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Time Domain Thermoreflectance (TDTR) and Photodeflection Signatures

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Introduction

In metals, ^3H decays to insoluble ^3He. ^3He clusters cause immediate swelling, deformation and H trapping in the material, resulting in a performance degredation.

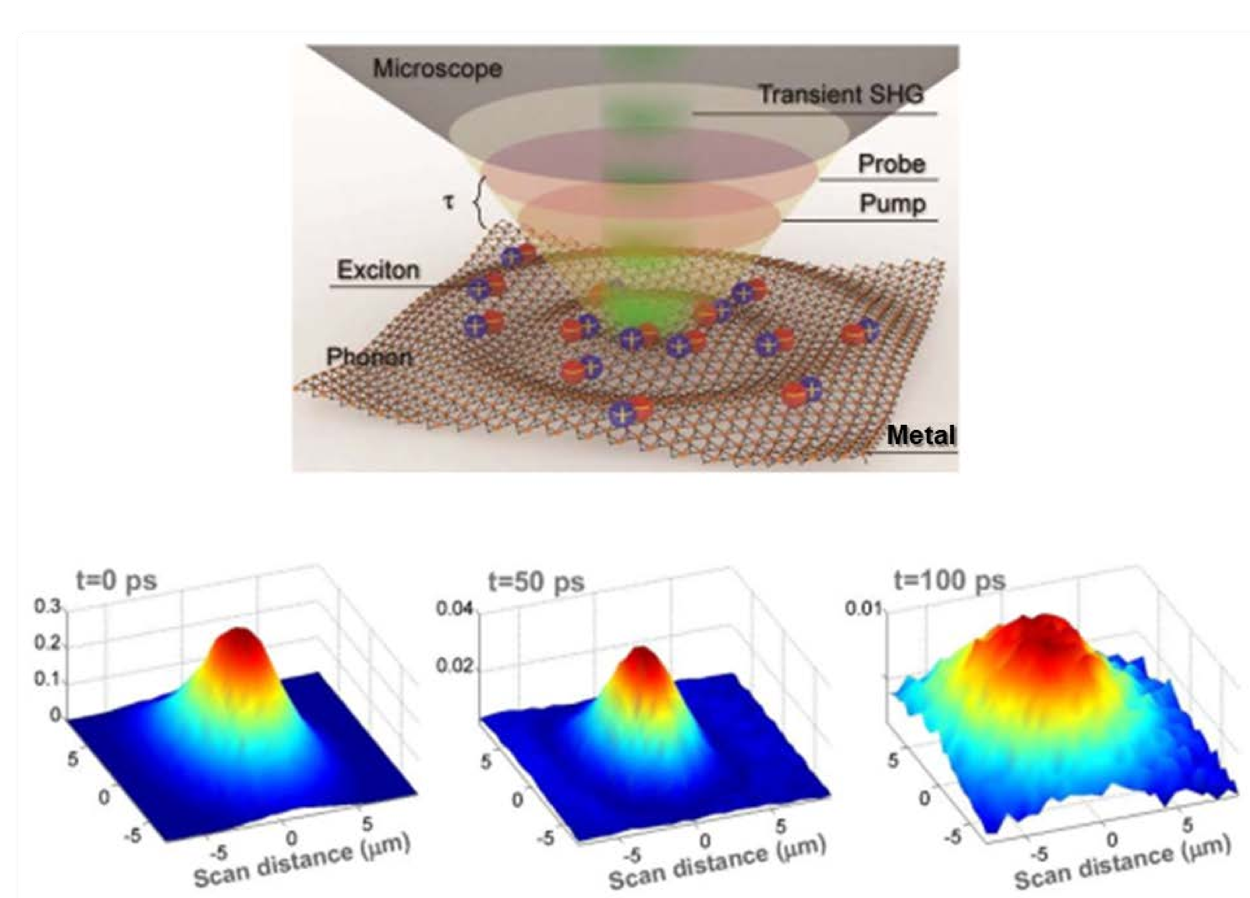
- No simple technologies are available to identify and quantify lattice damage caused by ^3He bubbles. Current technologies are time consuming and destructive. (TEM and isotherm determination with isotope exchange – late stage measurements).
- Thermal conductivity and heat capacitance measurements might provide a faster and early determination of He bubble damage to material.

