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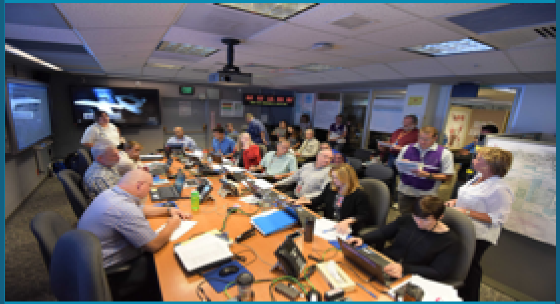
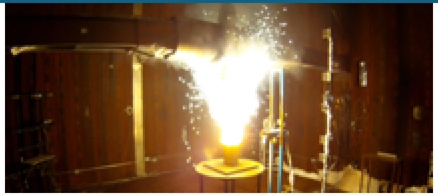
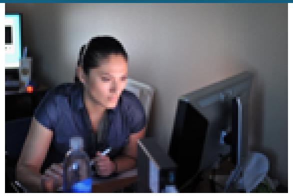
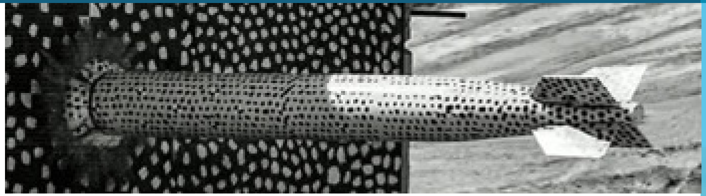


Infrared pyrometry on Z: possible but not easy







July 20, 2021

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U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

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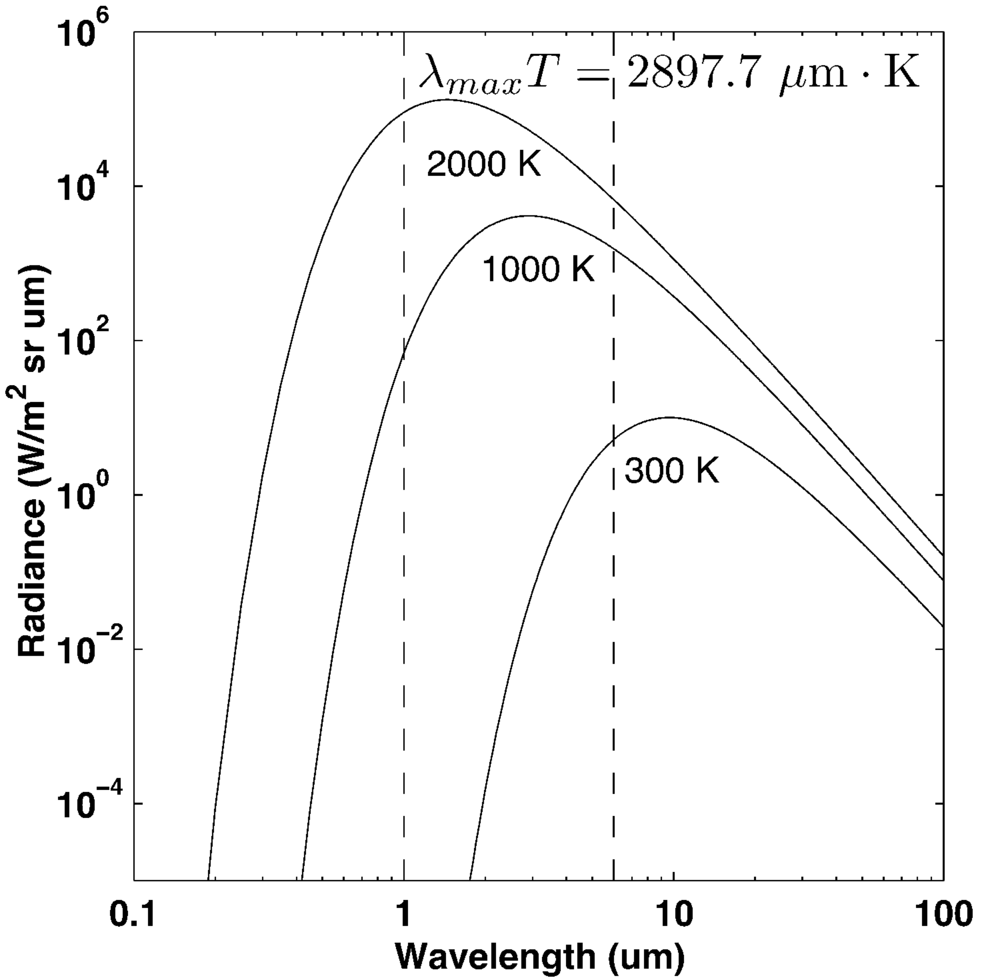
Pyrometry overview

