26pC04

Application of laser ultrasonics for plasma material interaction studies

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1. Introduction

There is a critical need in the plasma material interaction field for an *in-situ* and *non-contact* method for material characterization and health monitoring of installed components. To address this need, our proposed approach is to utilize laser ultrasonics [1] as a plasma-facing component diagnostic for fusion devices. A short pulsed laser results in generation of elastic waves in the ultrasonic range due to thermo-elastic expansion or ablation. These waves are subsequently detected using a laser vibrometer. Both surface and bulk waves can be generated and detected to measure surface and bulk properties, respectively. The material thickness, mechanical properties, and stresses can be deduced from analysis of the time trace of the detected waves. Here we focus on: (1) the determination of sound wave velocities in various tungsten materials which are required for thickness gauging of W components, and (2) determination of acoustic emission during crack propagation in W as a first step towards quantifying W fracture toughness under fusion relevant conditions.

2. Experimental

A Q-switched Nd: YAG laser at 1064 nm (15 ns FWHM) is focused to ~0.1 mm diameter on various W specimens which generate elastic waves in the ultrasonic range by thermo-elastic expansion or ablation. These waves are subsequently detected using a commercially available He-Ne laser (633.8 nm) vibrometer head and decoder from Polytec which measures the change in surface displacement and velocity. The displacement is determined by the phase shift of the backscattered probe beam while the velocity measurements are based on the Doppler effect. Wave velocity experiments were performed in air with laser energy < 20 mJ. The source and detection lasers were positioned directly opposite one another, sandwiched by the W specimen of interest (i.e. epicenter configuration). For detecting of acoustic emission during crack propagation, experiments were performed in-vacuo with 30 μm thick W specimens. Here the Nd: YAG laser was used to generate ablation force that resulted in crack propagation while the vibrometer was used to measure the acoustic emission generated when the crack propagated.

3. Results

Typical time trace of the surface displacement at the epicenter measured at the back surface of a polycrystal tungsten (PCW) sample is shown in Fig. 1. It was found that the longitudinal wave velocity depends weakly on deuterium retention, and grain size differences in the μm range. However, ultra fine-grained W with grain sizes in the order of a few hundred nm resulted in an increase in the wave velocity. Young's modulus is derived from the measured wave velocities. Next, it was found that crack propagation generates lamb waves or guided waves. A shift towards shorter time scales of the lower frequency parts indicated the distance to the source was decreasing (i.e. crack propagation towards detection point).

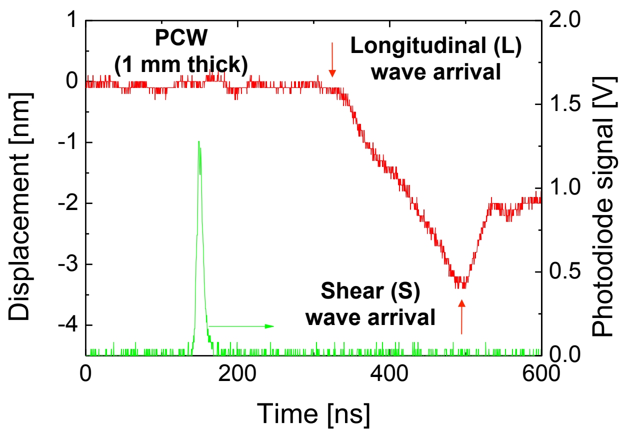

Fig. 1: Surface displacement at the epicenter measured at the back surface of PCW sample.

[1] C.B. Scruby, R. J. Dewhurst, D. A. Hutchins, and S. B. Palmer, J. Appl. Phys. 51, 6210 (1980)