5th International Workshop on Laser-Ultrasound for Metals
May 5-6, 2022
Gif-sur-Yvette, France

Fake Anisotropy of Thermal Diffusivity from Transient Grating Spectroscopy Measurements

Kristýna Zoubková[1,2], Petr Sedlák [1], Jakub Kušnír[1], Pavla Stoklasová[1], Hanuš Seiner[1]

[1]*Institute of Thermomechanics of the Czech Academy of Sciences, Prague, Czech Republic.*

[2] *Czech Technical University in Prague, Prague, Czech Republic.*

Transient grating spectroscopy [1] is used for contactless nondestructive laser-ultrasonic characterization of thermal and acoustic properties [2]-[4] of a given material from measurements on a single free surface. A pattern of standing acoustic waves with fixed wavelength λ and wavevector k is photothermally generated by an interference of two pulsed laser beams on a sample surface (see Fig. 1). Detection of an out-of-plane displacement of the sample surface provides information about the acoustic behavior and thermal diffusion in the direction parallel to k. In the case of anisotropic physical properties, the sample might be rotated along the surface normal. We are, therefore, able to obtain the angular distributions of both the elastic and thermal properties on the sample surface.

Our research had aimed to measure the thermal diffusivity of various cubic, single-crystalline metallic samples. Surprisingly, we observed anisotropic angular distribution of the thermal diffusion coefficient. To find the source of this physics-defying result, a numerical finite element method study of the transient grating spectroscopy method was carried out in Comsol (see Fig 2). It was found out that when elastically anisotropic materials absorb heat from the excitation laser in different crystallographic directions, they might produce slightly different out-of-plane displacement of the surface, despite having isotropic thermal diffusivity. This effect, even though seemingly insignificant, strongly influenced the calculation of thermal properties. Thus, it was shown that transient grating spectroscopy measurements might indicate fake anisotropy of thermal diffusivity for elastically anisotropic samples.

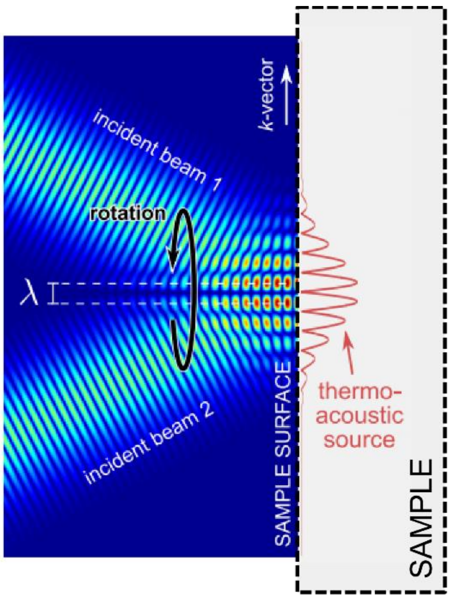

Fig. 1: Schematic illustration of the transient grating spectroscopy method.

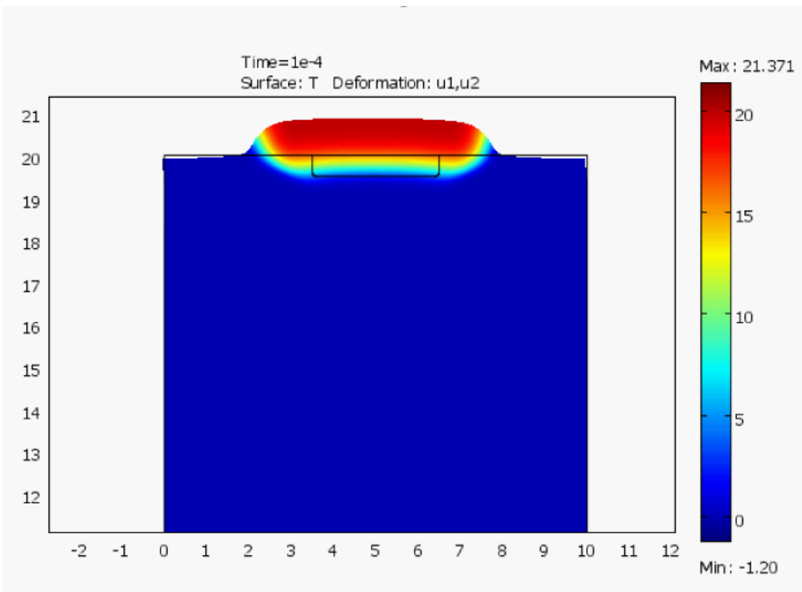

Fig. 2: A finite element method study of a single thermo-acoustic transient grating source in an elastically anisotropic metallic sample.

[1] A. A. Maznev, et al., Opt. Lett., vol. 23, no. 16, p. 1319, 1998.
[2] J. A. Johnson, et al., J. Appl. Phys., vol. 118, no. 15, 2015.
[3] C. A. Dennett, et al., J. Appl. Phys., vol. 123, no. 21, 2018.
[4] Stoklasová, et al., Exp. Mech., vol. 61, pp. 663 – 676, 2021.