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Demodulation of AM Ultrasound Using Freely Suspended Ferroelectric Liquid Crystal Film

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A freely suspended (FS) film of ferroelectric liquid crystal (FLC) has two free surfaces of which the thickness is in the range from several nm to several μm. The FS film of FLC has growing interest from the fundamental and practical view points[1-5], because of high sensitivity to external fields such as electric field and sound wave. A mechanical-vibration property of the FS film has been observed under external fields[6-8]. In this study, we describe mechanical-vibration characteristics of a FS film of FLC under irradiation of ultrasound in air. The frequency response of the FS film exposed by an irradiation of pulsed an amplitude-modulated (AM) ultrasound is investigated and demodulation of an AM ultrasound presented by using the FS film.

We prepared a glass substrate (Corning, 7059) of 30 mm × 20 mm in which a rectangular hole of 5 mm × 10 mm was drilled and two parallel electrodes were evaporated along the longer sides of the hole. A ferroelectric liquid crystal (Chisso, CS-1023) was used in this study and the hole was covered with the FS film with the Sm A phase for measuring at room temperature. Figure 1 shows an experimental setup of reflective light used in this study. A He-Ne laser (632.8nm) and a photodiode were used as a light source and a photodetector, respectively. An incident angle of the laser beam to the FS film was 45° and a pinhole was used in front of the photodiode. Two transducers for ultrasound in air (Murata

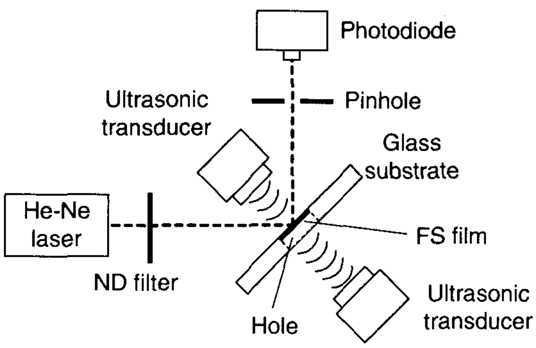

Fig.1. Experimental setup of measurement system for reflected light.

Manufacturing, MA40S3) were set to the both sides of the FS film. One transducer was used for sending an 40.7 kHz ultrasound in air and the other was used for detecting the ultrasound through the FS film. The mechanical vibration of the FS film induced by irradiating the ultrasound was measured. In this measurement, the amplitude and the response waveform of the output signal from the photodiode were measured using by a look-in amplifier and a digital storage oscilloscope, respectively.

It has been reported that a mechanical vibration in a FS film was excited by irradiating a sound wave to the FS film[6]. In this study, the mechanical vibration of the FS film is induced by an ultrasound instead of a low-frequency sound wave. Figure 2 shows the measured spectrum of the mechanical vibration of the FS film, obtained using a spectrum analyzer (HP, 8563E) under an irradiation of 40.7kHz ultrasound. The existence of several harmonic components is obvious besides the fundamental component. The amplitudes of fundamental and harmonic components as a function of applied voltage to the ultrasonic transducer are shown in Fig. 3. The amplitudes of both components increase with increasing applied voltage to ultrasonic transducer.

Figure 4 shows the observed waveforms via the mechanical vibration of the FS film induced by an application of RF pulse to the ultrasonic transducer. Two signal components are obvious observed in the reflected light output. One component of 40.7 kHz has the same as that of the ultrasound although the amplitude is weak. The other component of about 3kHz is rather strong, corresponding the envelope of the output signal. This frequency agrees with the strongest peak of the mechanical-vibration spectrum of the FS film, when the voltage is applied to the FS film. This result indicates that