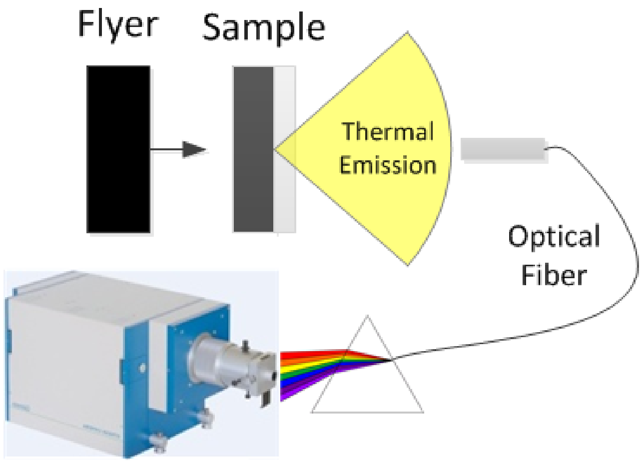
$$\frac{dL}{d\lambda} = \frac{c_1}{\lambda^5 \left[e^{c_2/\lambda T} - 1 \right]}$$

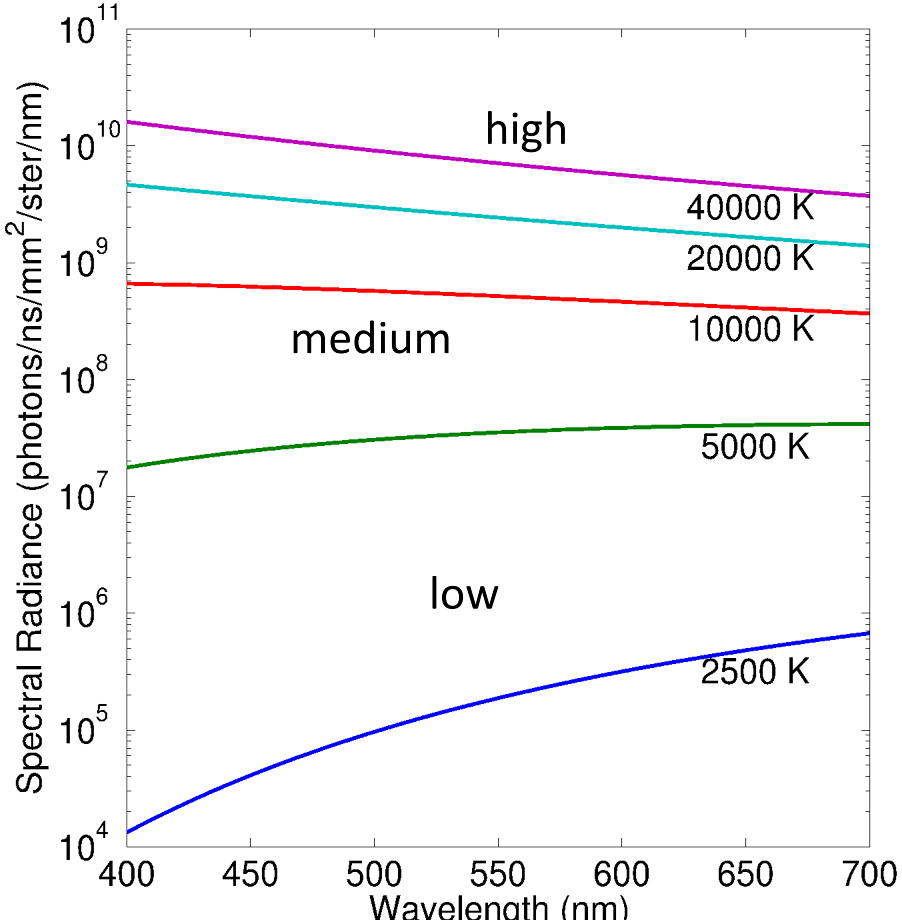
- Temperature limitations
  - Streaked visible spectroscopy (SVS)
  - Infrared pyrometry (800-2000 nm)
- Target requirements
  - Shock-ramp of an opaque sample
  - LiF window and special glue process
  - Stray light mitigation
- Diagnostic requirements
  - Imaging probe
  - Spectral coverage
  - Radiance calibration



