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Enhancement of Brillouin scattering peak by high frequency ultrasound

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1. Introduction

Brillouin scattering method enables non-destructive and non-contact measurements of materials. Brillouin scattering results from the inelastic collision between photons and thermal phonons, then, the light intensity of the scattered light is very weak. The weak intensity of Brillouin peaks leads the very long measurement time.

Kawabe et al tried to overcome the weak scattering problem by using the induced longitudinal wave generated from a ScAlN film[1)]. This piezoelectric thin film allows the excitation of longitudinal ultrasonic waves in the MHz - GHz range. Making use of the radiated coherent phonons, the peak strength was improved by 8,670 times due to the induced phonons. However, in order to use the Reflection Induced θ Angle (RIΘA) geometry (Fig.1) for the measurement without the effects of refractive index, the film should be set on the side surface of the sample. This means the method is not non-destructive and we cannot measure thin samples.

In this study, then, we have tried to enhance Brillouin scattering using the piezoelectric transducer at the rear side of the sample.

2. Experiments

2.1 RIΘA scattering geometry

The RIΘA scattering geometry is used for measurements[2)]. A mirror is set on the back of the sample which allows measurements of longitudinal wave velocity in-plane ($q^{\theta A}$) direction. The velocity of sample can be estimated using the frequency shift with the following equation.

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

Here, θ is an angle between the reflected light and incident light. λ is a wavelength of the light. $v^{\theta A}$ is the ultrasonic wave velocity of the sample. $f^{\theta A}$ is the shift frequency.

In the experiment, a solid-state laser (532nm) and Tandem Fabry-Perot interferometer was used. The light intensity in front of the sample was 88 mW. The sample was a thin quartz glass (0.5×10×20 mm^3, Tosoh, ED-H) and the transducer was placed on the back of the sample. The transducer was made of 3 layers Cu, ScAlN and Al thin films. The ScAlN layer

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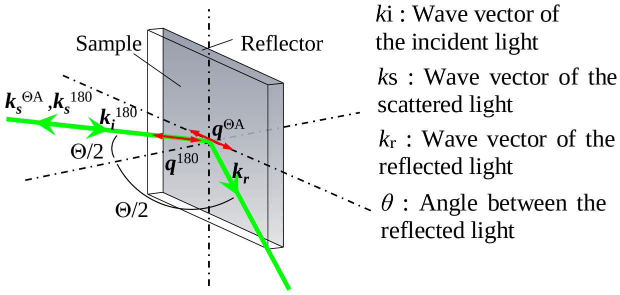

Fig. 1 RIΘA Scattering geometry

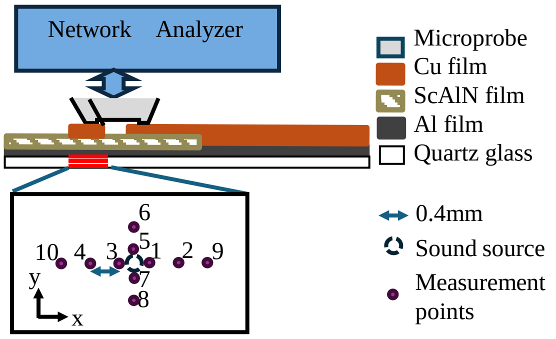

Fig. 2 The Glass sample and the transducer.

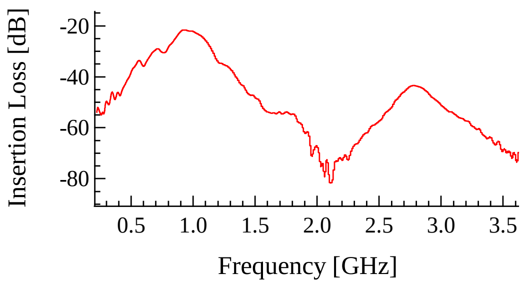

Fig. 3 Insertion loss of the transducer.

was piezoelectric. The Al film is positioned directly to the sample and used as a mirror as well.

The transducer (0.6×0.8mm^2) was created on the Al film surface. Generated soundwaves were emitted into the sample through the Al film. The setting is illustrated in Fig. 2.

2. 2 Experimental conditions

The characteristics of the transducer was measured by a network analyzer (E5071C, Agilent Technologies). Insertion loss of the transducer with the glass sample showed a peak of -21.6dB at 920 MHz as shown in Fig. 3. Considering the peak frequency and broad characteristics of the insertion loss, the angle θ for measurements was set as 5.6°. The longitudinal Brillouin peaks were found around 1.14 GHz.

