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Orientational control of the liquid crystal molecular using acoustic radiation force

音響放射力による液晶分子の配向制御

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1. Introduction

Liquid crystal, which is an intermediate state between the solid and liquid, is composed of a lot of liquid crystal molecules, and the incident light is refracted or scattered by the molecular orientation. The initial state of the molecular orientation without electric input depends on the condition of orientational films, and the orientational direction can be changed by the applying electric field and magnetic field[1,2]. As well known, liquid crystal is used for liquid crystal displays (LCDs), and the light intensity of the LCD can be controlled.

An optical variable-focus liquid lens with high-speed response using ultrasound have been reported[3]. By generating acoustic radiation force of ultrasound in the lens, the lens shape changed with high-speed response[4]. Here, by applying this technique, we investigated a new possibility for the orientation control of liquid crystal molecules using ultrasound.

2. Configuration and methods

Figure 1 shows the configuration of a liquid crystal (LC) cell. A liquid crystal layer (RDP-84, DIC, Nematic-type) with a thickness of 5 μm is encapsulated between two rectangular glass plates ($50\times10\times1$ mm^3, $30\times10\times1$ mm^3) with polyimide orientational films (SE-5811, Nissan Chemical). The liquid crystal molecules are arranged vertically against the orientational films and the glass plates in the initial state. Two rectangular ultrasonic piezoelectric lead zirconate titanate (PZT) transducers ($10\times10\times1$ mm^3) are bonded at both ends of the glass plate using the epoxy resin.

By applying the electrical signal to the PZT transducers at the resonance frequency of the LC cell, flexural vibration is generated in the length direction of the LC cell. The acoustic standing-wave field will be generated in the liquid crystal layer by the flexural vibration, and the acoustic radiation force acts to the liquid crystal layer so that the orientational direction of liquid crystals can be statically changed. The transmitted light distribution through the LC cell was observed by the crossed nicols method using two polarizers as shown **Fig. 2**. The LC cell was arranged between the polarizers so that a He-Ne laser beam (λ = 632.8 nm) with the beam width of 2 mm passes through the LC in the thickness direction. The transmitted light was observed by a photo detector (2051-FS, Newport).

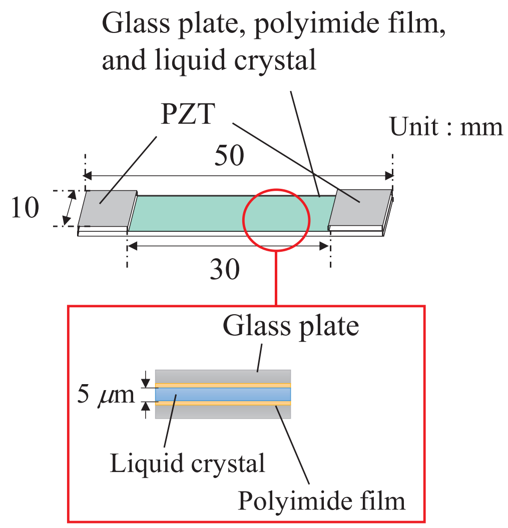

Fig. 1 Configuration of the LC cell.

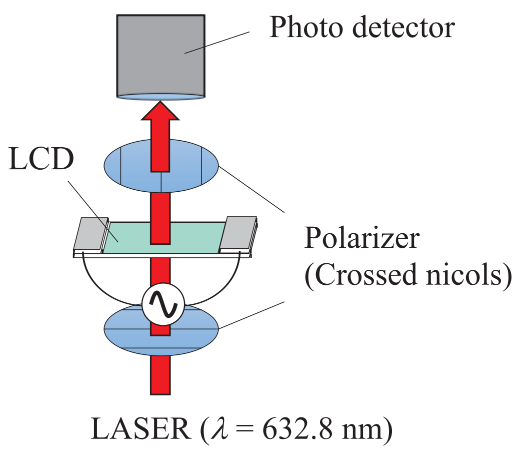

Fig. 2 Observational setup.