Streaked visible spectroscopy

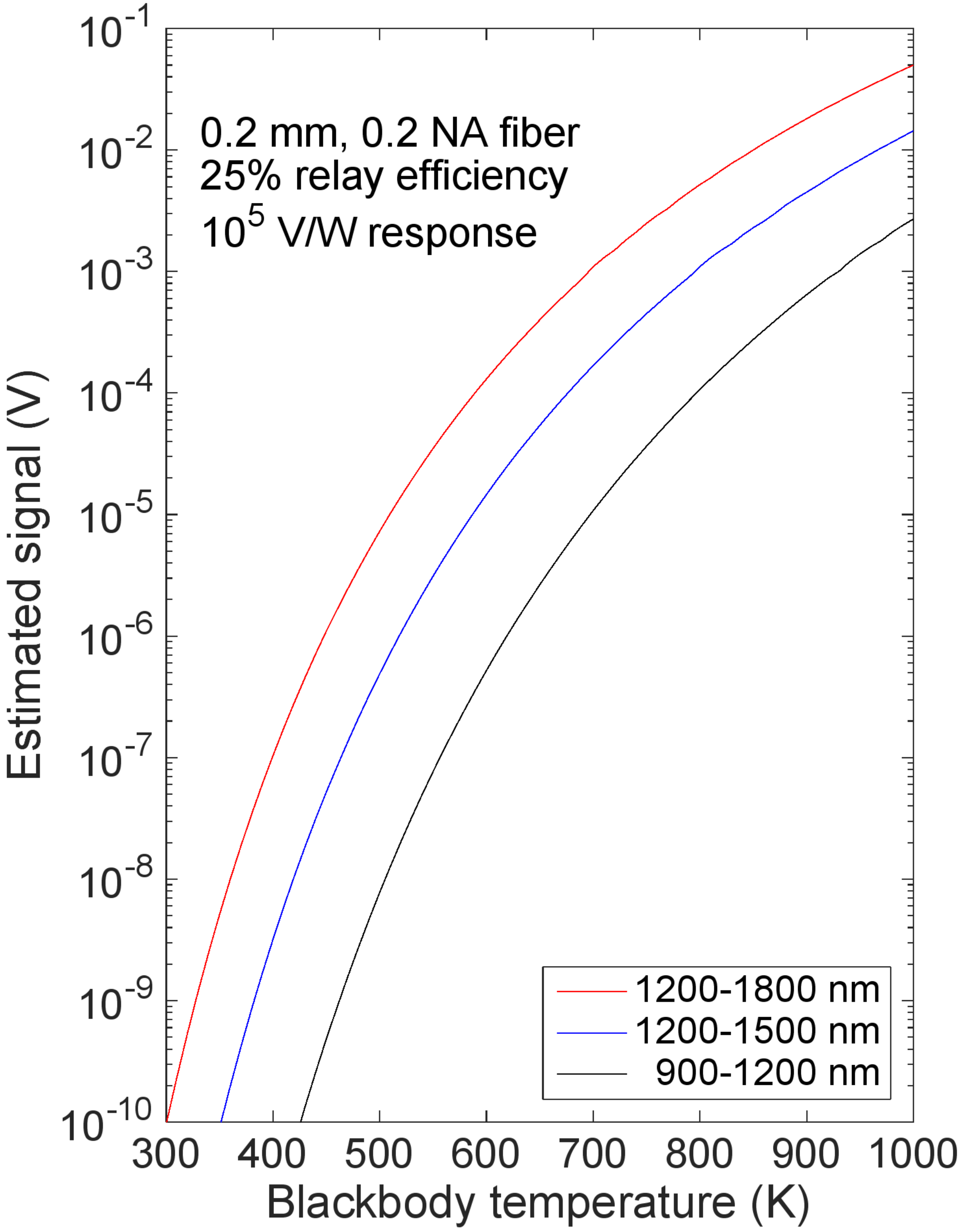
- High T (>20,000 K)
  - Minor spectral variation with T
  - Ample signal levels
  - Absolute calibration needed (?)
- Moderate T (<15,000 K)
  - Modest spectral variation with T
  - Reasonable signal levels
  - Shape-based analysis feasible
- Low T (<5000 K)
  - Significant spectral variation with T
  - Small visible signals
  - We might be able to go as low as 2000-3000 K





