SAND2007-4020C

Dynamic reflectance measurements of shocked materials

Gas gun experiments at NSLS

Shock Compression of Condensed Matter

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company,
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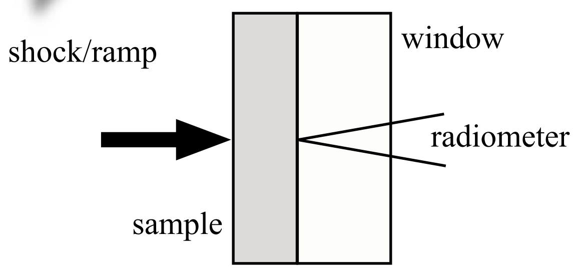
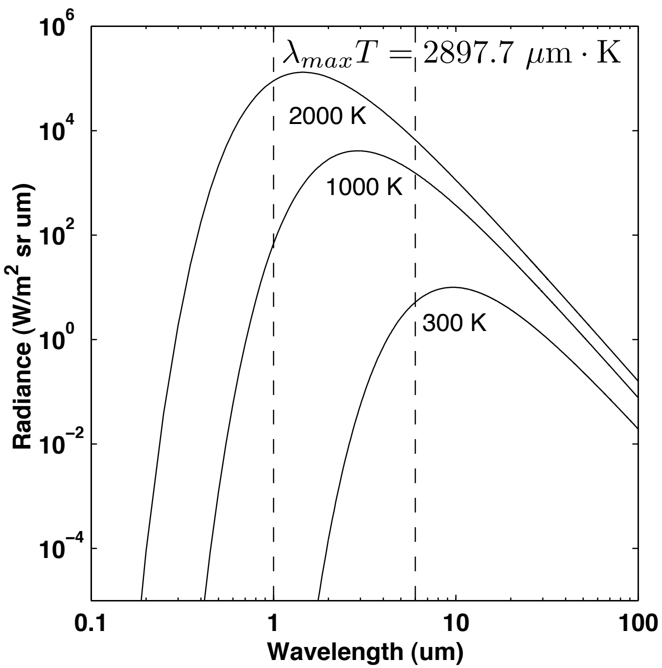
Project overview

- Primary goal: study infrared reflectance of shocked materials
  - Yields information about emissivity changes, which is important in dynamic pyrometry measurements
- Secondary goal: develop dynamic compression capabilities at a synchrotron light source
  - Leads the way towards future applications (x-ray diffraction)
- This project represents one of the first real-time, single-event applications of synchrotron radiation
  - No averaging over many events/pulses

The emissivity problem





$$L(\lambda, T) = \epsilon \times \left(\frac{c_1}{\lambda^5 \left(e^{c_2/\lambda T} - 1 \right)} \right)$$

$$\epsilon(\theta) = 1 - \rho(\theta; 2\pi) - \tau(\theta; 2\pi)$$

- **Pyrometry measurements depend on sample temperature AND emissivity**
  - **0≤ emissivity ≤ 1**
  - **Can be inferred from reflectance and transmission**
  - **~0.1 for metals (infrared)**

- **Emissivity changes in many ways**
  - **Material state (temperature, pressure, phase)**
  - **Surface condition (specular, diffuse)**

- **Without knowledge of emissivity, only the minimum pyrometer temperature is known**
  - **Temperature uncertainty scales with emissivity uncertainty**

