3P1-1

Simple and rapid measurement of hypersonic wave velocity by Brillouin scattering method

励起フォノンを用いた Brillouin 散乱計測の高速化

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1. Background

The Brillouin scattering method is a nondestructive and noncontact technique to measure local longitudinal and shear acoustic velocities in the GHz range. One problem of this method is weak light scattering from thermal phonons, which results in the long measurement time. In addition, Brillouin scattering method generally need the complex tandem Fabry-Perot interferometer (TFPI). To overcome this problem, we have proposed techniques to make use of induced strong coherent phonons from a high frequency transducer[1]. In this study, for the development of a precise and simple measurement system. We attempted to observe the induced scattered light using a single confocal Fabry-Perot interferometer (SFPI). We have used ScAlN film transducer to induce phonons and observed the strong light scattering using a SFPI.

2. Experiment system

Brillouin scattering measurements were carried out with a six-pass tandem Fabry-Perot interferometer (JRS scientific instruments) or a confocal Fabry-Perot interferometer (Thorlabs) using a solid-state laser at a wavelength of 532 nm (Laser Quantum). The laser power near the sample was 160 mW. The actual diameter of the focused laser beam spot on the sample was approximately 50 μm.

The wavelength of the observed phonons is determined by the scattering geometry, which specifies the directions of the incident and scattered light. The Reflection Induced Θ Angle (RIΘA) scattering geometry is shown in Fig.1[2]. This geometry is attained by attaching a flat metal to the reverse side of the specimen as a reflector. The interaction of incident and scattered lights enables the measurement of the phonons that propagate in the direction of wave vector of $\boldsymbol{q}^{\Theta A}$. From observed spectra, we can obtain the frequency shifts of $f^{\Theta A}$, which give us the wave velocity as

$$v^{\Theta A} = f^{\Theta A}\frac{\lambda_i}{2\cdot\sin(\Theta/2)} \quad (1).$$

Here, λ_i is the wavelength of the incident laser light. Equation (1) shows that the shift frequency $f^{\Theta A}$ change due to the incident angle $\Theta/2$.

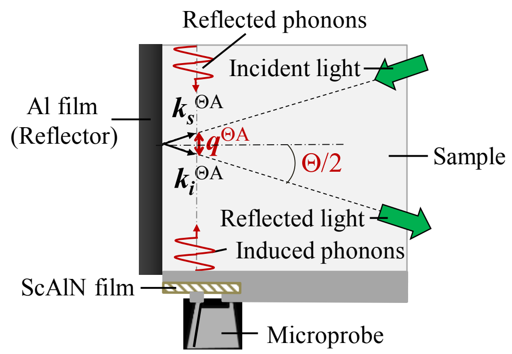

Fig.1 Specimen configuration.

3. Specimen and measurements

Figure 1 also shows the specimen configuration. We attempted to observe longitudinal phonons induced by a $Sc_{0.41}Al_{0.59}N$ piezoelectric film[3]. The film was grown by an RF magnetron sputtering on DC sputter-deposited Ti metal film (150 nm)/ silica glass specimen (5 × 5 × 25 mm, ED-H, Tosoh Corp.). The crystalline c-axis of the film was aligned along the substrate normal, allowing the effective excitation of longitudinal wave in the gigahertz range. The film (with applroximately 4 μm thick) was deposited on one side of a silica glass specimen. On the reverse side of the specimen, an Al film (applroximately 300 nm thick) was deposited as a light reflector for the RIΘA scattering geometry.

In this study, we used a network analyzer (E5071C, Agilent technologies) and a microprobe (SG750-D1847, Cascade Microtech) to induce phonons. The phonons were excited at 883 MHz (the primary resonance of the ScAlN film).

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4. Results and Discussion

Figure 2(a) shows a Brillouin scattering spectrum observed from the silica glass specimen without the induced wave by TFPI. Here, the incident angle of the laser beam was adjusted to $\Theta/2 = 2.3°$, which matched the shift frequency $f^{\Theta A}$ resulting from the longitudinal wave and the fundamental resonance frequency of ScAlN film[4].