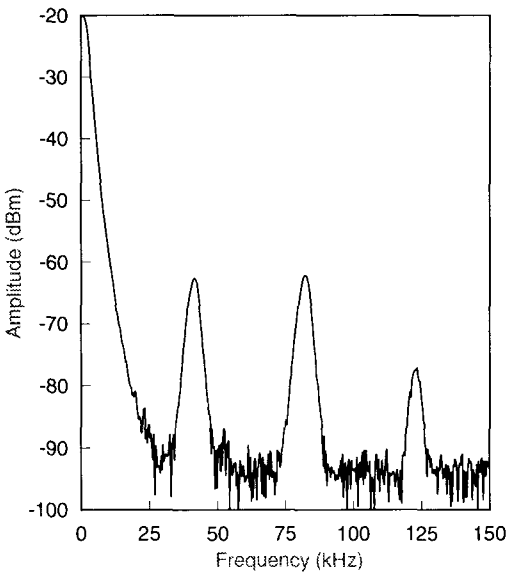

Fig.2. Frequency spectrum of reflected light under irradiation of ultrasound to FS film.

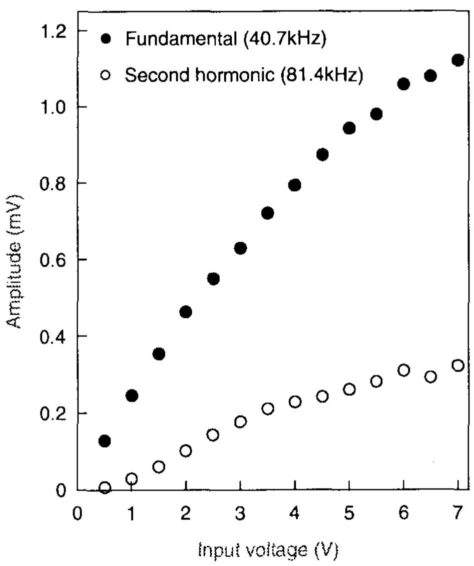

Fig.3. Amplitudes of fundamental and second harmonic component as function of applied voltage to ultrasonic transducer.

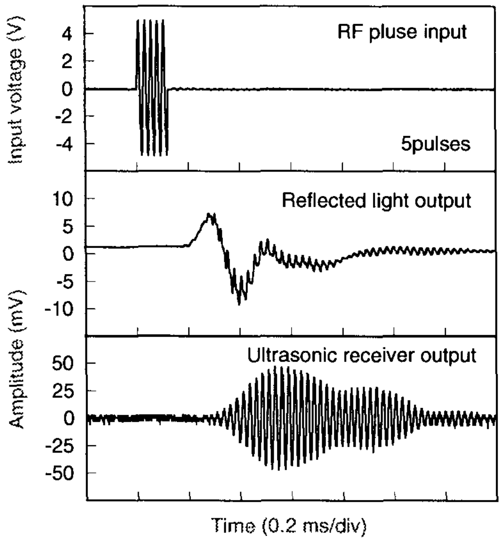

Fig.4. Observed waveforms of input voltage to sending ultrasonic transducer, output from reflected light and output from receiving ultrasonic transducer under irradiation of ultrasound excited by pulsed RF.

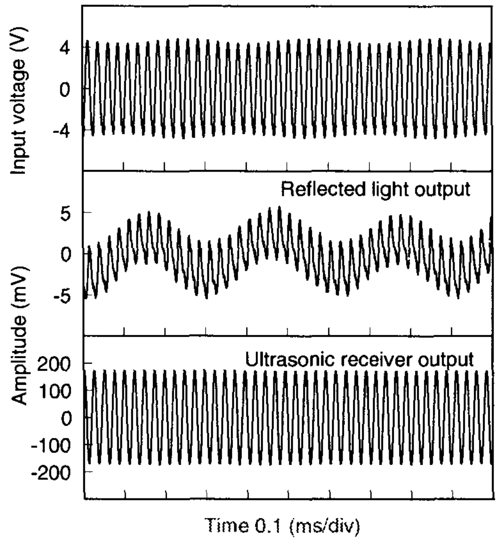

Fig.5. Observed waveforms of input voltage to sending ultrasonic transducer, output from reflected light and output from receiving ultrasonic transducer under irradiation of AM ultrasound.

the low frequency eigenmode vibration of the FS film is induced by the irradiation of the ultrasound.