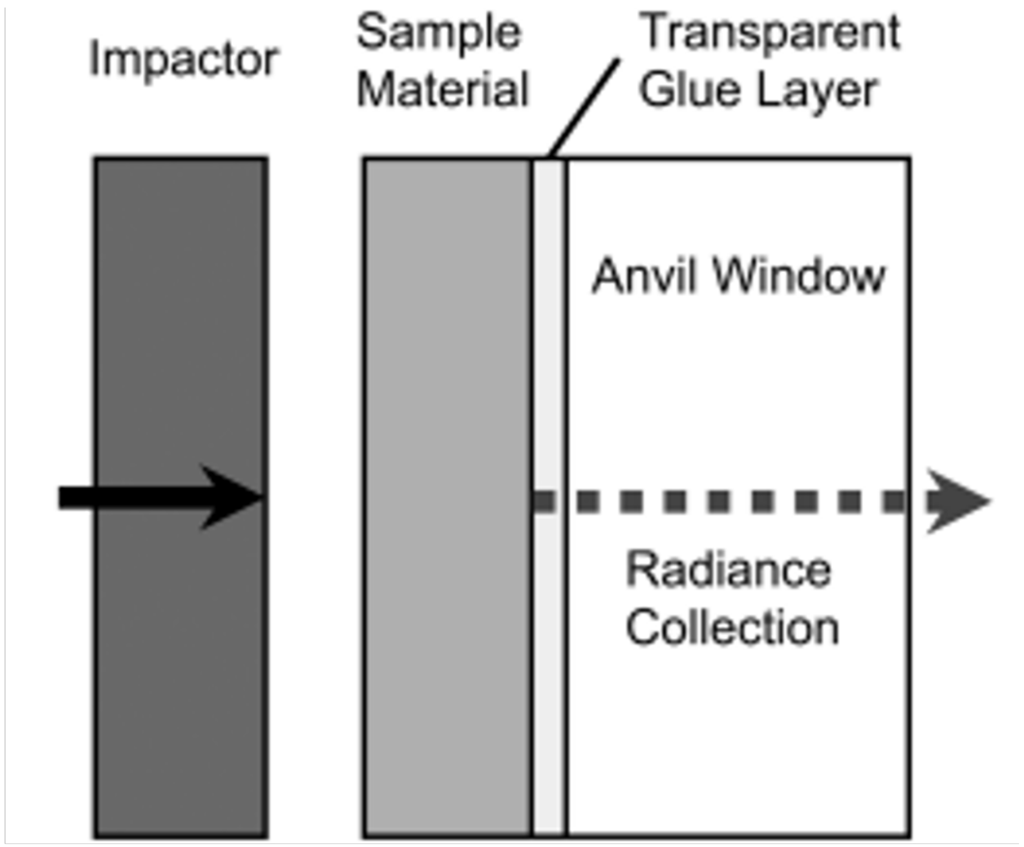
Pyrometry tricky <1000 K

- Intrinsically limited by sample emission
  - Temperature and emissivity
- >2000 nm measurements are impractical at Z
  - ~50 m fiber run
  - Silica is the only realistic choice
- Many fast pyrometers won't register blackbody <700-800 K
- Without a steady temperature (~100 ns), pyrometry in this range is largely doomed
  - Ramps aren't steady!

