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A TYPICAL BRILLOUIN LIGHT-SCATTERING SPECTRUM IN THE $SrLaAlO_4$ (SLAO) CRYSTAL

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A new wide-band frequency component in the Brillouin spectrum, arising from absorption, has been detected in the SLAO oxide crystal. This completes the typical Brillouin spectrum, where Rayleigh lines, inelastic Stokes and anti-Stokes lines have been observed as a result of scattering from bulk acoustic phonons and, for some experimental configurations, on surface acoustic phonons. This newly discovered spectral component is distributed uniformly in frequency, independently of the light power incident on a sample, and depends on the incident wavelength.

1. Introduction

Inelastic laser light scattering by acoustic waves of Brillouin type has been well known for many years as a very useful non-destructive method applied for samples, where acoustic features from the hypersonic range of frequencies are investigated [1-4]. Brillouin spectra typically have a set of strong peaks from elastic scattering, the Rayleigh lines, and very weak Brillouin signals resulting from creation and annihilation of acoustic phonons in interaction with photons. We should also mention the fourth component, or the Mountain's component, discovered in 1966 in Brillouin experiments in liquids. This phenomenon was interpreted as a result of the influence of internal degrees of freedom of molecules to Brillouin light scattering spectra. Its width is relatively large in comparison to Stokes and anti-Stokes components. The Mountain component creates a kind of background which extends between Brillouin and central peaks [5–6].

This paper presents a discovered exception to the above rules in the $SrLaAlO_4$ (SLAO) crystal, where both Brillouin and Rayleigh signals are superimposed on a very strong uniform background. The background forms a sea of frequencies, a level of its intensity has been investigated for different powers and light colors incident on a sample. This new channel for scattering is schematically shown in Fig. 1. The single SLAO crystal is an attractive compound used as a substrate for high temperature superconductor thin films. It has tetragonal symmetry and belongs to the I4/mmm space group [7].

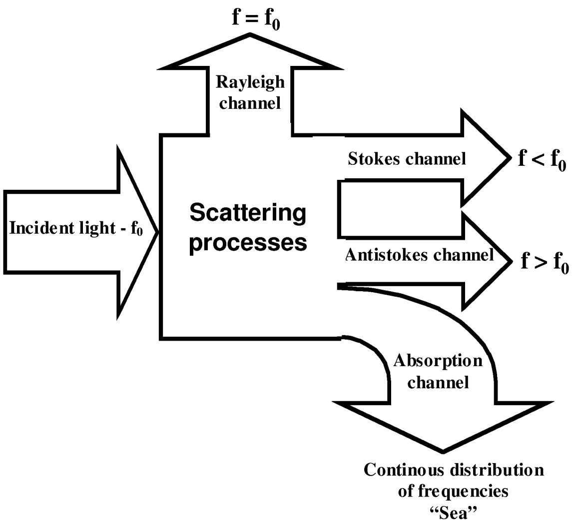
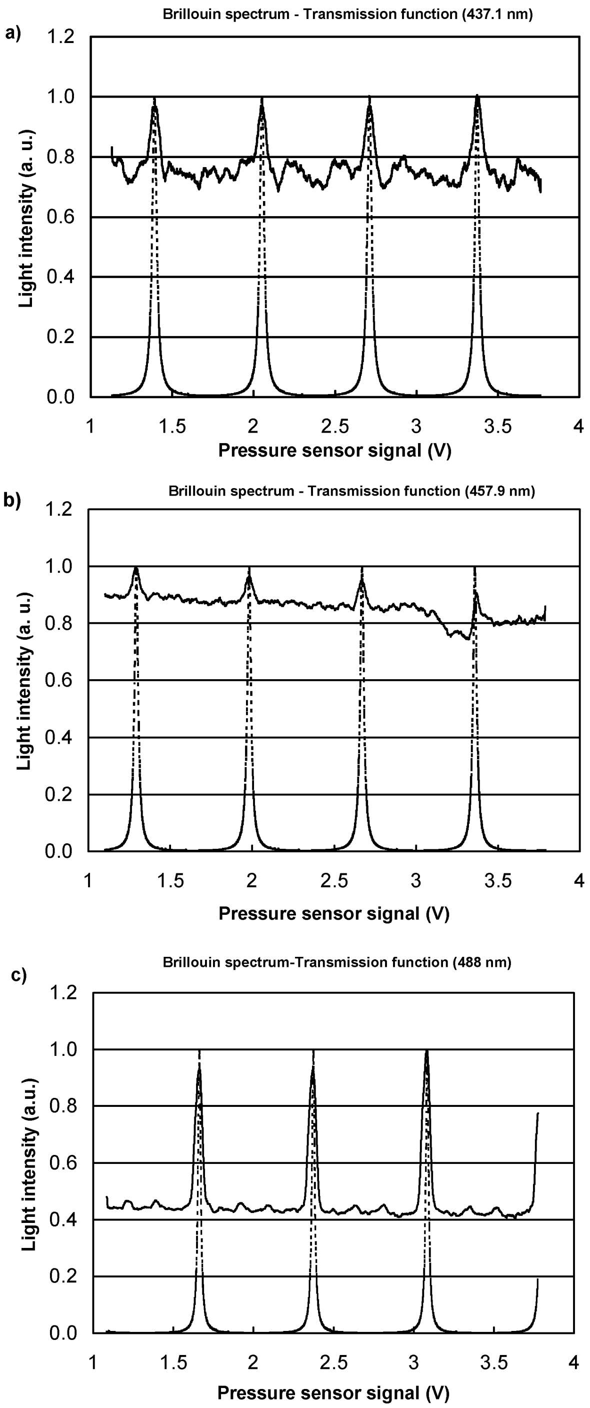


