

Lasing Characteristic at the Edge of a Photonic Stop Band in Short Pitch Ferroelectric Liquid Crystal Mixtures

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Introduction

The short pitch ferroelectric liquid crystal (FLC) has attracted attention in the point of the basic physical properties. Depending on a molar fraction of chiral dopant in components, FLC-mixtures with a broad range of pitch, covering the whole optical wavelength region, can be created. The typical helical pitch of the FLC is one to several tens μm. If the pitch is less than several hundreds nm, is expected to show various new characteristics.[1)]

On the other hand, in analogy with electronic bandgap in semiconductor, three-dimensional photonic bandgap has been expected in dielectric material with a periodicity of an optical wavelength.[2)] In the photonic band, the light propagation is inhibited, and attention is attracted not only from the fundamental interest but also from a viewpoint of device application.

FLC, due to their periodic structure, can be regarded as one-dimensional photonic bandgap materials. In this structure, circularly polarized light of the same handedness as the helical structure cannot propagate. Dowling *et al.* predicted that lasing should occur at the edge of a photonic band.[3)] When a fluorescent dye is dissolved in the FLC so that the fluorescent emission peak of the dye is overlapped on the selective reflection band of the liquid crystal, propagation of one normal mode of the emitted light is forbidden. As the intensity of a pump light for the fluorescence is increased, lasing occurs above a pump threshold. Lasing characteristics at the stop band edge using cholesteric liquid crystal[4)] and cholesteric liquid crystal elastomers[5)] have been reported.

In this paper, we report the laser action using the short pitch ferroelectric liquid crystal.

Experiment

The short pitch FLC used in this study is liquid crystal mixture consisting of phenylpyrimidin and biphenylpyrimidin. The chiral dopant induces the ferroelectric properties in a tilted smectic phase. The chiral dopant has a high twisting power and the helical pitch is therefore short enough. The FLC has a following phase sequence, SmC* 68 ℃ SmA 85 ℃ Iso

The rotational viscosity of the mixture of phenylpyrimidin and biphenylpyrimidin is much smaller than that of their homologues.

The FLC was inserted into a sandwich cell consisting of two glass substrates. The PET sheet of 50μm was used as a spacer. The alignment surfactant of polyimide is spin-coated onto a glass substrate. The sandwich cell was filled with FLC by capillary action.

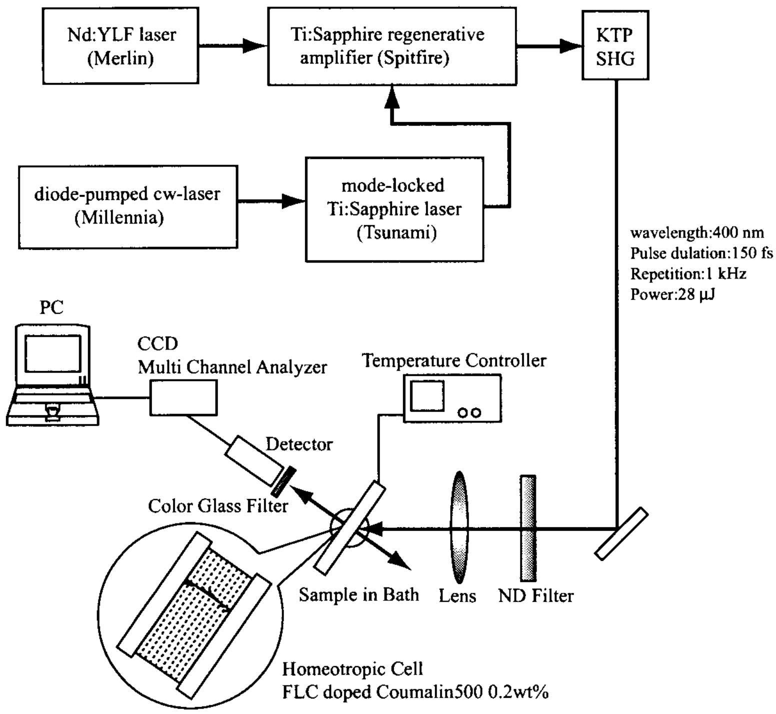

Fig. 1: Experimental setup for the measurement of lasing characteristics.

The laser dye, Coumalin 500 (Exciton) was dissolved in the short pitch FLC. The dye concentration was 0.2 wt.%. This laser dye has a fluorescent peak near 470nm in the FLC.

Figure 1 shows an experimental setup for lasing characteristic measurements. Ti:Sapphire regenerative amplifier was used. The generated laser pulse was then passed through second harmonic generator. The pulse duration, repetition and power of output laser were 150 fs, 1 kHz and 28 mW, respectively. The laser wavelength was 400nm. The laser pulses were directed to the sample making an angle of 40° with respect to the smectic layer. A lens was used to make a small light spot on the FLC cell. Neutral density (ND) filters were used to change the incident laser intensity. The emission from the sample was measured using a CCD photo multichannel analyzer (Hamamatsu,PMA-11) or spectro photometer (Oriel,MS257). A spectral resolution of the PMA-11 and spectro photometer is 3nm and 0.15nm, respectively.