3. Results and discussions

Figure 3 shows the distributions of transmitted light intensity measured by the photo detector. The measurement area was 15×3 mm^2 at the center of the glass plate, and the position where the beam passed was changed. When the LC was not excited (Fig. 3(a)), the transmitted light with a small amplitude was observed although it should be cut off in the crossed-nicols arrangement; this is attributed that the orientational direction of the LC is not perfectly vertical orientation. By applying an input voltage of 10 V_{pp} at 214 kHz, the transmitted light intensity increased dramatically (Fig. 3(b)). These results imply that the orientational direction of the liquid crystal molecules was changed by ultrasound. **Figure 4** shows cross-sectional profiles for the transmitted light scanned along the line A-A' in Fig. 3 at several input voltages. The transmitted light intensity changed with increasing the input voltage, and the maximum intensity increased approximately 720% by applying an input voltage 10 V_{pp}.

The dynamic response of the orientation control was investigated. **Figure 5** shows that the transient response of the transmitted light when switching on the electric excitation. A time constant τ of the response curve is 16 ms.

4. Conclusion

A control technique of orientational direction of liquid crystal molecules using ultrasound was proposed. The molecular orientation and the transmitted light distribution through the LC cell were changed by the ultrasonic flexural vibration of the substrate glass plate. The maximum transmitted light intensity increased approximately 720% by ultrasound excitation. A time constant τ of the response curve is 16 ms.

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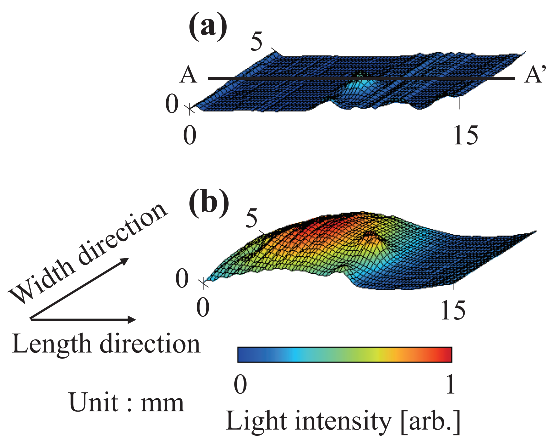

Fig. 3 Distributions of the transmitted light intensity through the LCC (a) without and (b) with ultrasound excitation.

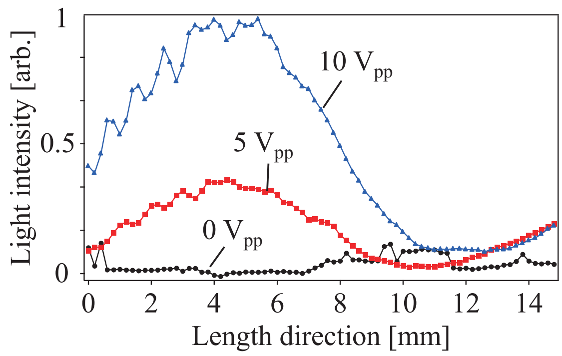

Fig. 4 Cross-sectional profiles of the transmitted light distributions along line A-A' in Fig. 3.

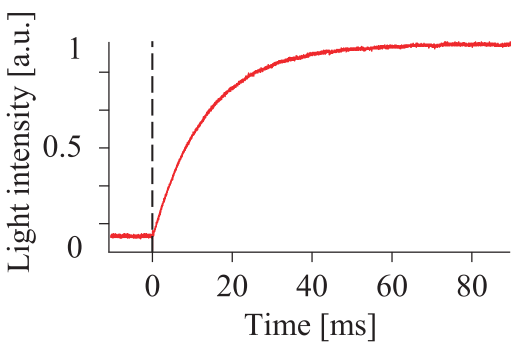

Fig. 5 Dynamic response curve of the transmitted light.

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