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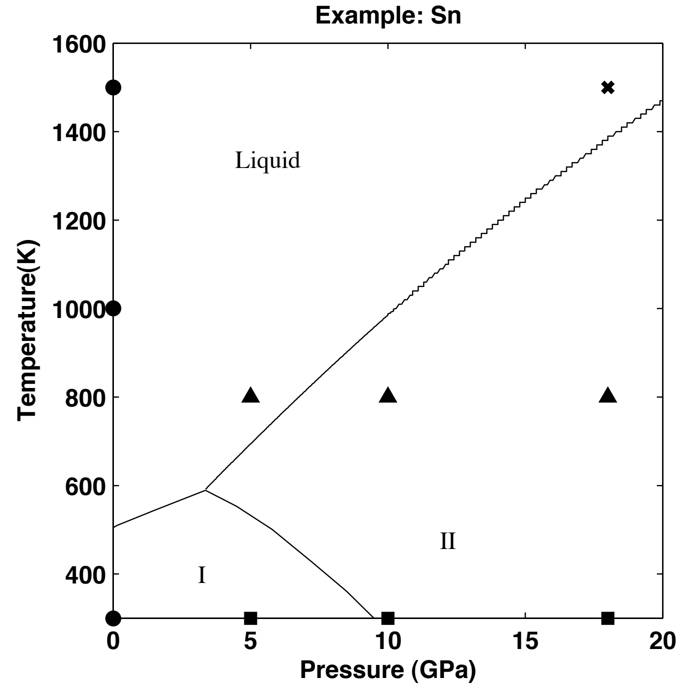
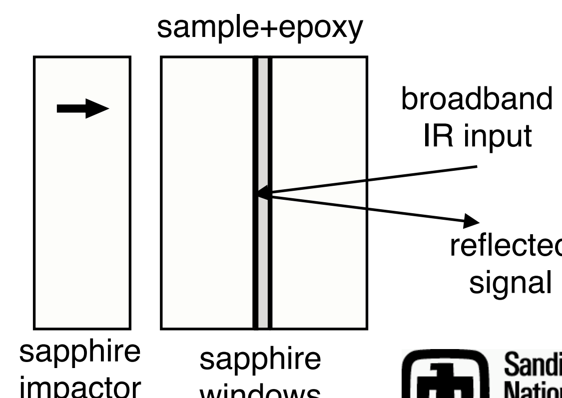
Dynamic emissivity characterization

- **Goal: create emissivity table for various (P,T) conditions**
  - **Provide reasonable bounds for temperature uncertainty**
- **Ambient emissivity typically well known**
- **High T, low P measurements underway at NIST**
- **Low T, moderate P shock experiments performed at NSLS**
  - **Thin sample + sapphire windows = quasi-isothermal compression**
  - **Preheat capability possible in future work**





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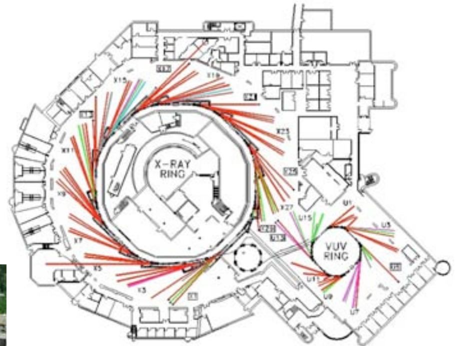
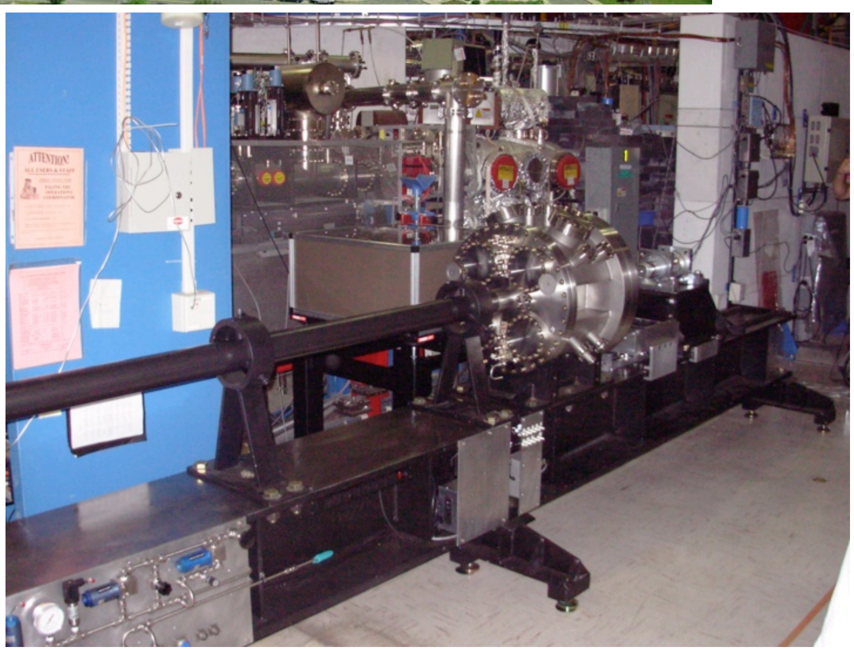
NSLS gas gun





