

#### Probing Microstructureinduced Swelling & Thermal Property Changes in Ion-Irradiated Oxide Fuels using Laser-generated Surface Acoustic Waves

September 2021

Amey Rajendra Khanolkar, Zilong Hua, David H Hurley, J. Matthew Mann





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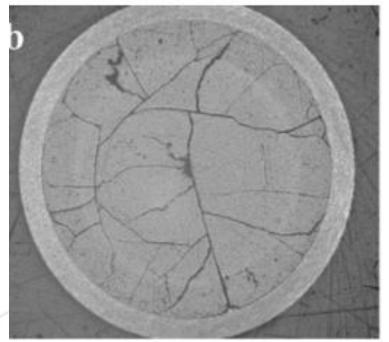
Idaho National Laboratory Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the U.S. Department of Energy Under DOE Idaho Operations Office Contract DE-AC07-05ID14517 PI: Amey Khanolkar, Co-PIs: Zilong Hua, David Hurley (B612), Collaborator: J. Matthew Mann (AFRL)

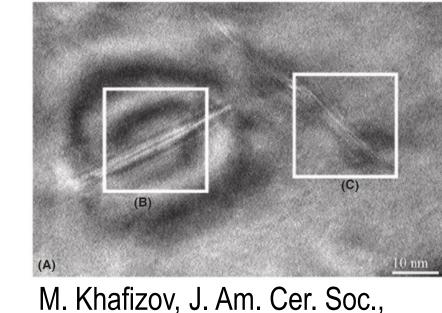
# Radiation Effects on Microstructure & Thermo-physical Properties of Oxide Fuels

Optical Micrograph of Irradiated UO<sub>2</sub> pellet



High Resolution TEM image of dislocation loops in H<sup>+</sup> irradiated CeO<sub>2</sub>

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- Point defects
- Cracks

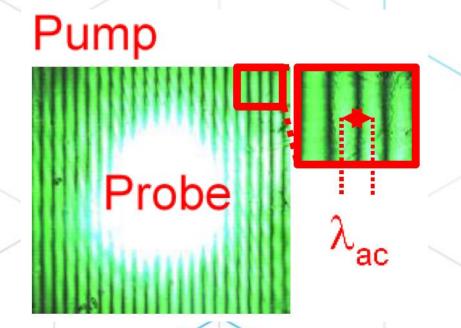
102(12), 7533-7542 (2019). C. Degueldre, Progress in Nuclear Energy, 92, 242-253 (2016).

- Post Irradiation Examination (PIE) techniques:
  - Optical & electron microscopy
  - Extensive sample preparation with local effects
  - Insufficient structure-property relationships

