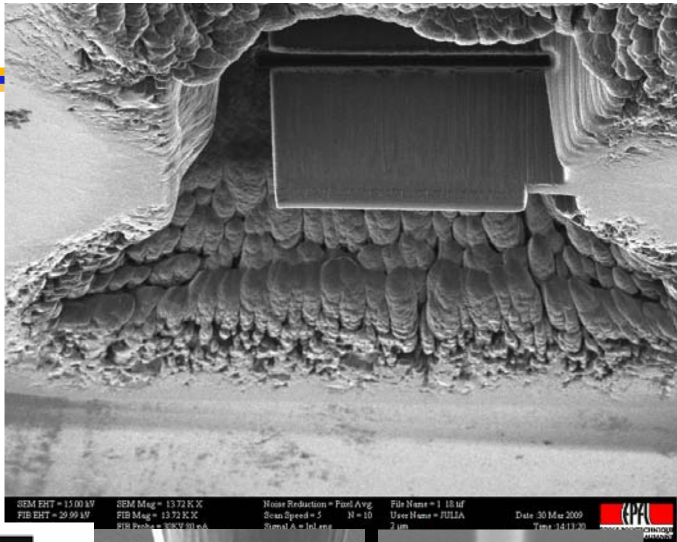
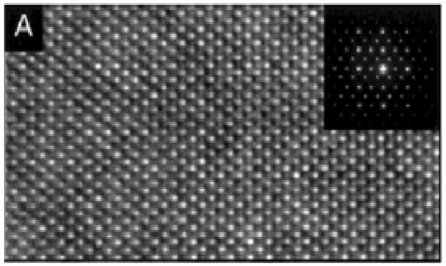
Advanced Experimental Techniques for Assessing Microstructural and Mechanical Changes Induced by Irradiation

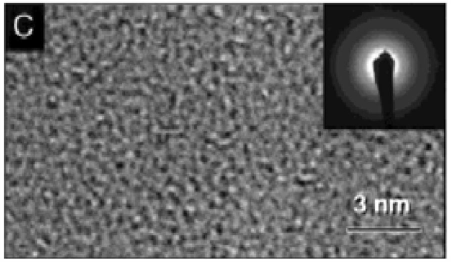
Kenji Kikuchi, Stuart Maloy

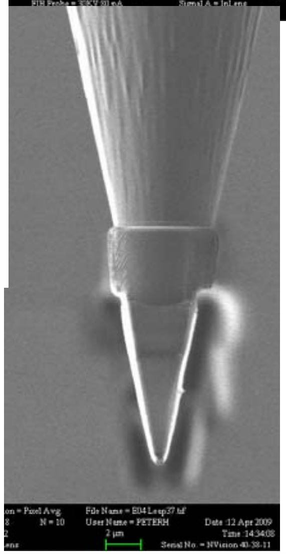
Microstructural Analysis Techniques

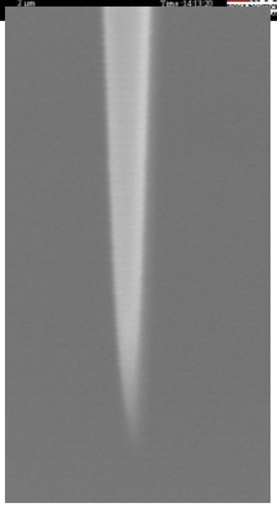


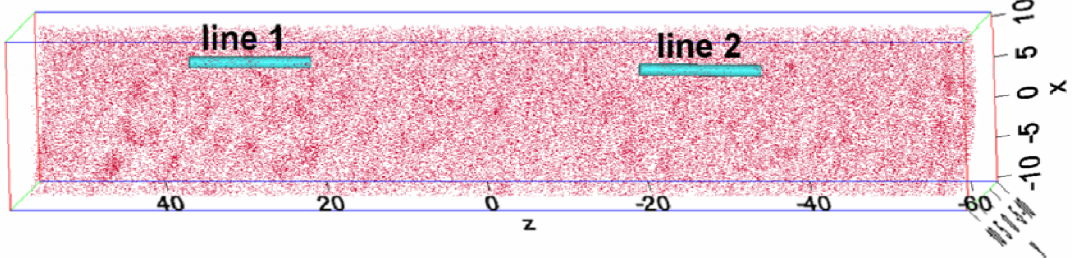
- Typical
  - Optical Metallography
  - Transmission Electron Microscopy (TEM)
  - X-ray Diffraction (XRD)
  - Scanning Electron Microscopy (SEM)
- Advanced
  - FIB prepared
    - Atom probe
    - TEM
  - **SANS**
  - Texture Analysis
  - **Neutron Reflectrometry**
  - Positron Annihilation Spectroscopy
  - **In Situ Measurements – (e.g. MaRIE)**