Then, using a microprobe (SG750-D1847, Cascade Microtech), signal at 1.14 GHz was applied to the ScAlN transducer from a network analyzer. Longitudinal wave was emitted in the thickness direction of the sample from the rear surface.

The scattered light was counted using a photon detector. Additional averaging was performed for each measurement during the experiment. Figure 2 also shows the measurement positions on the sample. The center dotted circle symbolizes the sound source.

3.Results and Discussion

Depending on which direction the soundwave applied in vector $q^{\theta A}$, the which side stokes or anti-stokes would be enhanced has determined. The Brillouin peaks before and after the enhancement on points 2 and 4 were shown in Figs. 4 and 5. Only either peak of stokes and anti-stokes had been enhanced.

Figure 6 shows the amplitude of Brillouin peaks on each measuring points, before and after the enhancement. In x-axis, the maximum enhanced rate from each measurement points were 44 times. The wavelength of the longitudinal wave is estimated around 5 μm, which is much smaller the diameter of transducer. Therefore, most of the soundwave propagated in the thickness direction of the quartz sample and a very small portion might propagate in the in-plane direction. As a result, the enhancement was much smaller than that in the previous results by Kawabe[1].

Then, at the further points from the sound source the enhancement became smaller. This is due to the attenuation during propagation as pointed by Yoshida [3].

This study showed the enhancement of Brillouin peaks by the excitation of high frequency ultrasound. The excitation from the rear side realizes the simple configuration for the measurements.

4.Summary

The experiment has shown it is able to enhance the Brillouin peak of thin samples using the RIΘA scattering geometry. The directivity and direction of the emitted soundwave from the transducer and the distance from the sound source were having huge influence on the enhancement of Brillouin peaks.

Acknowledgment

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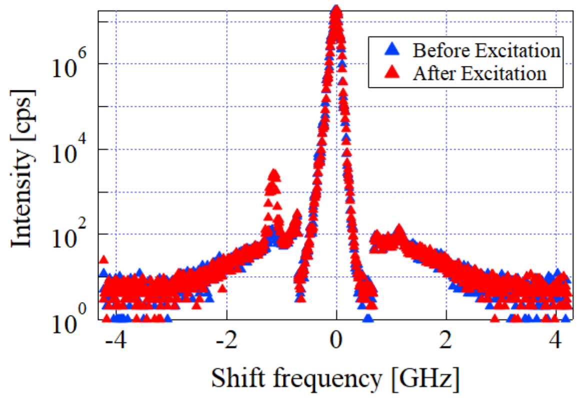

Fig. 4 Brillouin peaks before and after the enhancement at point 2

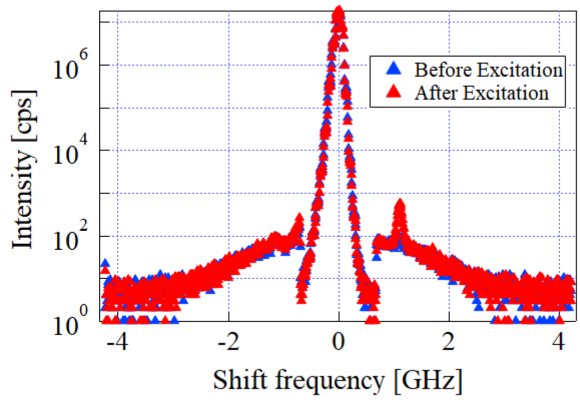

Fig. 5 Brillouin peaks before and after the enhancement at point 4

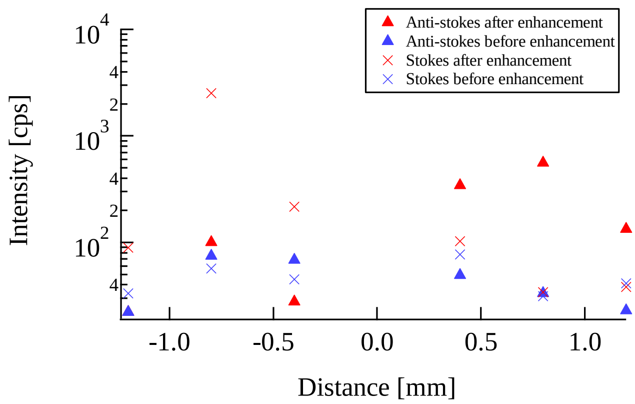

Fig. 6 Comparison of the amplitude of Brillouin peaks before and after the enhancement on x-axis

References

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