Fusion energy, Material evaluation, Non-destructive inspection

Laser-driven neutron resonance spectroscopy realizing instantaneous, transparent, element-selective temperature profiling

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Abstract

We have developed a novel single-shot laser-driven neutron resonance spectroscopy technique to measure temperature profiles inside materials under extreme conditions. Using high-intensity laser interactions, neutrons are generated and utilized to determine spatially resolved temperature information within a single laser shot, enabling instantaneous diagnostics of high-energy-density matter.

Background & Results

Conventional neutron spectroscopy requires multiple shots to accumulate sufficient signal, making it difficult to capture transient plasma conditions. In this study, we realized a single-shot neutron resonance spectroscopy system using laser-driven neutrons generated by proton-induced reactions on heavy metal targets. The measured neutron energy spectrum, analyzed through resonance absorption features, allowed the extraction of internal temperature distributions in real time. The experimental results, published in Nature Communications and Physical Review X, demonstrated the world's first single-shot neutron resonance measurement and confirmed strong agreement with theoretical models. This innovation enables high-precision diagnostics for inertial confinement fusion and opens new avenues for material science under extreme environments.

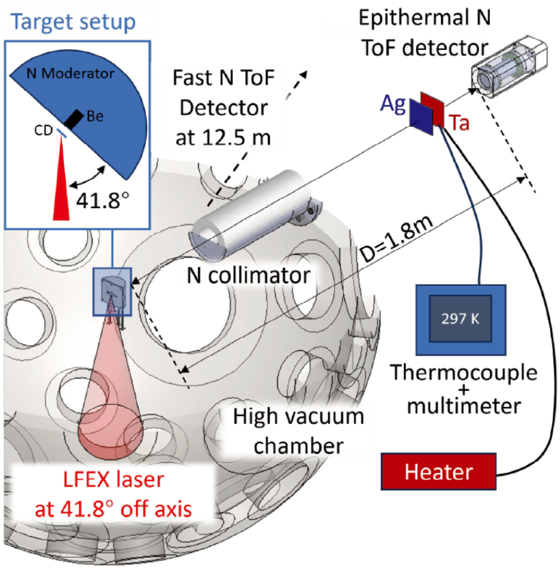

Fig. 1 The experimental setup of the laser-driven epithermal neutron generation and resonance absorption measurement using the TOF method.
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Significance of the research and Future perspective

The proposed technique revolutionizes temperature diagnostics in high-energy-density physics and contributes to the advancement of laser fusion research. Moreover, it paves the way for novel applications such as non-destructive inspection using compact laser-driven neutron sources and laboratory astrophysics studies that mimic planetary and stellar conditions.

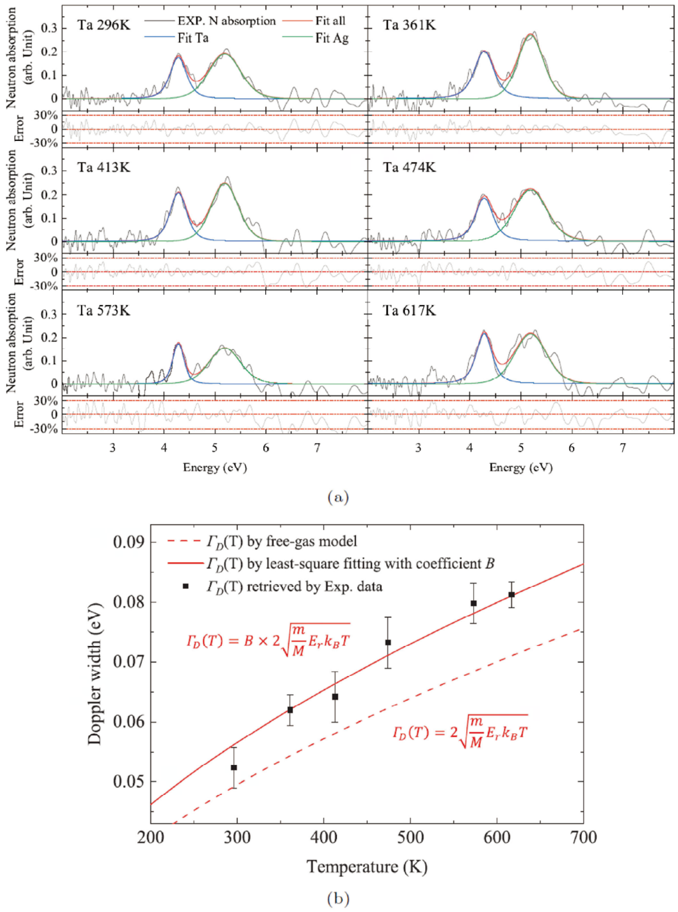

Fig. 2 (a) Experimental neutron absorption results and model. The temperature of Ag was kept at 296K and Ta was heated to T = 297, 361, 413, 474, 573 and 617 K. (b) Theoretical Doppler width and experimental results. The error bars of Doppler width depend on the fitting error and the noise level of the original signal. The temperature of each data point was measured by the thermocouple in the experiment.
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Patent	
Treatise	Lan, Zechen; Yogo, Akifumi et al. Single-shot laser-driven neutron resonance spectroscopy for temperature profiling. Nature Communications. 2024, 15(1), 5365. doi: 10.1038/s41467-024-49142-y Yogo, Akifumi; Arikawa, Yasunobu et al. Laser-driven neutron generation realizing single-shot resonance spectroscopy. Physical Review X. 2023, 13, 011011. doi: 10.1103/PhysRevX.13.011011
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