Fig. 1. Schematic view of energy channels in the scattering phenomenon of the Brillouin type. The discovered channel is named a "sea" one.

2. Experimental

The equipment used in the measurements included: a single-mode argon-ion laser working at 437.1 nm, 457.9 nm, 488 nm, and 514.5 nm wavelengths, with a power range of 1.5 mW to 48 mW measured just before the sample; a single-pass pressure-scanned Fabry-Perot interferometer with finesse parameter equal to about 35; and a single photon counting unit produced by Photon Inc. for low-level intensity light detection equipped with the R4240P Hamamatsu photomultiplier. Pressure-controlled interferometry with linear scanning was obtained in a very simple way making use of silicone-membrane pressure sensors which provide voltage signals linearly proportional to the pressure in the chamber where the interferometer is placed. In our case, the Siemens KPY 43 MA sensor was applied. The sensor detects the absolute value of the atmosphere pressure [8]. All the measurements were done for configurations where the angle between incident and scattered light was equal to $\pi/2$. The polarizations of the incident light and scattered light were also controlled and were perpendicular for the results presented here. The full spectral range FSR of the Fabry-Perot interferometer was equal to 37.5 GHz. As the plane of scattering the (110) one was chosen. The laboratory background was taken into account during data processing. It was a function of the laser power as well as the light wavelength.

At the beginning of the measurements the influence of the Fabry-Perot interferometer transmission function on Brillouin spectra was verified [9]. Four measurements, for the four above-mentioned light wavelengths, were made in the same scattering configuration. Figure 2 provides Brillouin spectra with added transmission functions. Different wavelengths influenced the Fabry-Perot's mirrors reflection coefficient R. It was measured as


a)
Brillouin spectrum - Transmission function (437.1 nm)
Light intensity (a. u.)
Pressure sensor signal (V)
b)
Brillouin spectrum - Transmission function (457.9 nm)
Light intensity (a. u.)
Pressure sensor signal (V)
c)
Brillouin spectrum-Transmission function (488 nm)
Light intensity (a.u.)
Pressure sensor signal (V)

[Fig. 2a, b, c]

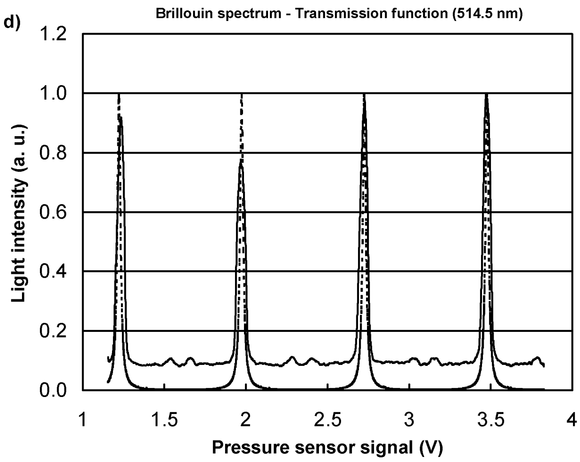


Fig. 2. Brillouin spectra measured for the different laser wavelengths; 437.1 nm (a), 457.9 nm (b), 488 nm (c), and 514.5 nm (d). Transmission functions of the Fabry-Perot interferometer added for comparison (dashed lines).

equal to 0.860, 0.885, 0.914, and 0.910, for the 437.1 nm, 457.9 nm, 488 nm, and 514.5 nm wavelengths, respectively. As we can see this kind of the influence on atypical spectra features can be considered as not important.

Another factor to consider was the influence of the light power incident on a sample. Detailed measurements have been carried out for the 488nm wavelength. Two kinds of characteristics were obtained, namely; the relation between the energy falling in the full spectral range of the Fabry-Perot interferometer above the sea signal intensity divided by the total energy falling in the full spectral range and the power incident on the sample (Fig. 3 a), and the same characteristic, but obtained for the ratio of the Rayleigh peak intensity to sea signal intensity (Fig. 3 b). In both cases the laboratory background was taken into account. As clearly seen in Fig. 3a, the effect is power-independent. This result enables us to make similar measurements for different light wavelengths, where the requirement of equal powers is difficult to maintain for the argon-ion laser applied. Figure 4 provides the same characteristic as Fig. 3a, but as a function of the four above-mentioned laser wavelengths. The minimum in the dark-blue region is visible.

