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Low Frequency Brillouin Scattering Observing System for Soft Materials

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A high-resolution Brillouin scattering observing system has been developed in order to obtain spectra in a low frequency region. A spherical Fabry-Pérot interferometer is employed as spectrometer instead of the usual plane parallel Fabry-Pérot interferometer for the purpose of utilizing its higher resolution. A method for accumulating spectra has been introduced and found to be effective in preventing the destructive distortion on spectra through the frequency instability of the light source laser. The system produced by way of trial proved to have a high-resolution with the total instrumental width of less than 20 MHz. In the lower frequency range under 100 MHz or intermediate region between hypersonic and ultrasonic, the acoustic waves in soft materials are likely to have important characteristics. A more practical new system aimed for soft materials is under development.
Key words: Brillouin scattering, spherical Fabry-Pérot, law frequency, high-resolution

1. INTRODUCTION

Brillouin scattering, as well as ultorasonic method, is an important and well-established method for observing acoustic waves in materials [1–3]; frequency shifts and widths of lines in the Brillouin spectra provide the velocities and the damping parameters of acoustic waves respectively. Although the velocities of acoustic waves in the frequency range over the order of GHz or hypersonic region are measured with sufficient resolution, in the lower frequency range especially under 100 MHz. On the other hand, Rayleigh scattering is used in the frequency range up to about 10 MHz. Thus, the intermediate frequency range between hypersonic and ultrasonic, where the acoustic waves in soft materials would have important characteristics, observation of Brillouin spectra has not been performed with sufficient resolution, especially in observing widths of the lines.

2. HIGH-RESOLUTION BRILLOUIN SCATTERING OBSERVING SYSTEM

A high-resolution Brillouin scattering observing system has been developed in order to obtain spectra in low frequency region. Spectrometer of the system is a spherical Fabry-Pérot interferometer [4] instead of a plane parallel Fabry-Pérot, which is a typical spectrometer for Brillouin scattering system. According to the increase in resolution of the spectrometer, a small amount of frequency instability of the light source laser is no longer negligible and becomes to affect destructively on the spectra.

However, a spectra accumulating method which avoids this fatal influence has been found and introduced to the system. The light source of the system is not a specially stabilized laser but a typical longitudinal single mode argon ion laser. Observation for several materials including plastic polymer has been performed with the system made for trial.

2.1 The spectra accumulating method

The present method depends on the fact that the frequency of a longitudinal single mode laser sufficiently stable in a short period such as 1 s, although it may drift several hundred MHz in a long time. Therefor, by selecting short time for sweeping the spectrometer, every spectra from each single sweep have sufficient resolution. Then the Rayleigh line in each spectra is utilized as a reference of accumulation; each spectra is aligned to the Rayleigh line before. This procedure is accomplished with two set of multi channel scalers, one for holding spectra from each sweep of spectrometer, another is for accumulating spectra.

In addition, the sweep region of the spectrometer can be set so that neighboring two Rayleigh lines to fall into spectra, the distance of these lines, which is referred to as the 'Rayleigh-span', can be used to examine the amount of frequency drift during the sweep. If the frequency during a sweep occasionally drifts large amount or mode hopping is occurred in the laser, the value of the 'Rayleigh-span' will be different to those of other sweeps. Thus, accumulating only those spectra which has almost same 'Rayleigh-span', influence of the temporal frequency instability will be eliminated.

2.2 The system for trial purpose

Figure 1 shows the schematic illustration of the system made by way of trial. The spherical Fabry-Pérot for spectrometer (Spectra-Physics, Model 470-01) has a free spectral range of 2.0 GHz with an instrumental width of 13 MHz. An argon ion laser operated at 514.5 nm line are the light source of the system. It is an ordinary available (NEC,GLG3200) longitudinal single-mode laser.

The system was achieved through modifying a usual Brillouin scattering system; replacing spectrometer and spectra accumulating unit. This unit is a home-made microcomputer based system, which is named 'spectrum acquisition system' or SAS. A typical line profile of the response of this system to the monochromatic light is shown in Fig.2, which shows the high-resolution of this system.

This system has been mainly applied to the observing the soft acoustic phonon in the ferroelastic phase transition of deuterated potassium trihydrogen selenite [5].

From an acrylic resin block, stokes and anti-stokes Brillouin spectra are shown in Fig. 3 and 4 respectively, with the scattering angle is of 90o. The line width of about 150 MHz are obtained, which implies large damping of hypersonic wave in acrylic resin.

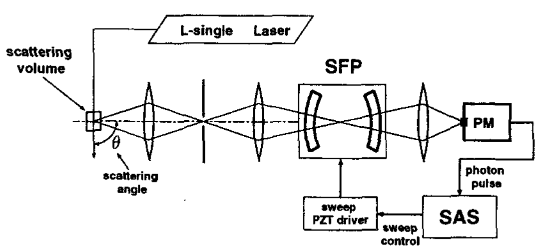

Fig. 1: A schematic illustration of the system made by way of trial. The spherical Fabry-Pérot for spectrometer (Spectra-Physics, Model 470-01); free spectral range of 2.0 GHz, instrumental width of 13 MHz. An argon ion laser (NEC,GLG3200) operated at 514.5 nm line are the light source of the system. It is an ordinary longitudinal single-mode laser. Unit SAS is a home-made microcomputer based system, which is named 'spectrum acquisition system'.