For exciting the eigenmode vibration, an AM voltage was applied to the ultrasonic transducer. Figure 5 shows the observed waveforms of input signal to the ultrasonic transducer and output signals from the reflected light and from the receiving ultrasonic transducer, where the AM voltage with the carrier frequency of 40.7 kHz, modulation frequency of 3.3 kHz and modulation ratio of 10% was applied. The output voltage of the receiving transducer was constant via the FS film. On the other hand, the output from reflected light has two of components, carrier frequency of 40.7kHz and modulation frequency of 3.3kHz, as obvious from the observed waveform. Figure 6 shows the observed modulation ratio dependence of the amplitude of the modulation frequency component of the reflected light output. The amplitude of the reflected light increases with the modulation ratio below 80%. This result indicates that the modulation ratio could be related with the amplitude of the reflected light, and also that the FS film might be functional for the demodulating AM ultrasound.

Figure 7 shows the measured relationship between the amplitude of the reflected light and the modulation frequency of the AM ultrasound, where a peak amplitude is observed around 3kHz. This peak frequency is coincident with the strongest peak of the mechanical vibration induced by application of voltage to the FS film. Furthermore, the operation ranges from 1 to 5 kHz integrates many peaks of the eigenmode vibrations. This behavior is an advantage in the use of the FS film for demodulating an AM ultrasound.

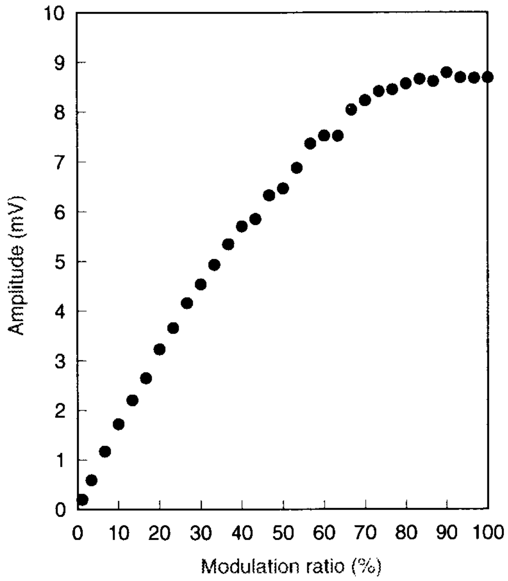

Fig.6. Measured modulation ratio dependence of amplitude of reflected light under irradiation of AM ultrasound.

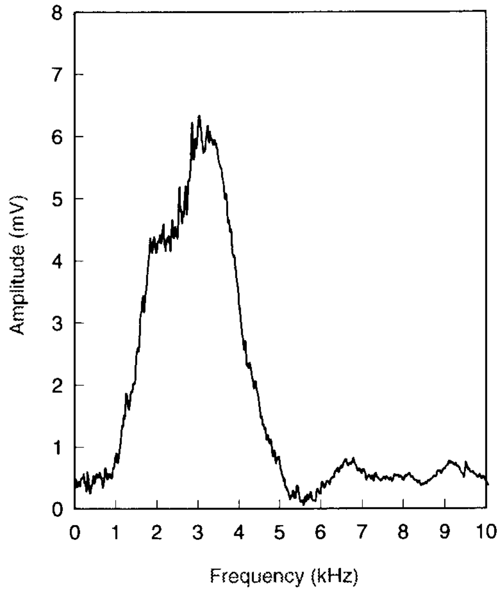

Fig.7. Measured amplitude of modulation frequency component of reflected light as function of frequency under irradiation of AM ultrasound.

In conclusions, mechanical vibration characteristics of a FS film of FLC under irradiating a ultrasound were investigated. The mechanical vibration under the existence of an ultrasound had harmonic components besides the fundamental frequency component. Two components of the mechanical vibration were observed separately by irradiating RF pulse or AM ultrasound. The predominant and other components correspond to have the carrier frequency and the frequency of the eigenmodes of the resonance vibration. This mechanical vibration of the FS film property might be useful for demodulating an AM ultrasound.

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