- Multi-organizational effort
  - Extensive review by Brookhaven National Laboratory
  - U1 floor space from ExxonMobil
  - U2A beam access from Carnegie DOE Alliance Center
  - Optical relay and diagnostics by National Security Technologies
- Gun based on WSU design
  - Identical to Sandia DICE gun
  - 3” diameter projectiles
  - Velocities up to 400 m/s (1000 psi He wrap around breech)

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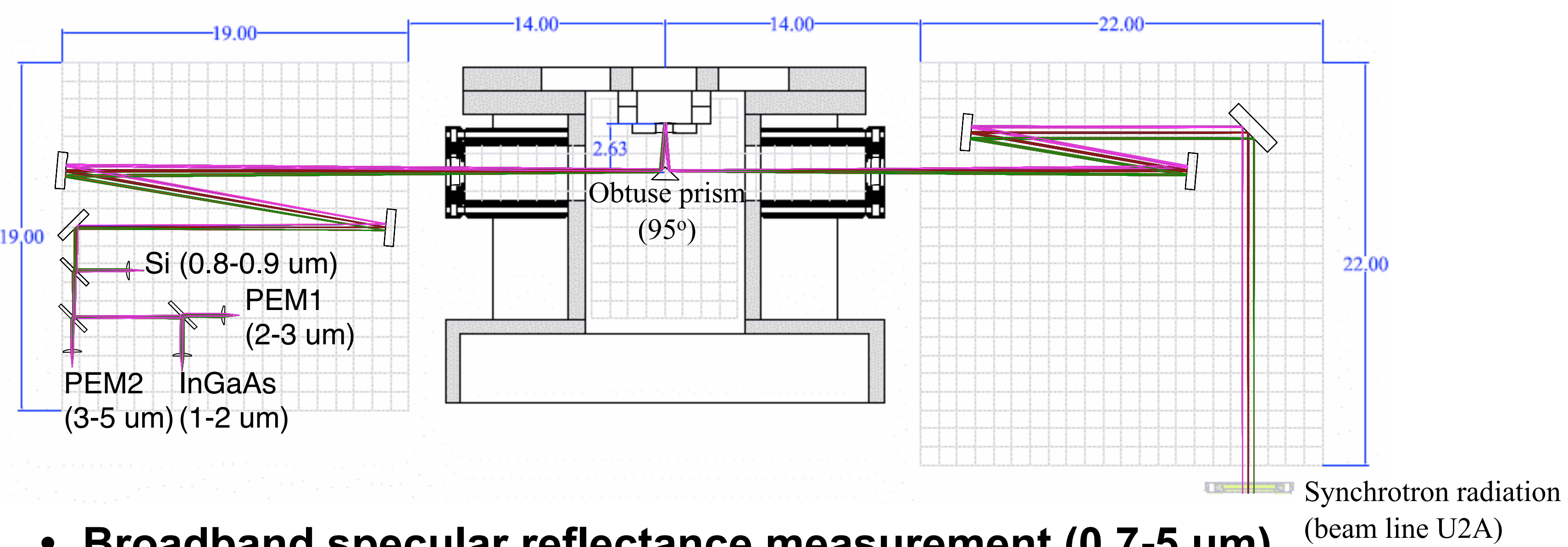
Specular reflectance measurement