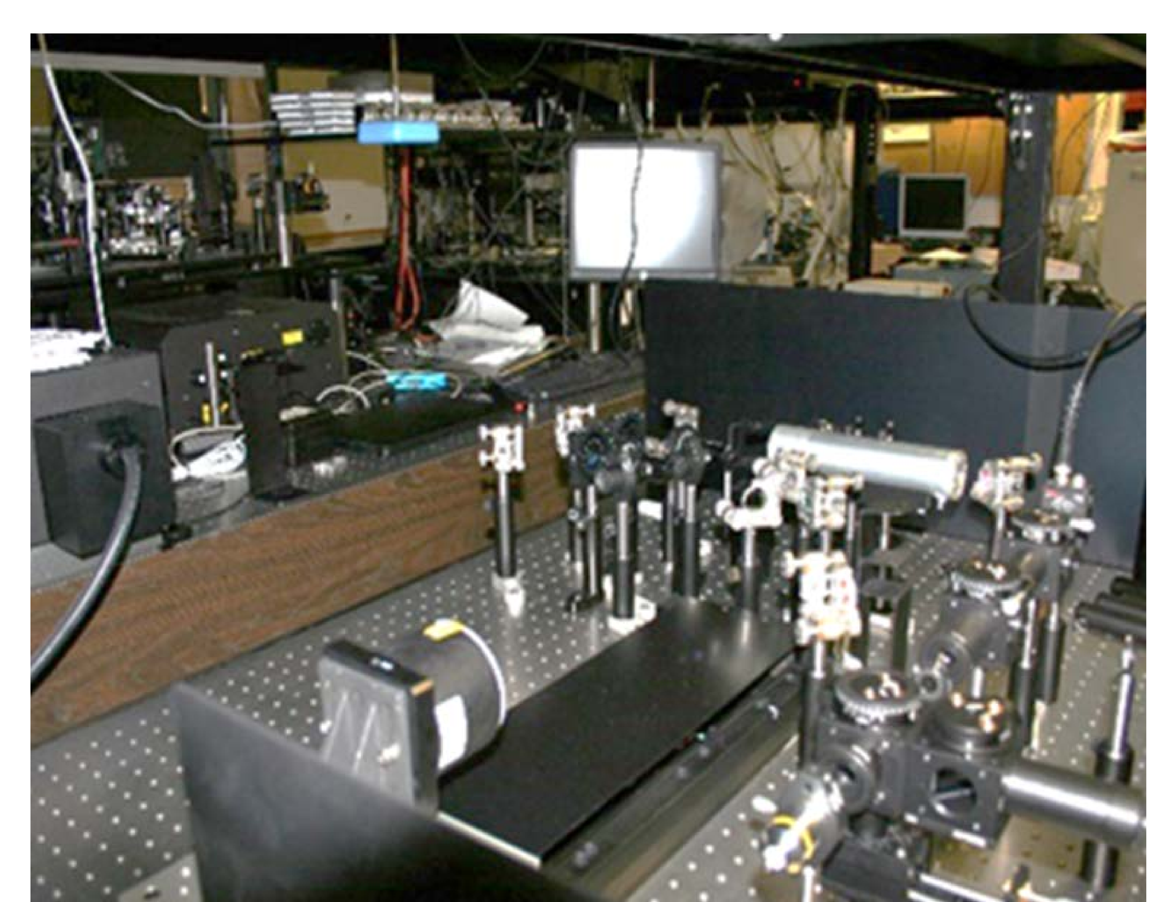
Time-domain thermoreflectance (TDTR) and photodeflection (PD) techniques have been used to characterize microscopic metallic surfaces. These techniques have the potential to measure He bubble related damage to the lattice in steel and alpha decay in actinide materials (Pu- and U-bearing compounds).

Methods

- Quantized lattice vibrations or phonons are responsible for many of the characteristic properties of matter, such as specific heat, thermal conductivity, electrical conductivity, optical and dielectric properties, phase change phenomena, etc. TDTR and time-resolved incoherent anti-Stokes Raman scattering (TRIARS) can be used to characterize radiolytic damage in a material. A pump-probe setup was developed to answer these material property questions.

Thermal diffusion in a material can be measured by an optical technique such as TDTR. TDTR has the potential to provide information regarding radiological damage to the material. A TDTR breadboard was assembled to conduct experiments on materials exposed to tritium, gamma and alpha radiation and examine the growth of He bubbles. TDTR uses two laser beams (pump and probe). The modulated laser beam (pump) is used to heat the surface while probe laser beam follows the temporal changes induced by the pump laser on the material surface. The energy dissipation on the surface is related to the thermal properties of the material.





Results

- A TDTR setup consisting of two optical paths delivering the pump and the probe laser beams to the sample was assembled on an optical table.
- The probe and pump beam were produced from a spectrally broad 35fs pulse using two optical filters.
- Modulation of the pump laser was accomplished with an electro optic modulator.
- Laser beams were aligned using a 785 nm CW laser.
- Demonstrated the extraction of weak modulated reflected light from the noise level using a lock-in amplifier.
- Developed software to control stage
- Developed software to calculate thermal diffusivity and heat capacity from the data.
- Devised methodology to conduct experiments with Bi, Si, steel, $LiAlO_2$, UO_2, and PuO_2.
- Assembled a setup used for coherent anti-Stokes Raman scattering to conduct TDTR experiments.
- Prepared a setup with Time-resolved incoherent anti-Stokes Raman scattering (TRIARS) to provide similar information to the TDTR.
- Raman spectroscopy was used to provide a characterization baseline of the material.