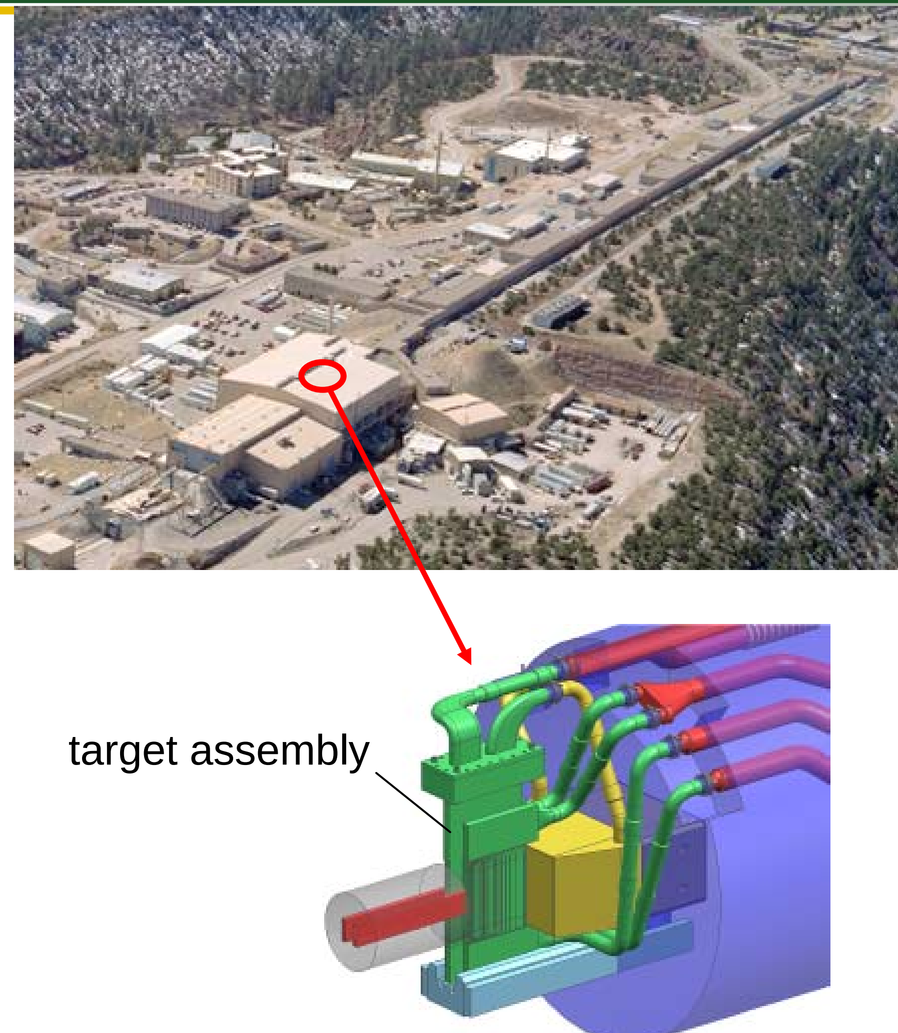






The Materials Test Station is planned to be a fast spectrum fuel and materials irradiation testing facility

- **MTS will be the only fast spectrum irradiation facility in the Western Hemisphere and Europe**
- **MTS will be driven by a 1-MW proton beam delivered by the LANSCE accelerator**
- **MTS will have 1/3 to half the peak flux of the world's leading research fast reactors**
- **Cost range is \$60M to \$90M, and can be operating as soon as 2016**