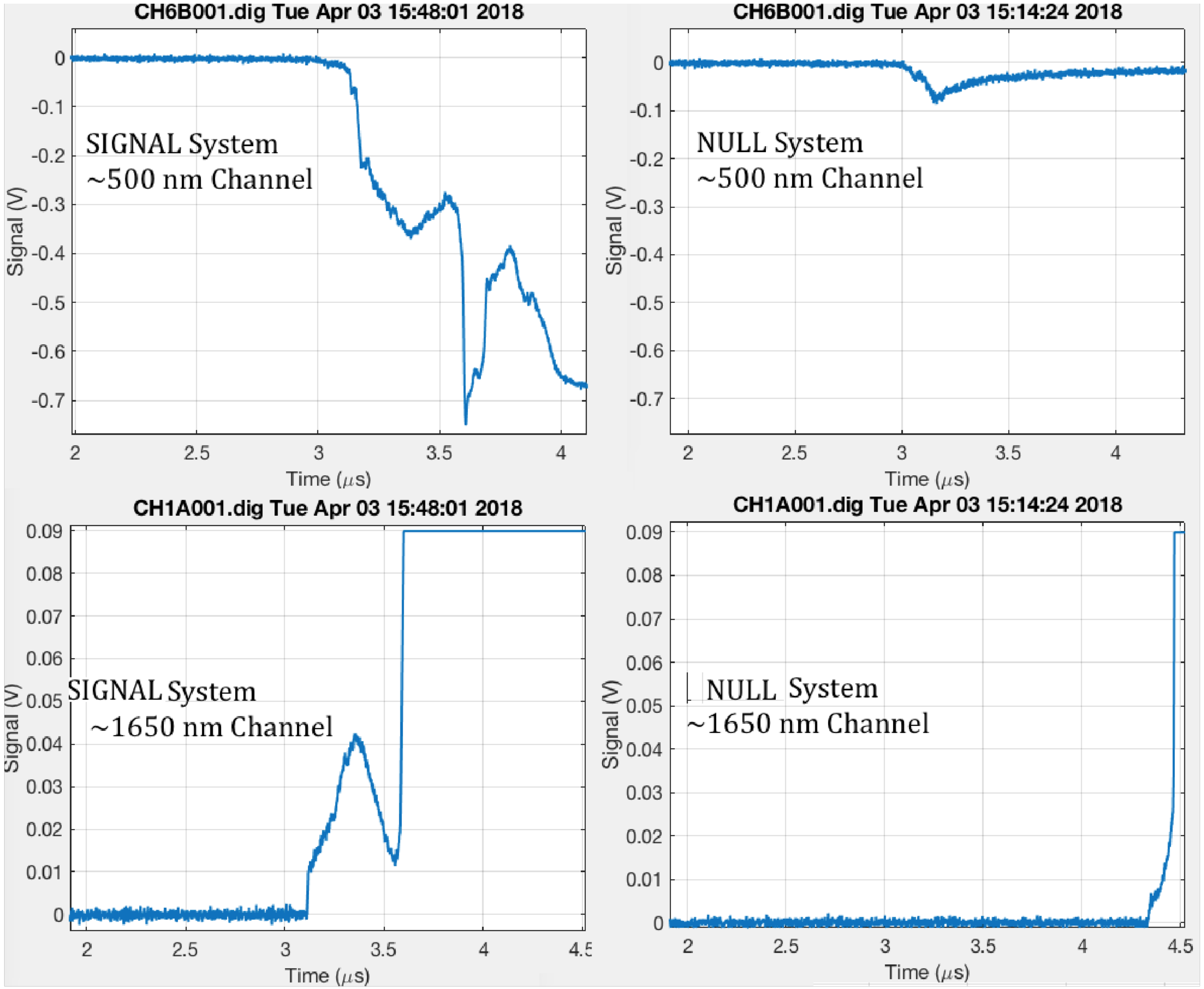


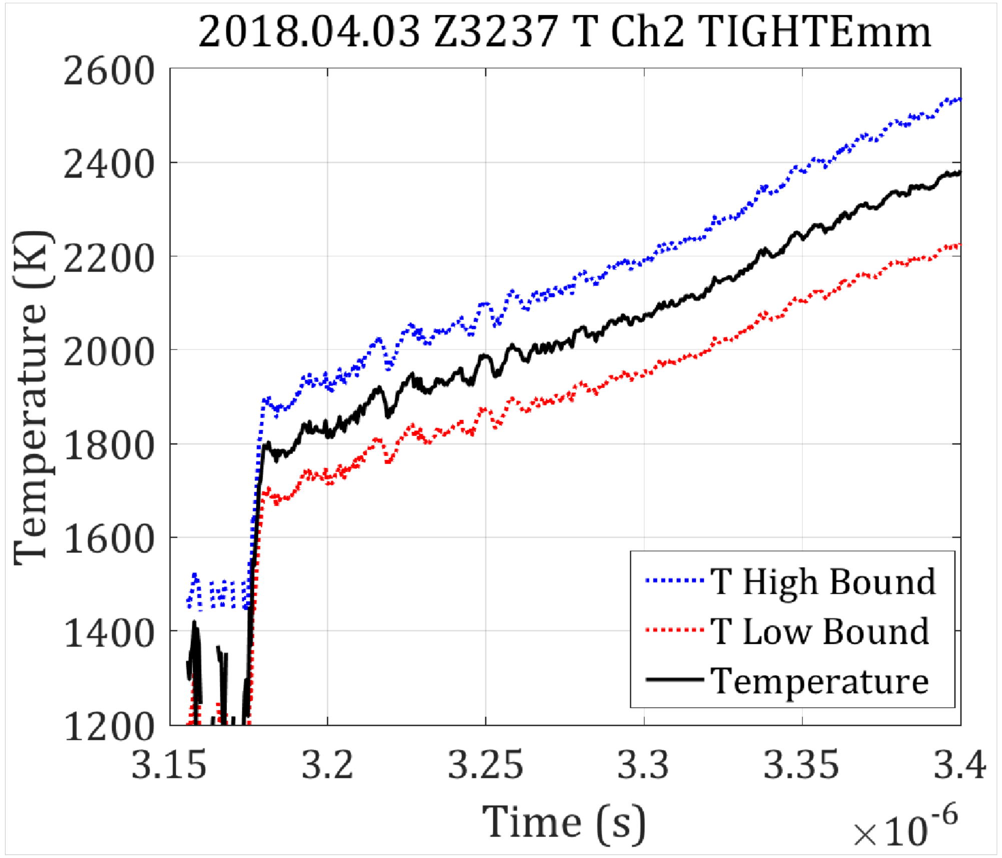
Infrared pyrometry can work on Z

- Transmitted-wave configuration
- Shock-ramp where T_s >1000 K
- 1100-1700 nm photodiodes
- Coaxial loads
- Extensive masking and light management



Example signals (LANL pyrometer)

