍志漳　　張哲誠
康豐麟　　王淑華

執行單位：淡江大學　化學系

中　華　民　國　92　年　9　月　15　日

Abstract

This report describes a new type of neat liquid crystal that incorporates a two-photon absorbing chromophore in its structure. The nonlinear optical properties including two-photon induced fluorescence spectrum and decay behavior, as well as the effective two-photon absorption coefficient of this novel liquid crystal in its isotropic phase are presented. Fairly good optical limiting and stabilization performances with this nonlinear material have been achieved by using ~815-nm and ~5-ns laser pulses.

Keywords: two-photon absorbing chromophore, two-photon induced fluorescence, optical power limiting, nonlinear optical material, liquid crystal

摘要

含有雙光子吸收功能官能基的液晶分子呈現雙光子吸收引導螢光及光能抑制性. 此液晶分子可以吸收兩個長波長的光子而後發射短波長的光子. 雙光子螢光光譜與單光子螢光光譜相同. 由於此液晶分子的有效雙光子吸收效率很大, 在澄清相時, 可以有效的抑制強雷射光的透過.

關鍵詞 : 雙光子吸收液晶分子 雙光子吸收官能基 雙光子吸收引導螢光 光能抑制性 非線性光學材料

The linear absorption spectrum of a 10-μm thick liquid crystal film at room temperature is also shown in Fig. 1. The sample film was prepared by heating a liquid crystal drop between two glass slides to ~100°C and then pressing the two slides to form a film, in which the thickness could be controlled via a proper spacer between the slides. The spectral curve shown in Fig. 1 was obtained one hour after the heating ended and the optical loss from two cover slides was subtracted. It is seen in Fig. 1 that there is no linear absorption in the very broad spectral range from 500 to 1100 nm. However, upon excitation with an intense IR pulsed laser beam of wavelength about 800 nm, a frequency-upconverted and visible fluorescence could be readily observed from the liquid crystal sample either in its film form at room temperature or in the isotropic liquid phase at temperature ≥87 °C. This frequency-upconverted emission is due to two-photon absorption (TPA) of the input IR laser radiation. As an example, Fig. 2 shows the TPA-induced fluorescence spectrum of an ~20-μm thick liquid crystal film at room temperature, obtained at one hour after cooling down from the isotropic liquid phase. The excitation beam was provided by a pulsed dye laser system with the following output characteristics: wavelength ~815 nm, pulse duration ~5 ns, beam divergence angle ~1 mrad, and repetition rate 10 Hz.

From the viewpoint of application for optical power limiting and stabilization, the nonlinear medium should be highly transparent for a weak input optical beam with an appropriate wavelength, but becomes more absorptive at higher intensity input. At room temperature, if the thickness of our liquid crystal film is greater than 0.5 mm, the linear transmission drops down significantly even for a weak input beam due to strong scattering loss inside the thick liquid crystal layer in the columnar hexagonal (D_h) phase. For this reason, our optical limiting performance was conducted by using a 1-cm long quartz cell filled with the liquid crystal sample that was kept at ~100 °C. Therefore the sample was linearly transparent in the spectral range of 500-1100 nm, i.e. without scattering loss. The pulsed IR beam of ~815-nm wavelength and ~5-ns pulse duration from the dye laser source was passed through an ~1.5-mm diaphragm and then focused by an *f*=20-cm lens into the center of the 1-cm cell. The measured nonlinear transmissivity and the output pulse energy as a function of the input pulse energy are shown in Fig. 3 (a) and (b), respectively. The input laser pulse energy was controlled through a polarization prism with a variable attenuation ratio. According to the basic theory of TPA, the nonlinear transmissivity can be expressed as

$$T(I_0) = \left[Ln(1+\beta l I_0)\right]/(\beta l I_0), \quad (1)$$

where I_0 is the input light intensity, l is the thickness of the sample, and β is the TPA coefficient of the nonlinearly absorbing medium. In Fig. 3 (a) the thick solid-line curve is a theoretical curve obtained by the use of Eq. (1) with the best fitting value of β=6.25 cm/GW, while in Fig. 3 (b) the thin solid-line curve is a theoretically predicted curve using the same β value. From Fig. 3 (b) one can see that when the input energy levels varied from 0.2 to 2.0 mJ (10 times increase), the transmitted energy changed only from 0.15 to 0.55 mJ (3.7 times increase). This is a typical optical limiting behavior.