#### Laser-based Materials Diagnostic Tools Transient Grating Spectroscopy (TGS)

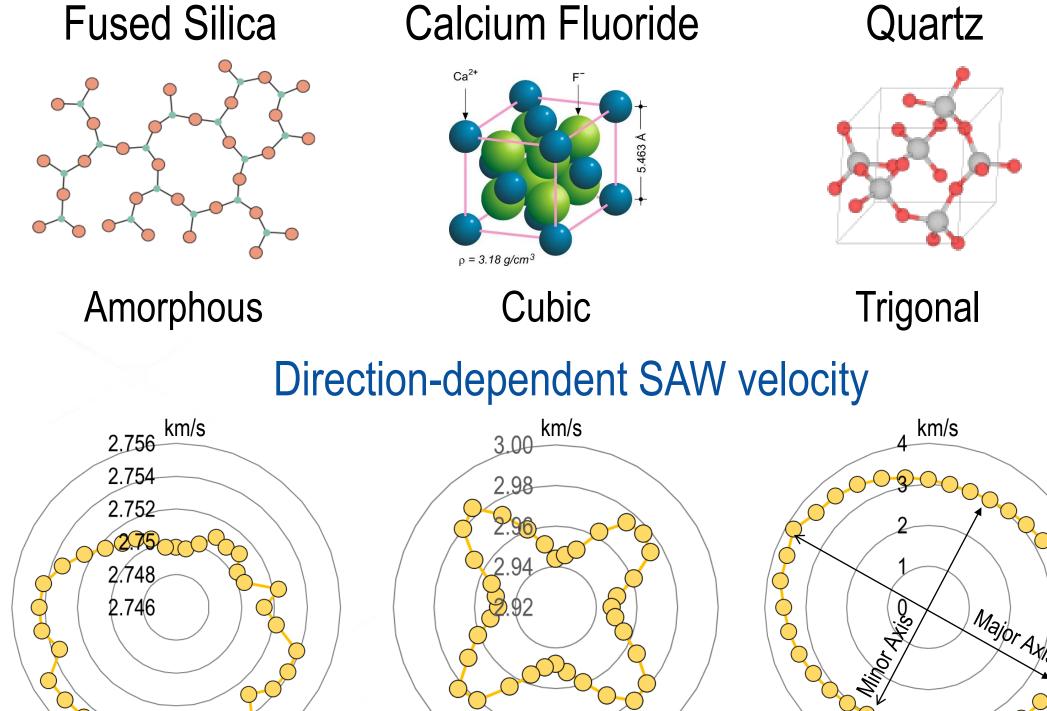
Pump Two pulsed laser beams crossed on sample surface Probe Localized heating Sample Surface acoustic waves (SAWs)

Interference Pattern projected on sample



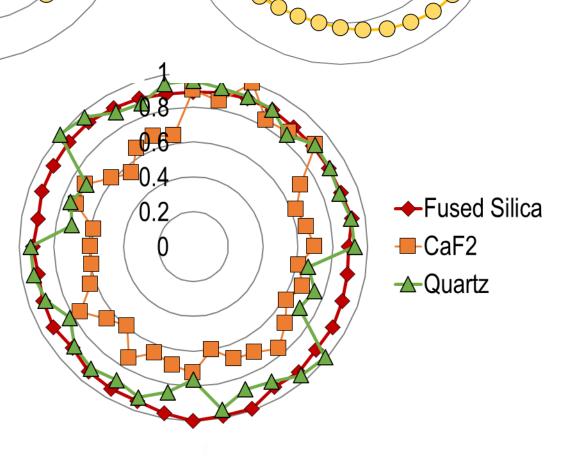
- Enables simultaneous mapping of elastic & thermal properties
- Confined to surface-confined micrometer length-scales