3. Conclusions

From the frequency domain point of view, the absorption-like channel in a scattering process can be interpreted as the sea of frequencies from where some specific values of frequencies are seen as Rayleigh peak and Brillouin components. For these reasons, the effect of energy leaking from a sea into elastic and inelastic channels is a function of the light wavelength. The dependence on the total energy incident on a sample, in the range of powers applied, was not observed; however, as one might expect, there is such a dependence for the ratio of the Rayleigh line intensity to the sea signal intensity.

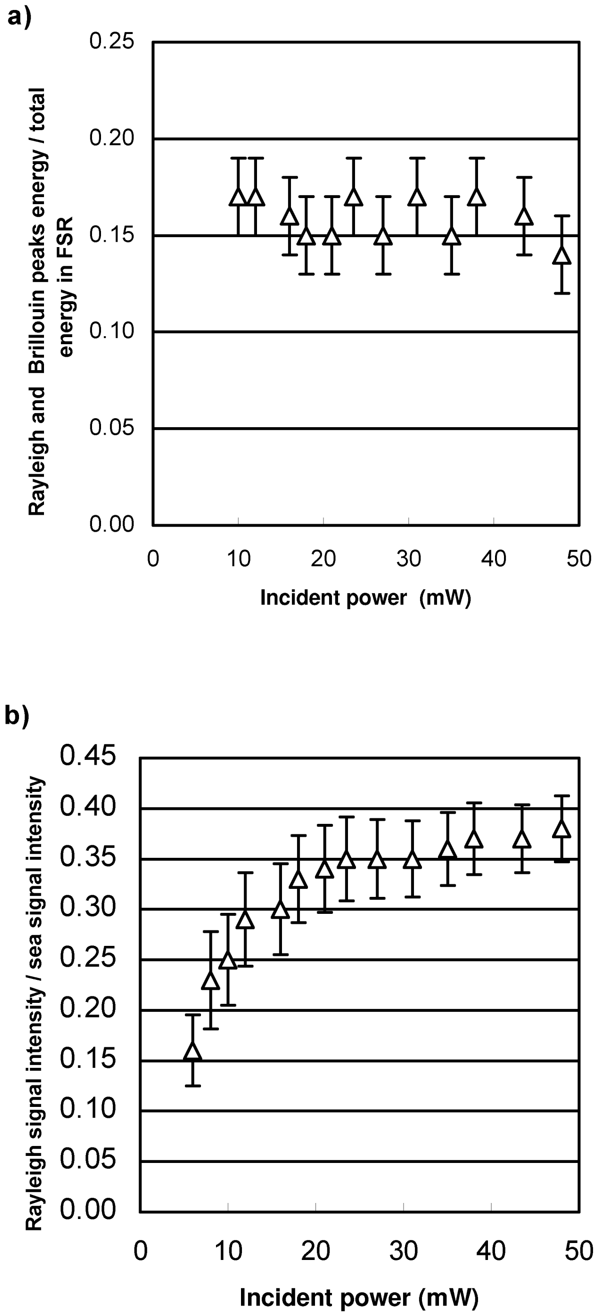


Fig. 3. The energy falling in the full spectral range (FSR) of the Fabry-Perot interferometer above sea signal divided by the total energy falling in the full spectral range as a function of the power incident on a sample (a), and the ratio of the Rayleigh peak intensity to the sea signal intensity as a function of the power incident on a sample (b).

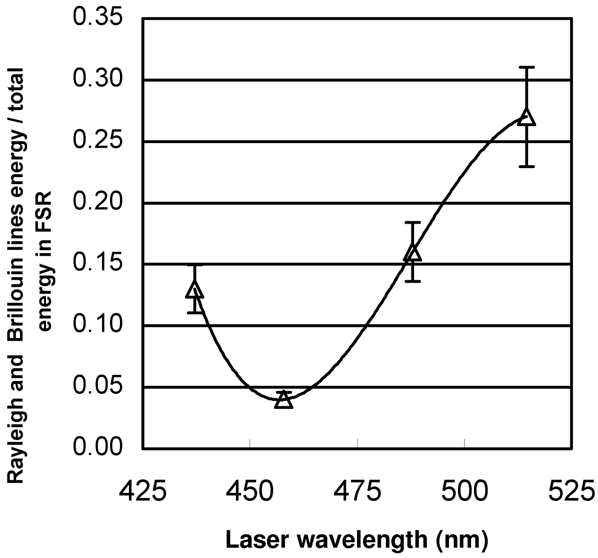


Fig. 4. The energy falling in the full spectral range (FSR) of the Fabry-Perot interferometer above sea signal divided by the total energy falling in the full spectral range as a function of the laser wavelength.

The measurement results indicate that this ratio approaches a constant value as the light power increases.

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