On the other hand, from Fig. 3 (b) it is also seen that if the input energy (or intensity) level fluctuates within a range, for instance, from 1.5 to 2.0 mJ, the output level fluctuates within a much small range, i.e. from 0.49 to 0.55 mJ. In this case the relative fluctuation values for the input and output are Δ_0=0.29 and Δ'=0.12, respectively. Based on this observation, one can use a highly two-photon absorbing medium to effectively reduce the intensity fluctuation and to stabilize the optical power at a constant level.

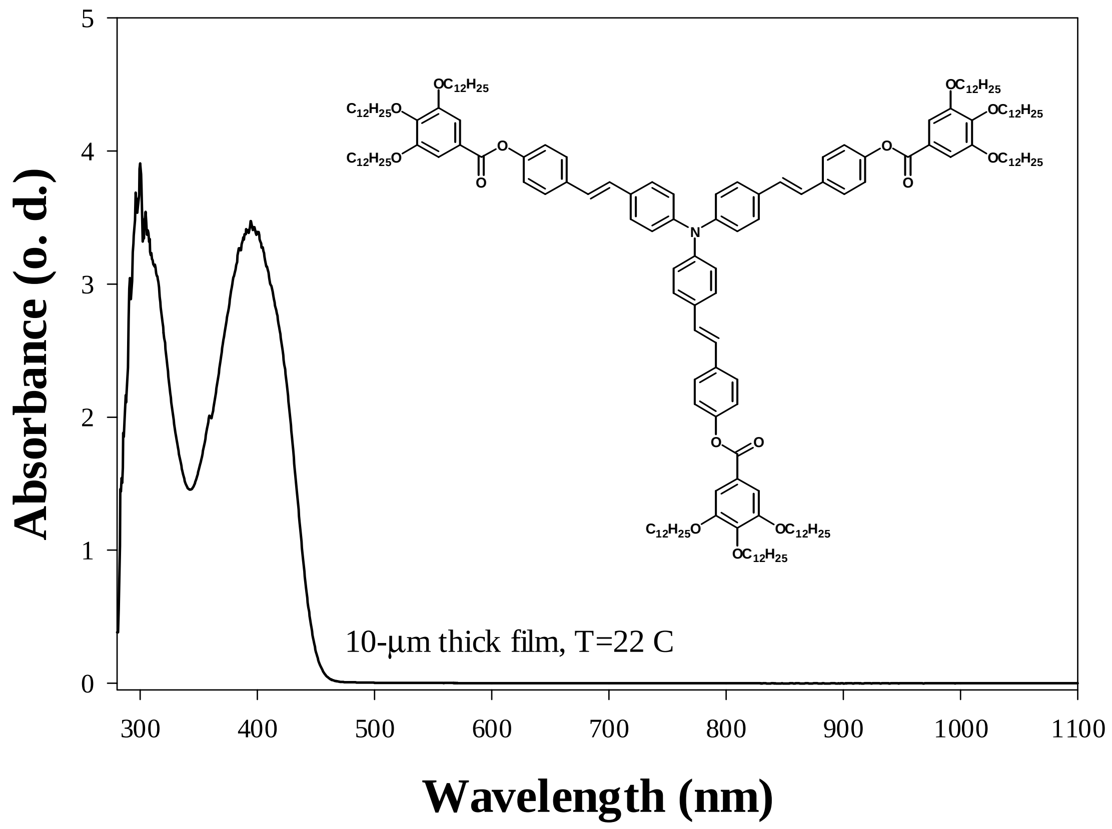

Fig. 1 Linear absorption spectrum of a 10-μm thick liquid crystal film at room temperature. The chemical structure of this sample is shown in the right-top corner.

