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In situ ion irradiation transient grating spectroscopy (I³TGS)

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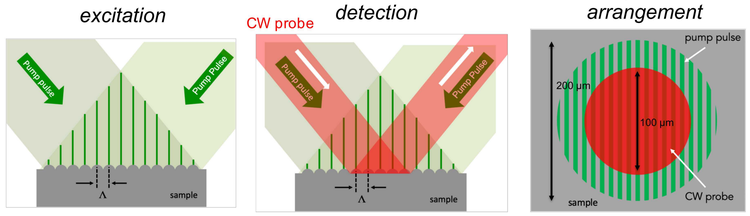
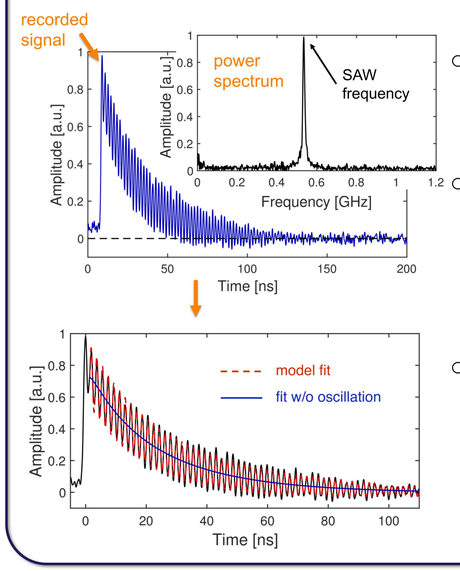
Transient Grating

TGS offers laser-based, non-contact, non-destructive evaluation of acoustic, elastic, and thermal properties over micron length scales



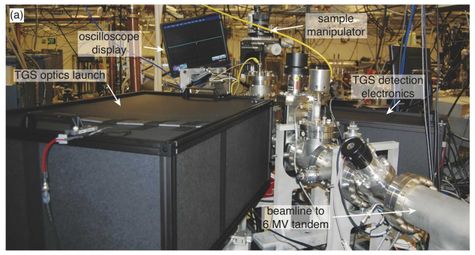
- Impulse periodic surface excitation from pulsed laser causes transient changes in temperature and displacement



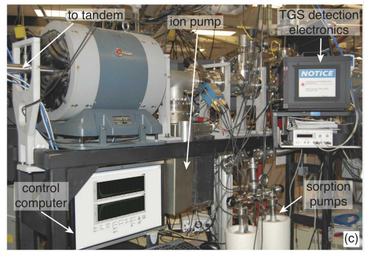
- Probing laser monitors the decay and oscillation of these excitations
- Surface acoustic wave (SAW) frequencies are easily extracted and provide a link to elastic mechanical properties
- Fitting to a thermal equilibration model provides a direct measure of thermal diffusivity

I³TGS Beamline @ Sandia

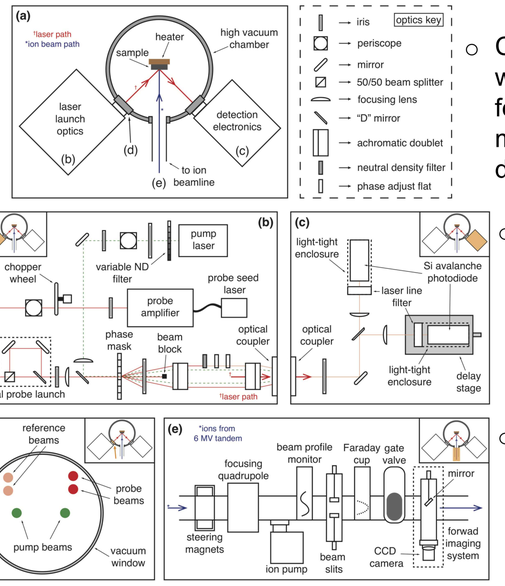
Laser diagnostic installed on a dedicated beamline on the 6 MV tandem ion accelerator at SNL



