Contribution ID: **36**   Type: **Talk**

Time-domain Brillouin scattering for 3D-imaging of texture, phase transitions, elastic and plastic properties of solids compressed in a diamond anvil cell

Monday, 11 May 2026 16:40 (20 minutes)

Time-domain Brillouin scattering (TDBS) technique uses ultrafast laser pulses to generate coherent acoustic pulses (CAPs) and monitor their propagation through transparent samples. Local velocity of a CAP along depth of a sample (V_A, where A represents longitudinal (L) or transversal (T) sound velocity) is extracted from oscillating intensity of the probe light scattered by the CAP and interfering with that reflected by stationary interfaces [1]. Frequency of the oscillation, f_B, is given by the well-known equation used in classical Brillouin light scattering in the backscattering geometry: $f_B = 2 n V_A / \lambda$, where λ is the wavelength in vacuum of the probe laser beam and n the refractive index of the examined material at this wavelength. Spatial distribution of the f_B values can be extracted with micron and submicron resolution in lateral and axial directions, respectively. The latter capability of the TDBS technique permits measurement of single crystal elastic moduli, $C_{ij}(P)$, of any transparent solid compressed in a diamond anvil cell (DAC) to Mbar pressures [2] including polycrystalline cubic phases not available at ambient conditions, e.g. high pressure phases [3, 4]. Similarly, shear modulus of an amorphous or of an isotropic polycrystalline solid, $G(P)$, can be determined if its bulk modulus, $B(P)$, is known [5]. In the case of elastically anisotropic solids, the TDBS technique provides 3D-images of texture of the polycrystalline samples including orientation of individual crystallites in space [6]. Finally, it permits 3D-monitoring of progress of phase transitions or chemical reactions to pressures accessible using the DAC technique [7]. Combination of the TDBS technique with high-resolution X-ray diffraction in a DAC provides a straight-forward way to an assumption-free high-pressure scale. A novel secondary pressure scale based on the $f_B(P)$ dependence of the mixture of methanol and ethanol in the volume ratio 4:1 was already proposed and applied to measure pressure dependence of yield strength, $\sigma_y(P)$, of this amorphous solid [5].

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