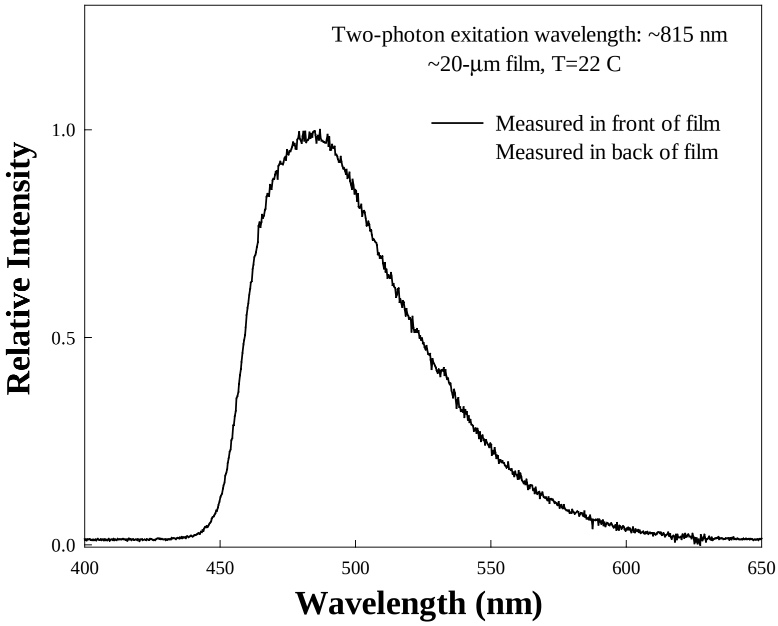

Fig. 2 Two-photon induced fluorescence spectrum of a 20-μm thick liquid crystal film at room temperature, excited by ~815-nm and ~5-ns laser pulses.

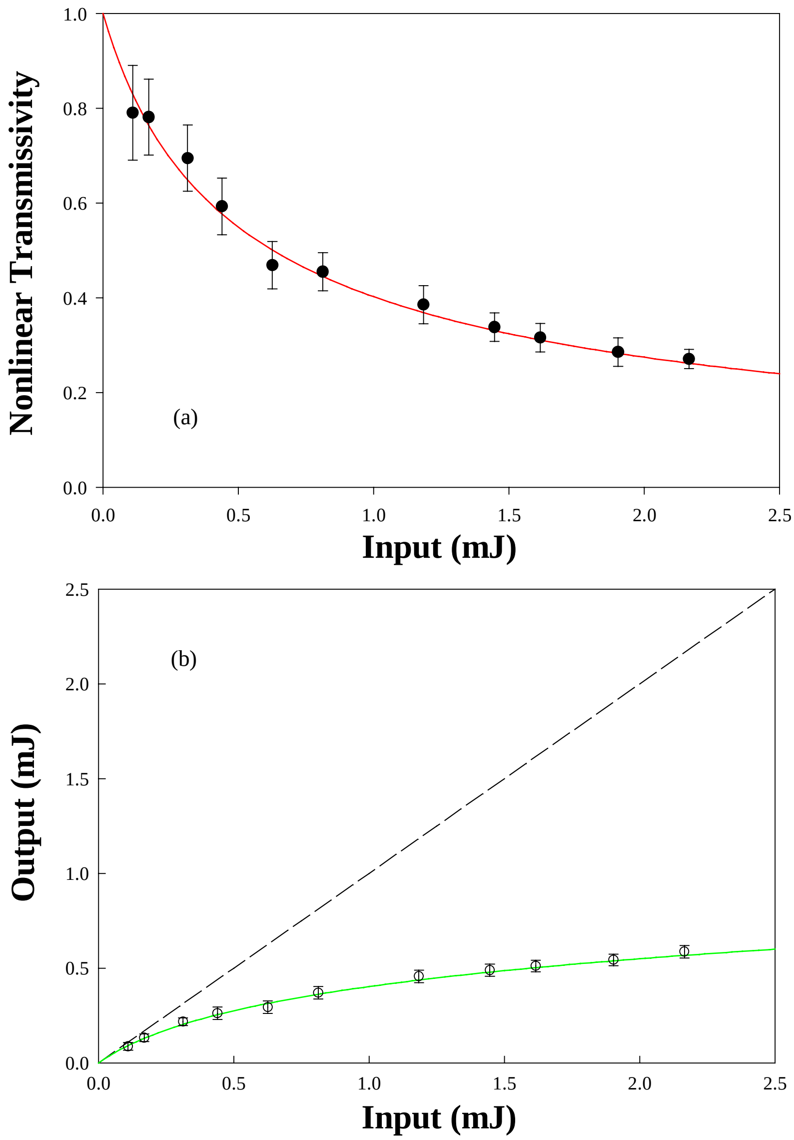

Fig. 3 (a) Measured nonlinear transmissivity data as a function of the input energy; the thick solid line is the best fitting curve with β=6.25 cm/GW. (b) Measured output energy versus input energy; the thin solid line is the best fitting curve with the same β value.