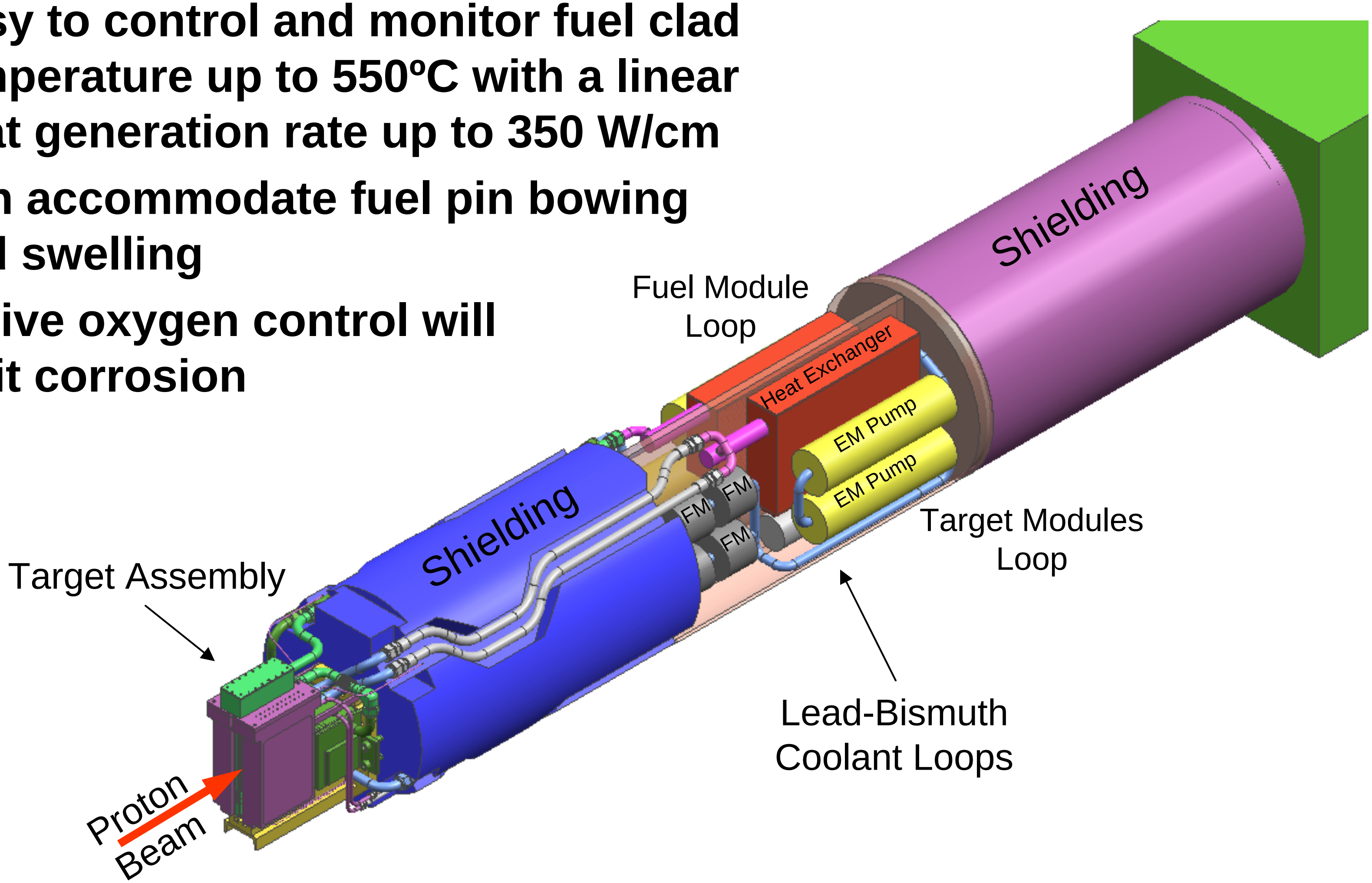


U.S. DEPARTMENT OF ENERGY

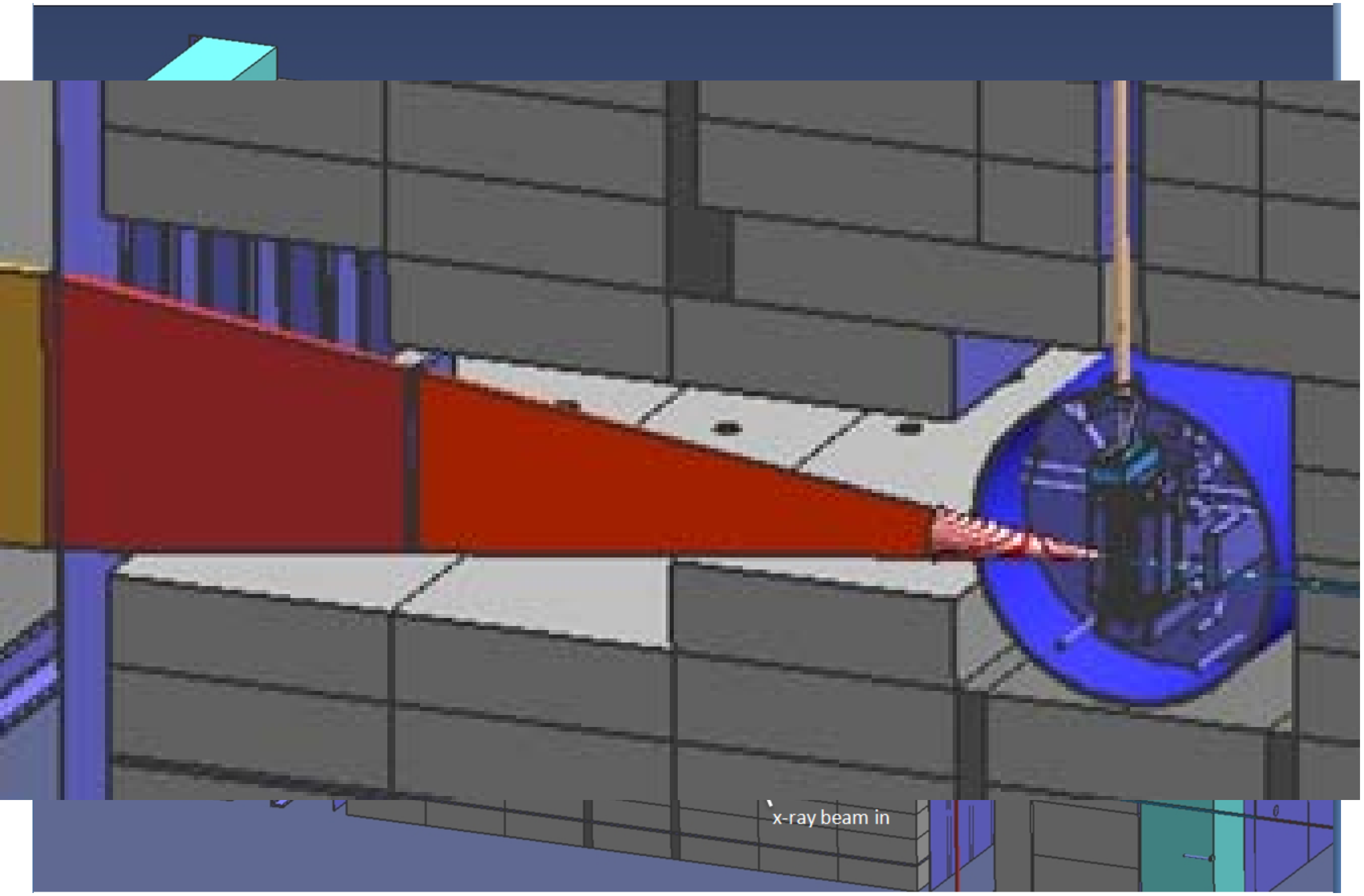
Nuclear Energy

The use of Pb-Bi as a fuel and target coolant allows prototypic irradiation temperature

- **Easy to control and monitor fuel clad temperature up to 550ºC with a linear heat generation rate up to 350 W/cm**
- **Can accommodate fuel pin bowing and swelling**
- **Active oxygen control will limit corrosion**



Combining a 4th generation light source with MTS enables an *in situ* measurement capability in the neutron environment



Concept for inserting samples into MTS "in situ" location using a transfer cask and X-Ray scattering geometry