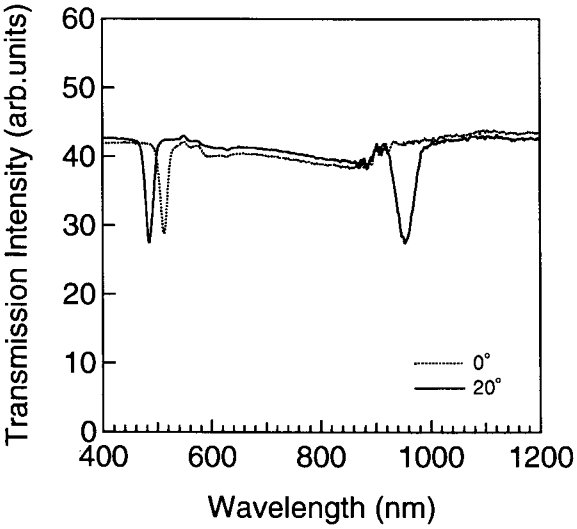

Fig. 2: Transmission spectra at various incidence angle of the light.

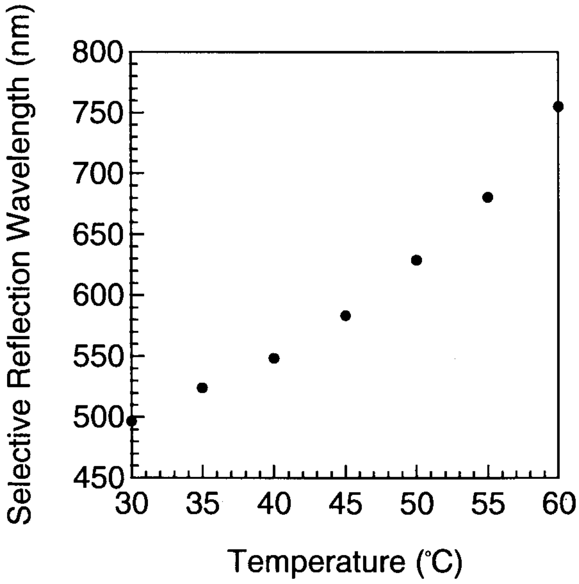

Fig. 3: Tempetarture dependece of the selective reflection wavelength.

Results and Discussion

Figure 2 shows transmission spectra of the homeotropically aligned FLC as a function of an incidence angle. For a normal incidence, only one reflection band around 500nm was observed, while, for an oblique incidence (20°) another band was observed near 950nm. Therefore, it turns out that the reflection band near 500nm is a half pitch band and that near 950nm is a full pitch band.

Figure 3 shows the temperature dependence of a selective reflection wavelength. In the SmC* phase, helical pitch can be tunable by changing temperature, and selective reflection can be in the visible light range.

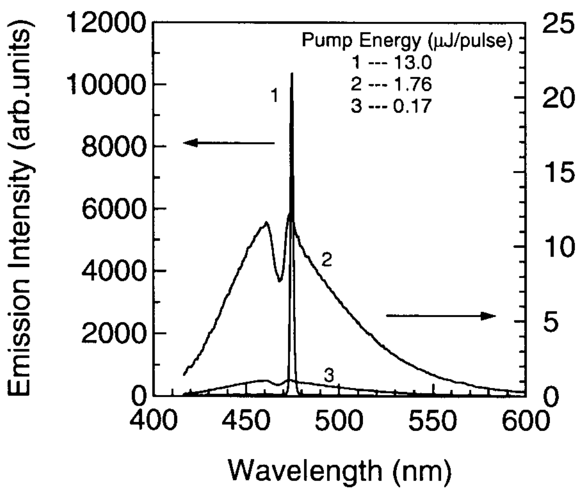

Fig. 4: The pump energy dependence of emission spectra.(20°C)

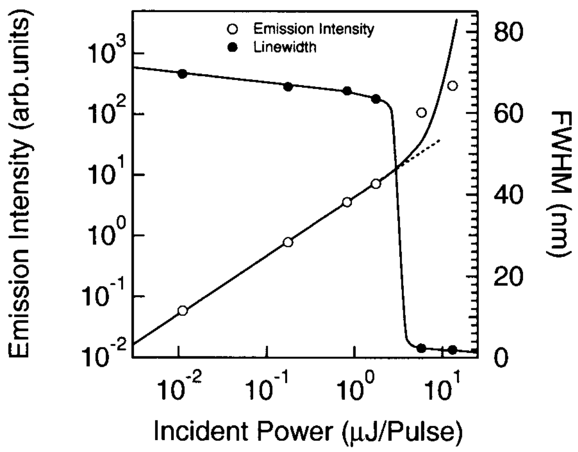

Fig. 5: The pump energy dependence of emission intensity and linewidth.(23°C)

Figure 4 shows fluorescent spectra as a function of an incident laser intensity. At low pump energy, fluorescence peak is shown near 465nm, and in this spectrum, stop band can be seen between 450nm and 475nm, which corresponds to the selective reflection band of the FLC. That is only the same circularly polarized light of the emission as handedness of helical structure is selectively reflected in the helical structure. In the reflection band, emission is suppressed, but is enhanced at the band edges. As a result, when the pump energy above about 3 μJ/pulse, lasing at the band edge occurred.

Figure 5 shows the pump energy dependence of peak intensity and linewidth of the emission. When lasing occurs at the band edge above the threshold energy, the emission intensity nonlinearly increases and linewidth is dramatically diminished.

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