- **Broadband specular reflectance measurement (0.7-5 um)**
  - **Wavelength range limited by sapphire (ports/windows) and gold mirrors**
  - **Mirrors avoid chromatic aberrations**
- **Fast detectors resolve individual synchrotron pulses**
  - **vis/NIR: standard photodiodes (Si, InGaAs)**
  - **mid-IR: photoelectromagnetic detectors (HgCdTe)**
  - **Upstream monitor (not shown) tracks pulse-variations**

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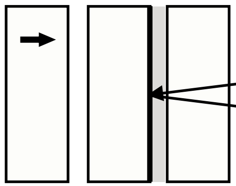
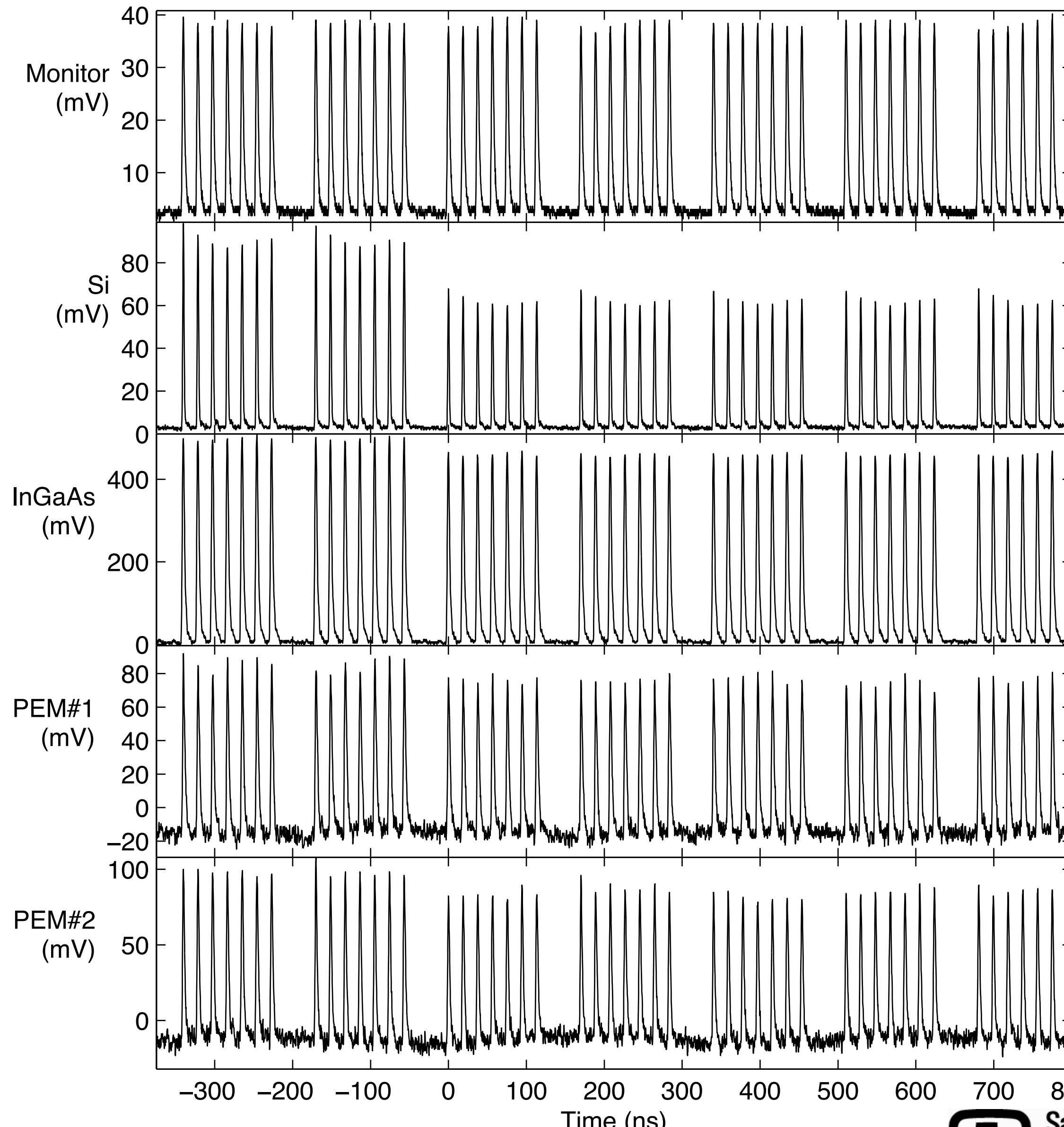
Aluminum reflectance test (8 GPa)