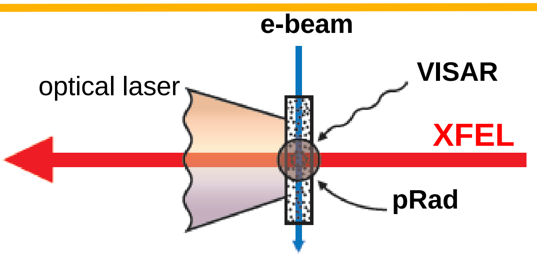
High fluence, high energy, low divergence X-ray sources offer the potential of placing detectors far from the sample

Technological challenges include:

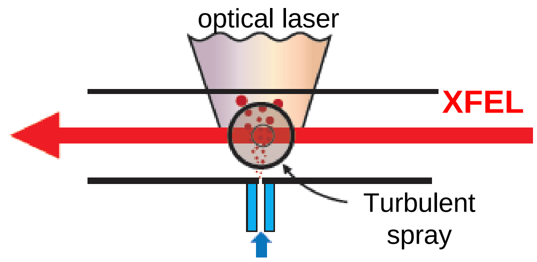
- **Detector operation in high radiation fields**
- **X-ray source definition**
- **Sample handling and temperature control**

Frontier experiments identify performance gaps that form the basis of MaRIE’s functional requirements

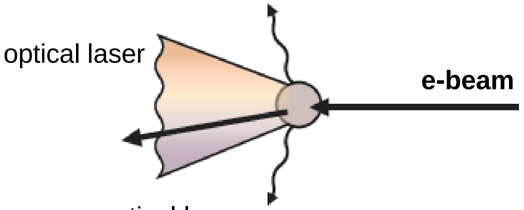
- **Measuring stress on fuel cladding under irradiation**



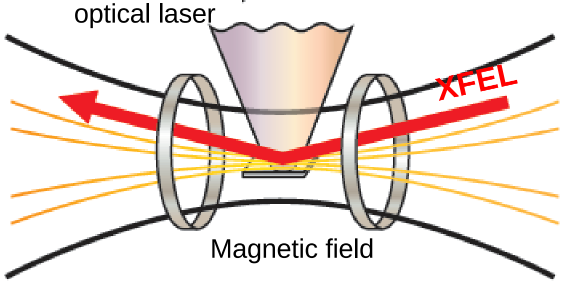
- **Performing Creep experiments under irradiation**



- **Performing fatigue experiments under irradiation**

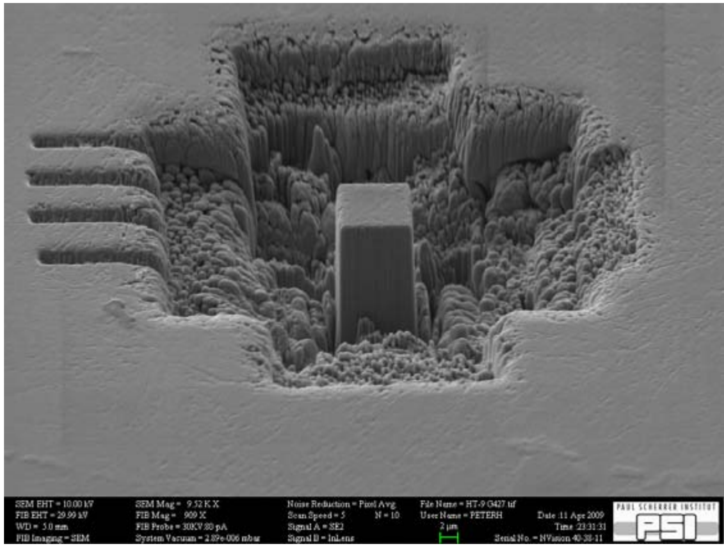


- **Emergent Phenomena in Complex Materials**
  - **Ultrafast (10–100 fs) measurements in Extreme Environments**



Mechanical Testing Techniques

- Typical
  - Tensile (16 x 4 x 0.75 mm)
  - Toughness (12.5 x 2 mm)
  - DBTT (Charpy, 3 x 4 x 27 mm)



- Advanced
  - FIB prepared
    - Microcompression
    - Nanohardness
  - In Situ Creep (w/nanohardness?)
  - In situ fatigue
  - Microtensile?
  - Microbend?