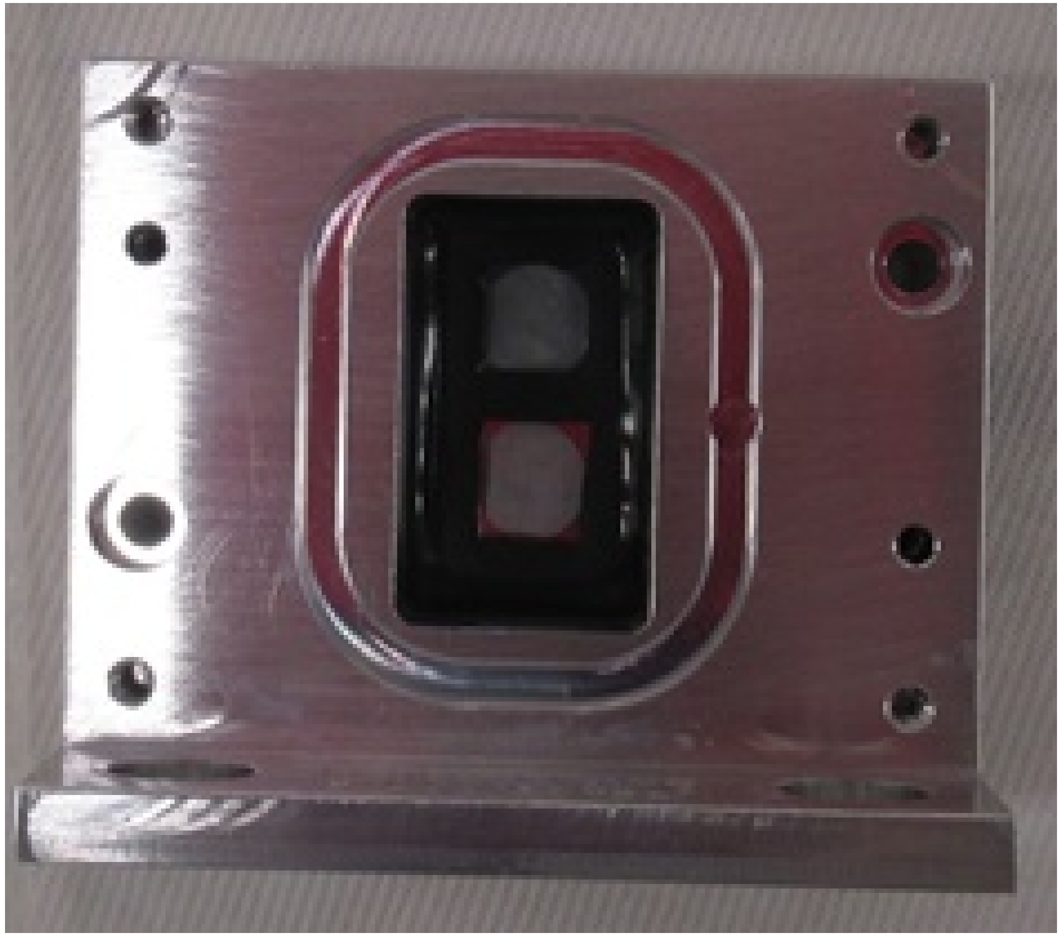


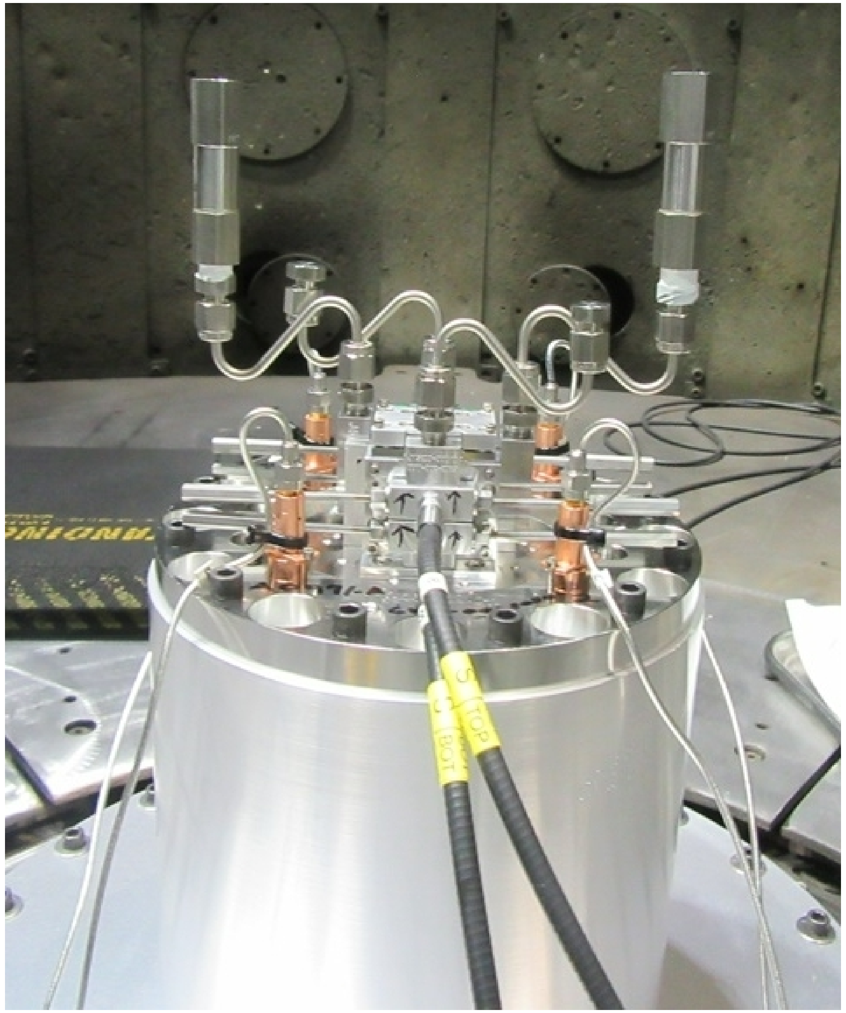


1060 nm (+/- 139 nm)
20-40% emissivity

“Stubby” coaxial panel

