

THERMO-ACOUSTICS OF PULSED LASER-INDUCED PHASE TRANSITION IN TUNGSTEN BY FDTD NUMERICAL CALCULATION

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INTRODUCTION.

Metal-to-liquid phase transition in refractory metals can be generated by laser-irradiation of the surface. Short laser pulses can lead to surface heating, melting or evaporation. During laser-induced melting, the molten mass loses its rigidity and the generation of the shear waves is significantly influenced by a shallow melt pool, while the propagation of longitudinal waves remains less influenced [1]. This work investigates the metal-to-liquid phase transition induced by a nanosecond pulsed-laser with potential application for laser-based remote and localized examination of refractory materials present in harsh environment (Fig. 1). Thereby, the generation of the elastic waves is described by the coupled heat conduction and elastic wave equations and solved using a numerical technique [2].

METHODS.

The delay between the shear and the longitudinal wave arrivals at the onset of melting along the epicentral axis has recently been observed experimentally [1]. This time delay will be reproduced in this work using numerical FDTD technique based on the solution of the coupled heat and wave equations. Laser-generation of ultrasound is governed by the coupled heat and wave equations [2]:

Spatial discretization of thermal conduction and acoustic wave equations is implemented with finite differences using staggered grids and axial symmetric boundary conditions. Temperature dependent isotropic mechanical properties are assumed for tungsten. The melting is assumed to occur between 3530-3700K where the thermophysical properties strongly change. Above melting (3700 K), a longitudinal wave velocity of $c_L=3005$ m/s is assumed with a bulk modulus of $B=c_L^2\rho=173.89$ GPa. The material properties at room temperature are given as: $E^0=408$ GPa, $\nu^0=0.28$, $c_v^0=136$ J(kgC)⁻¹, $K^0=173$ W(mK)⁻¹. The heat equation was solved in a “thermal window”[2] with a spatial discretization of $dr = 180$ nm, $dz = 116$ nm. The discretization of the wave equation was successively increased to $dr = 630$ nm and $dz = 408$ nm to the boundaries of the modeled area.

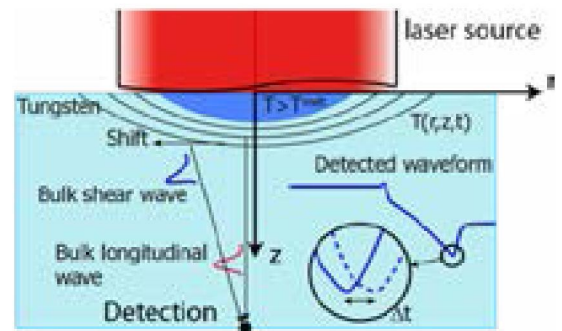


Figure 1. Experimental setup for studying metal melting using a pulsed-laser technique.

$$K \left(\frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial T}{\partial r} \right) + \frac{\partial^2 T}{\partial z^2} \right) = \rho c_v (T + \tau T') - q$$

$$\rho u_r = \frac{\partial \sigma_{rr}}{\partial r} + \frac{\partial \sigma_{rz}}{\partial z} + \frac{1}{r} (\sigma_{rr} - \sigma_{\theta\theta}),$$

$$\rho u_z = \frac{\partial \sigma_{rz}}{\partial r} + \frac{\partial \sigma_{zz}}{\partial z} + \frac{1}{r} \sigma_{rz},$$