Standard configuration



- **Return signal drops when sample is shocked**
  - **Si: 32%**
  - **InGaAs: 7%**
  - **PEM1: 16%**
  - **PEM2: 13%**
- **Reflectance decrease vs epoxy extinction**
  - **Loctite 326 ←**
  - **AngstromBond**



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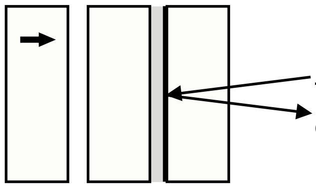
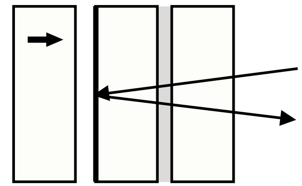
Epoxy has several effects

Reverse configuration

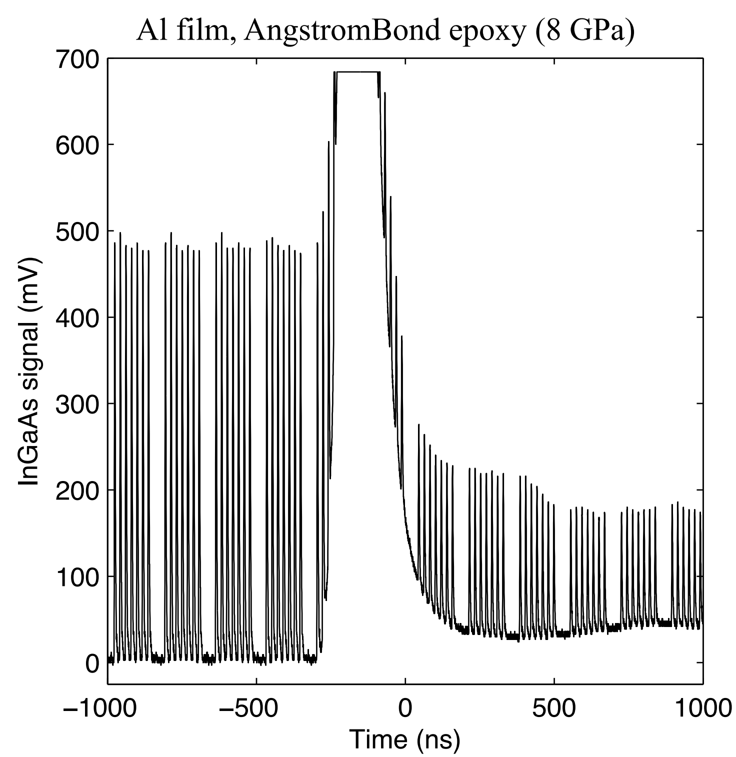


Separate configuration



- **No signal drop observed without epoxy transit**
- **Nearly constant reflectance reflectance observed to 8 GPa for:**
  - **aluminum**
  - **copper**
  - **chromium**
  - **platinum**
- **Higher stress states require further study**
  - **Faster impact systems under construction (LANL)**

Shocked AngstromBond <u>sometimes</u> emits light



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Summary

- Dynamic compression research using synchrotron radiation has begun
- At modest stresses and room temperature, metal reflectance is largely unchanged from the ambient state.
  - Ambient emissivity is a reasonable starting point for pyrometry
- Higher stress (>10 GPa) and temperature states require more study
- Epoxy raises several optical concerns:
  - Compression flash
  - Absorption (complicates interpretation)

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