Surface Acoustic Wave (SAW) measurement with the Nanofinder® confocal Brillouin/Raman imaging system

Elastic constants evaluation

What is new?

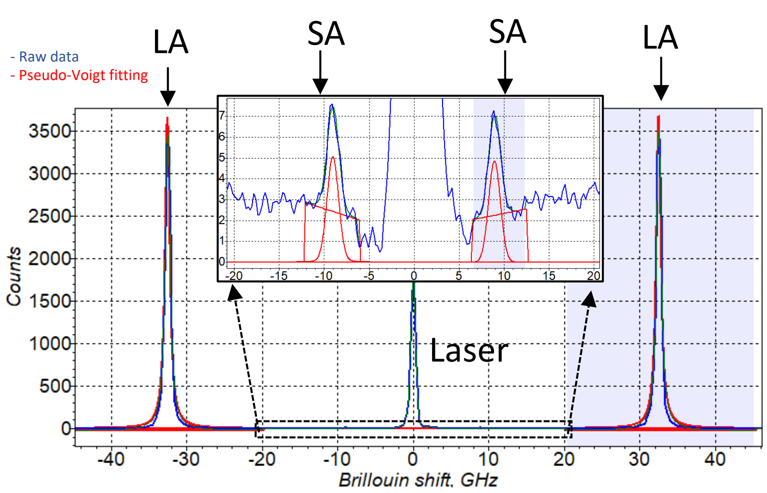
Elastic constants of materials can be obtained by measurements of Surface Acoustic Waves (SAW) by means of Brillouin spectroscopy. If sample surface under the microscope is tilted relative to the incident laser beam, then surface acoustic phonons spectra can be detected in back-reflection geometry (the scattering angle between excitation and detection beams is 180°). Brillouin spectra of transparent samples simultaneously obtained in the same geometry contain also longitudinal phonons signals. These two values are enough to evaluate all elastic constants of isotropic uniform samples.

It is worth to note, that in the tilted sample geometry the microscopic observation of the mirror polished sample surfaces (essential for effective surface waves generation) is complicated, and, hence, it is difficult to ensure exact focusing condition of the laser beam on the sample surface. Raman detection channel of Nanofinder® confocal Brillouin/Raman system, equipped with piezo XYZ scanner permits exact laser beam auto-focusing with using of Raman signal detection.

Tilted sample measurement for elastic moduli evaluation

All elastic moduli of isotropic uniform samples can be obtained in a few simple steps (example of UVFS glass):

1. Set the sample tilt angle to, for example, 45 degree. Measure the Brillouin spectrum of the sample in the conventional 180° back-reflection geometry.



Spectrum above: Brillouin spectrum of UVFS
LA – Stokes and anti-Stokes components of longitudinal acoustic waves
SA – Stokes and anti-Stokes components of surface acoustic waves (Rayleigh waves)
Confocal Brillouin/Raman system based on Nanofinder 30A, Objective lens 20X0.35, laser power on the sample 28 mW, Signal accumulation 5 min

2. Use Pseudo-Voigt fitting for the LA and SA components to obtain Brillouin shifts: ν_{LA} = 32.53 GHz (longitudinal)
ν_{SA} = 8.98 GHz (surface)

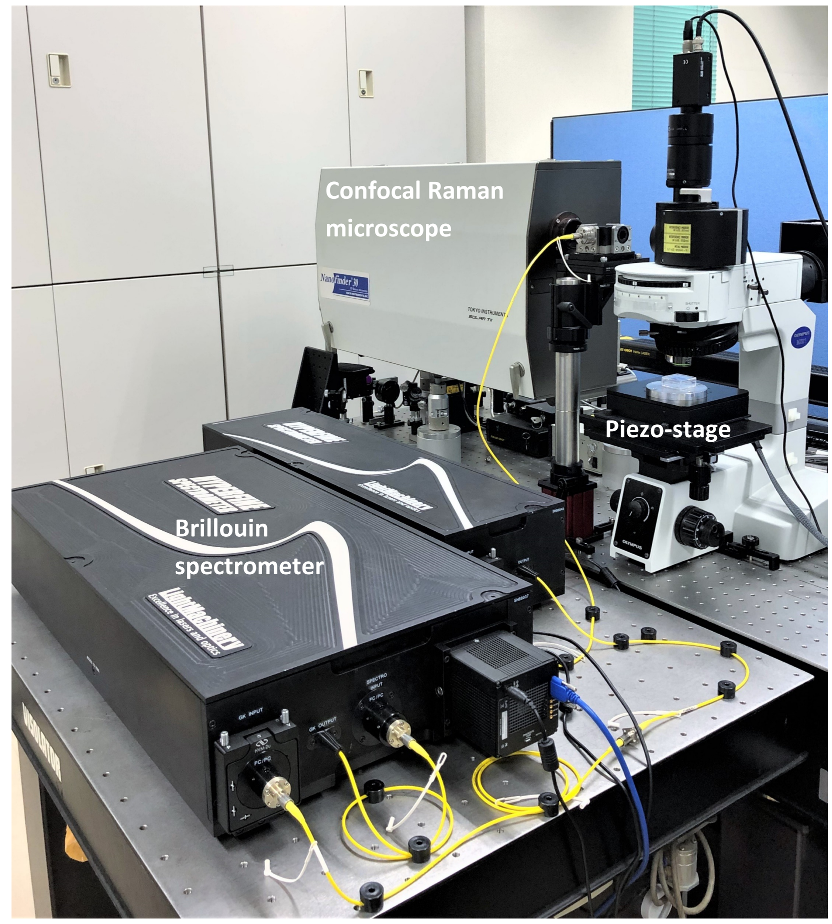
3. Calculate the longitudinal V_{LA} and surface V_{SA} acoustic speeds:

$$V_{LA} = \frac{\nu_{LA}\lambda_0}{2n_{UVFS}} = 5{,}925 \text{ m/sec}$$

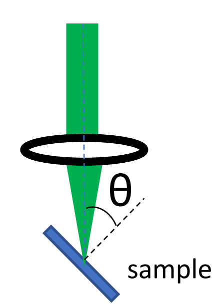
$$V_{SA} = \frac{\nu_{SA}\lambda_0}{2\sin(\theta)} = 3{,}379 \text{ m/sec}$$

Laser wavelength λ_0=532 nm
Refractive index n_{UVFS}=1.4607
Angle Of light Incidence θ=45°

System and Components



Confocal Brillouin/Raman imaging system Nanofinder® 30A (Tokyo Instruments, Japan)



Tilted sample measurement in Back-Scattering geometry

4. With obtained values of V_{LA} and V_{SA} calculate transverse acoustic speed V_{TA}:

V_{TA} = 3,729 m/s

5. Calculate the longitudinal L and and shear G moduli:

$$L = \rho_{UVFS} \times V_{LA}^2 = 77.33 \text{ GPa}$$

$$G = \rho_{UVFS} \times V_{TA}^2 = 30.63 \text{ GPa}$$

Mass density: ρ_{UVFS}= 2.203 g/cm³

6. With the obtained values for L and G, the other elastic constants can be calculated:

Bulk modulus	$K = L - \frac{4}{3}G =$	36.48 GPa
Young's modulus	$E = \frac{G(3L-4G)}{L-G} =$	71.80 GPa
Poisson's ratio	$\nu = \frac{L-2G}{2(L-G)} =$	0.172
Lamé's first parameter	$\lambda = L - 2G =$	16.06

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