# Simultaneous Mapping of Elastic & Thermal Anisotropy in *Insulators*

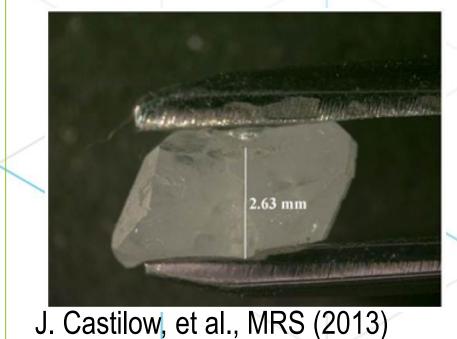


Direction-dependent Normalized Thermal Diffusivity

> Circular symmetry indicates thermal isotropy



# Thorium Dioxide (ThO<sub>2</sub>) Fuel



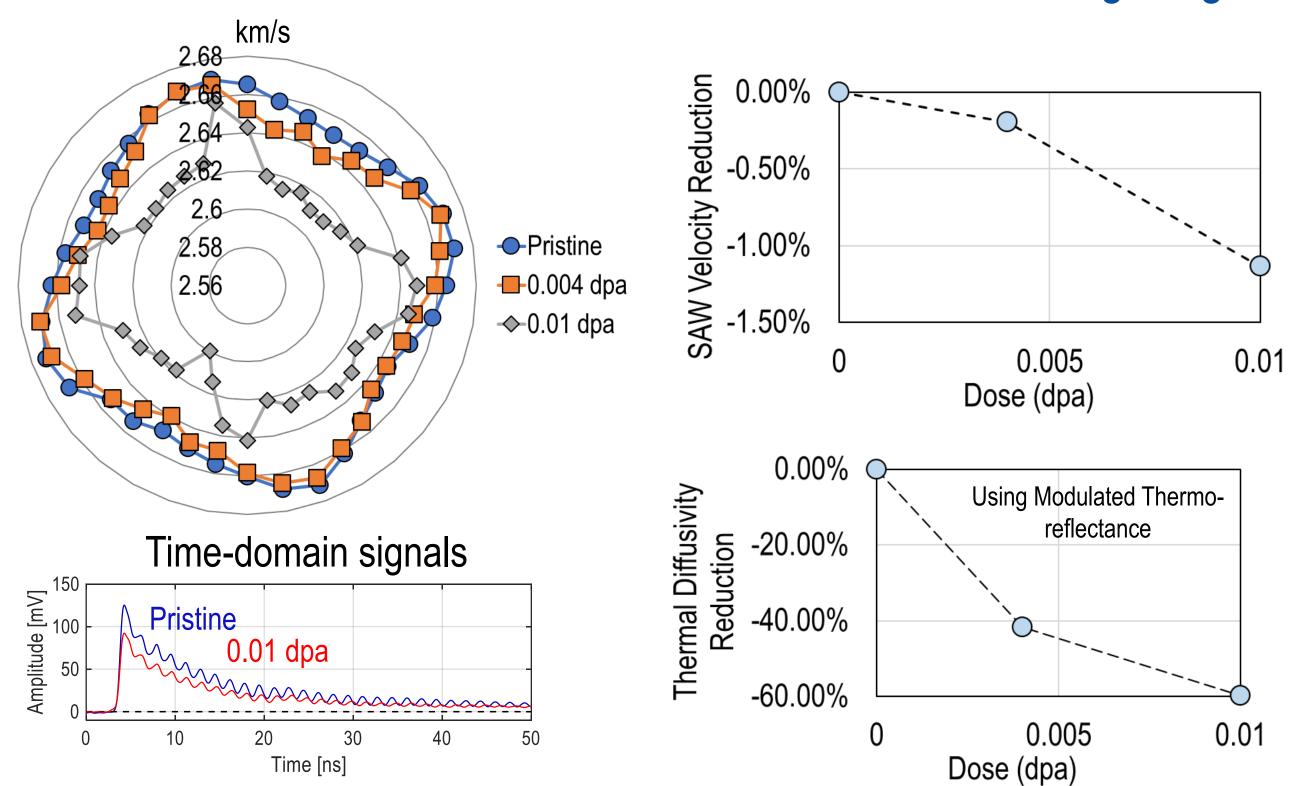
- Alternative to traditional UO<sub>2</sub> for advanced reactor concepts
- Very limited experimental data available for single crystal ThO<sub>2</sub>

ThO<sub>2</sub> single crystals synthesized using hydrothermal growth at the Air Force Research Laboratory (AFRL)

# Radiation-induced Elastic & Thermal Property Changes in *Thorium Dioxide*

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- ThO<sub>2</sub> single crystals irradiated with 2 MeV H<sup>+</sup> ions at room temp.
- TGS enables measurements in micrometer-thick damage regions



## Research Output

A. Khanolkar, Z. Hua, C.A. Dennett, M. Khafizov, J.M. Mann, D.H. Hurley, "The influence of radiation-induced microstructural defects on the optical and elastic properties of ceramic nuclear fuels", TMS 2022 (accepted)

### Harvest Strategy

- INL LDRD in Condensed Matter Physics: Property evolution in ThN under high pressure & low temperature
- INL Seed LDRD: Utilizing Laser ultrasonics for rapid screening of complex alloys -> Materials for extreme environments

Project Tracking #: 19P43-012FP





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