top view of beamline with laser enclosures



side view of control system



I³TGS system schematic for laser and ion beams

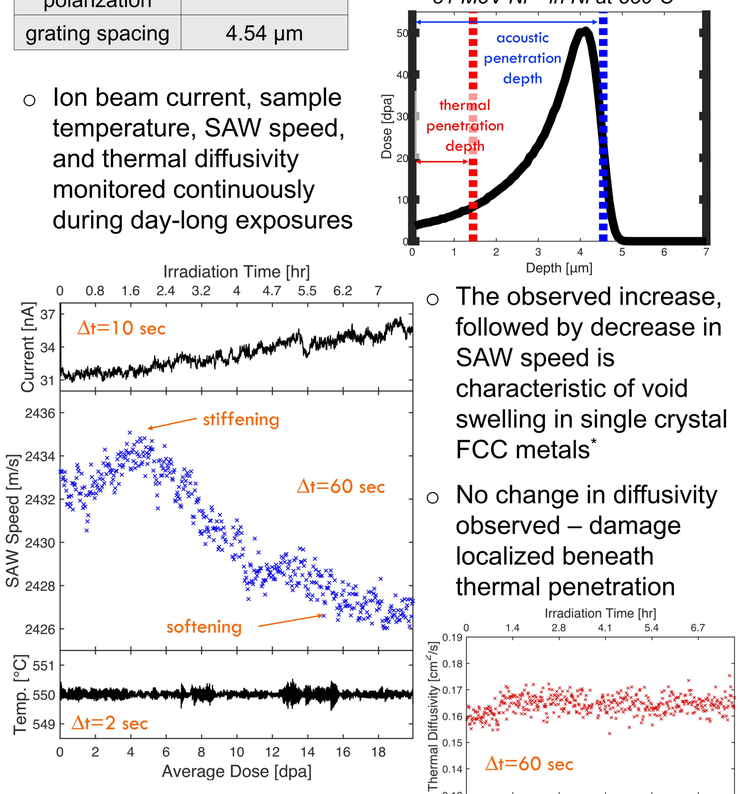
- Combining a TGS diagnostic with an ion beamline allows for real-time monitoring of material **property** changes during irradiation
- Properties are measured with orders-of-magnitude higher resolution in applied dose than traditional post-exposure examination
- Microstructure effects are related to property evolution through theory, prior testing, or coordinated modelling

High Temperature Self-Ion Irradiation

Initial experiments demonstrate void swelling can be monitored via changes in SAW speed

material	Single crystal {001} Ni
ion species	Ni^{5+}
ion energy	31 MeV
temperature	550˚C
spot size	1.6 mm dia.
beam current	33.7 nA (avg.)
acoustic polarization	13˚ from ⟨100⟩
grating spacing	4.54 μm

- Ion beam current, sample temperature, SAW speed, and thermal diffusivity monitored continuously during day-long exposures

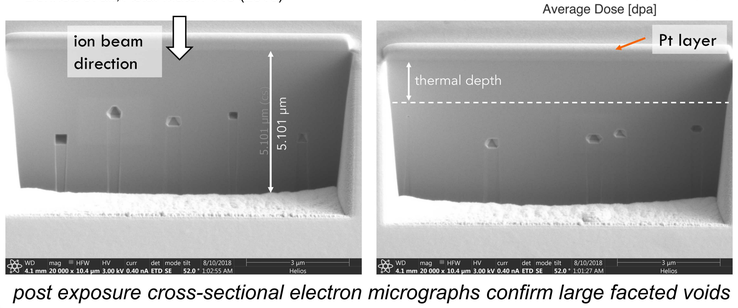


- Ion irradiation conditions set to induce void swelling
- Length scale between the damage layer depth and measurement sensitivity is matched by tuning the ion beam energy

SRIM damage profile for 31 MeV Ni^{5+} in Ni at 550˚C

- The observed increase, followed by decrease in SAW speed is characteristic of void swelling in single crystal FCC metals*
- No change in diffusivity observed – damage localized beneath thermal penetration

*Dennett et al., Acta. Mater. **145** (2018)

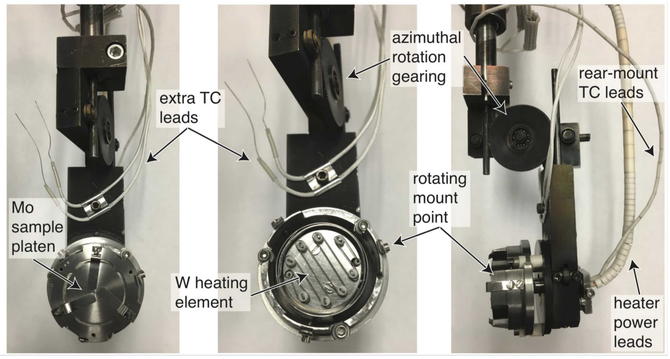


post exposure cross-sectional electron micrographs confirm large faceted voids

Capabilities Under Development

More user-friendly alignment and data acquisition tools – coming online as a user facility soon!

- Upgraded ion beam diagnostics and imagining for improved coincidence positioning
- Platen-based sample transfer for easy exchanges
- Azimuthal sample rotation for alignment and exploration of higher-order elastic behavior



new high temperature sample stage with manual azimuthal rotation

Acknowledgement

Facility Description
Dennett et al., NIMB **440** (2019)

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