Figure 2(b) shows a Brillouin spectrum from the specimen with the induced wave by TFPI interferometer. the anti-Stokes peak was strongly amplified by the excitation of longitudinal wave more than the Stokes peak. The anti-Stokes peak intensity was found to be approximately 4.57×10^6 cps (the power applied was 10 dBm). Because the coherent phonon propagates in one direction from the transmitter, we can usually obtain asymmetric Brillouin peaks. We can expect strong Anti-stokes peak from the induced phonons propagating from the transmitter. However, we can also find a strong Stokes peak, telling the wave propagation to the transmitter. The Stokes peak was a little smaller than the anti-Stokes peak. From the size of ScAlN transducer and wavelength, we can estimate the wave field in the specimen. At 883 MHz, the wave field in the specimen was in the Fresnel region (near field). Then, the wave possibly propagated straight and reflected at the other side of the specimen, which was measured as the Stokes peak.

Figure 3(a) shows a Brillouin scattering spectrum from the silica glass specimen without the induced wave using a SFPI. Brillouin scattering light could not be observed. Figure 3(b) shows a Brillouin scattering spectrum from the silica glass specimen with the induced wave by SFPI. Brillouin scattering peaks could be observed clearly.

5. Conclusion

We have succeeded in the Brillouin scattering measurement of longitudinal wave using by a single confocal Fabry-Perot interferometer, making use of the strong scattered light. This technique enables easy, rapid and simple measurement of wave velocity in the sub GHz to GHz range, which can be applied for the 2D velocity imaging of the sample.

Reference

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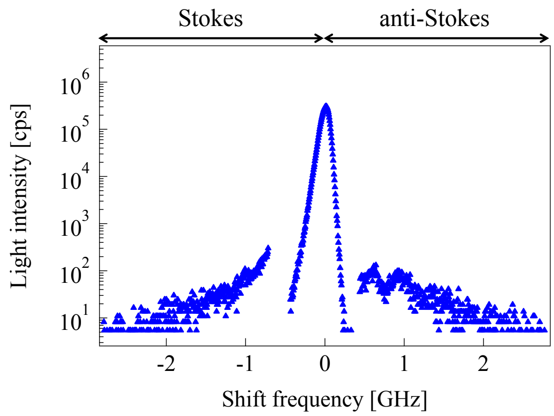
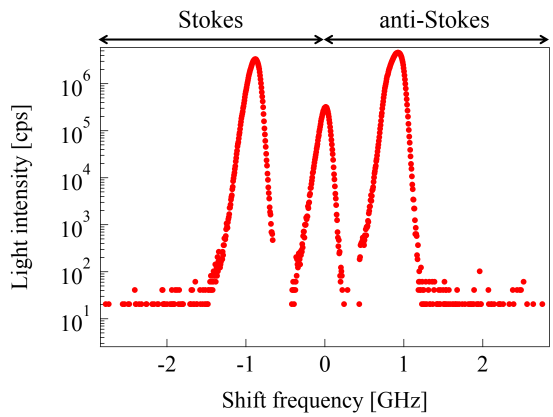
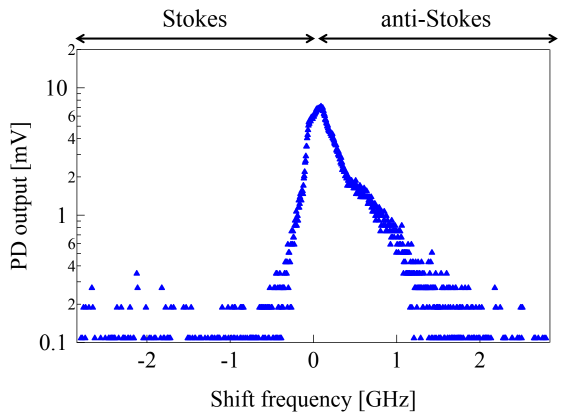


(a)Without induced longitudinal wave.

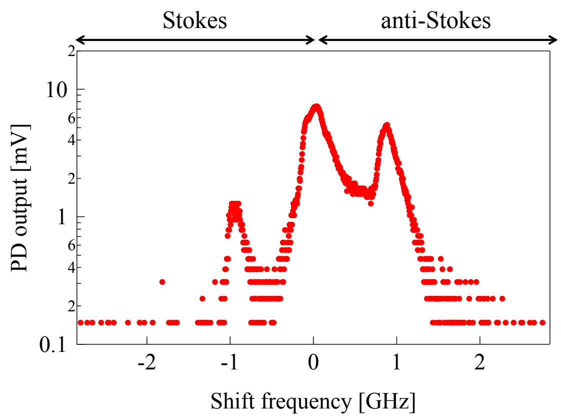


(b)With induced longitudinal wave.

Fig. 2 Observed spectra by TFPI.



(a)Without induced longitudinal wave.



(b)With induced longitudinal wave.

Fig. 3 Observed spectra by SFPI.