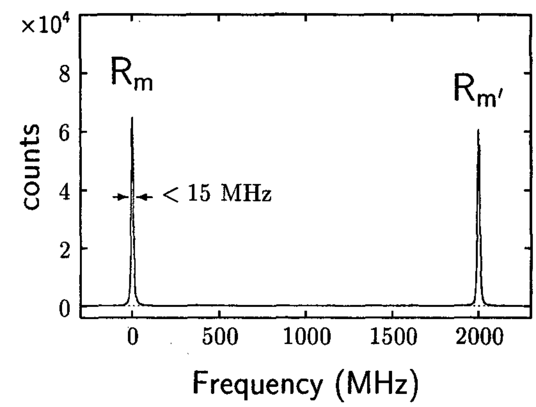

Fig. 2: A typical example of response of the present high-resolution system to the monochromatic incident light. Two sharp peaks labeled Rm and Rm′ are Rayleigh lines or elastic scattering. Suffixes m and m′ denote the order of resonanse of the spectrometer.

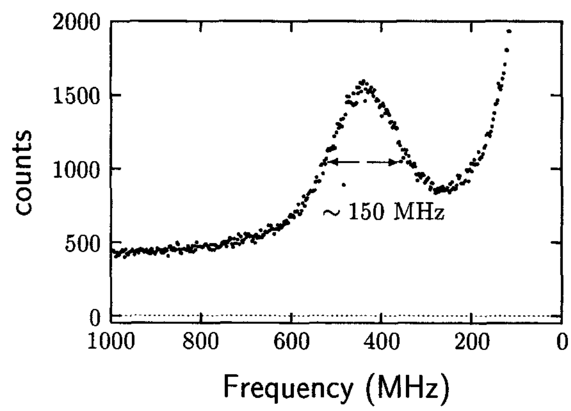

Fig. 3: A stokes Brillouin spectra of acrylic resin at room temperature with a right angle scattering.

3. SUMMARY

A new system aimed for soft materials is under development is shown in Fig.5, which will be an attach system to a personal computer. It is because the resent PC has huge system memory and high speed CPU so that the spectra accumulating method will be implemented as an application software for PC. However, the attach system must perform the important part which needs real-time process: counting photon pulses detected with a photo multiplier and controlling sweep voltage of the spectrometer according to the timing signal. The new system will have the advantage of employing such as more precise and efficient algorithm to determine the positions of Rayleigh lines and 'Rayleigh-span'.

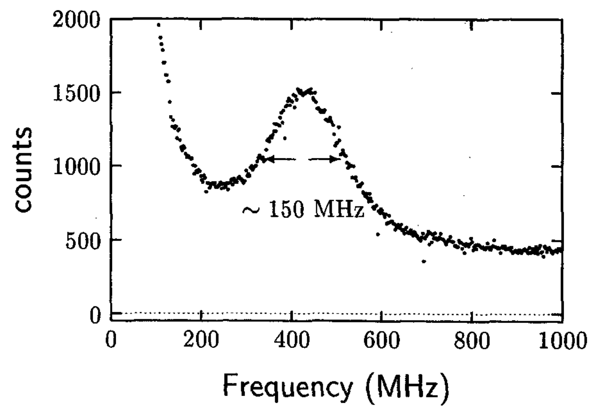

Fig. 4: An anti-stokes Brillouin spectra of acrylic resin at room temperature with a right angle scattering.

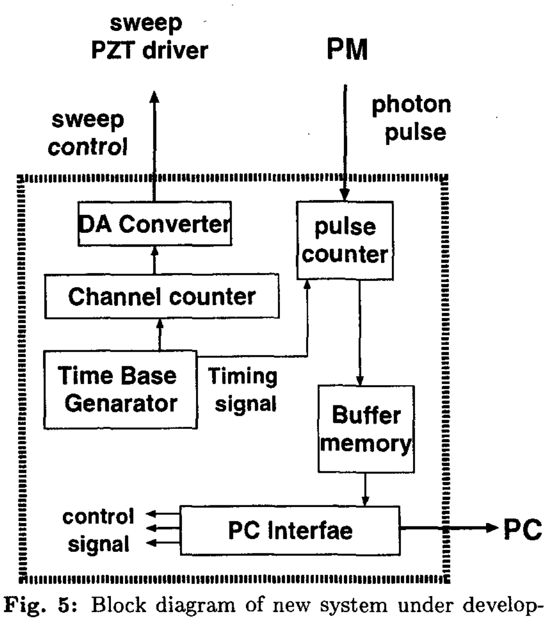

Fig. 5: Block diagram of new system under development; an attach system to a personal computer, performing real-time procedure.

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