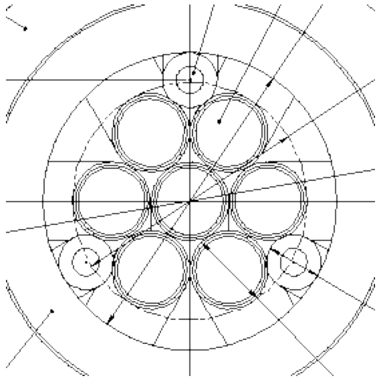
- Two samples per panel



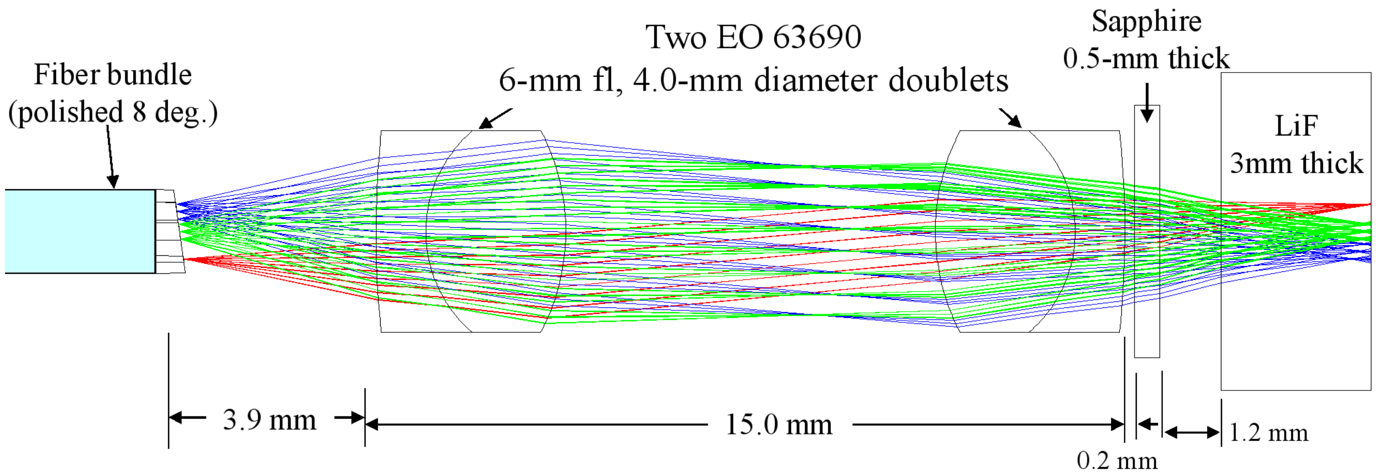


LAO imaging probe

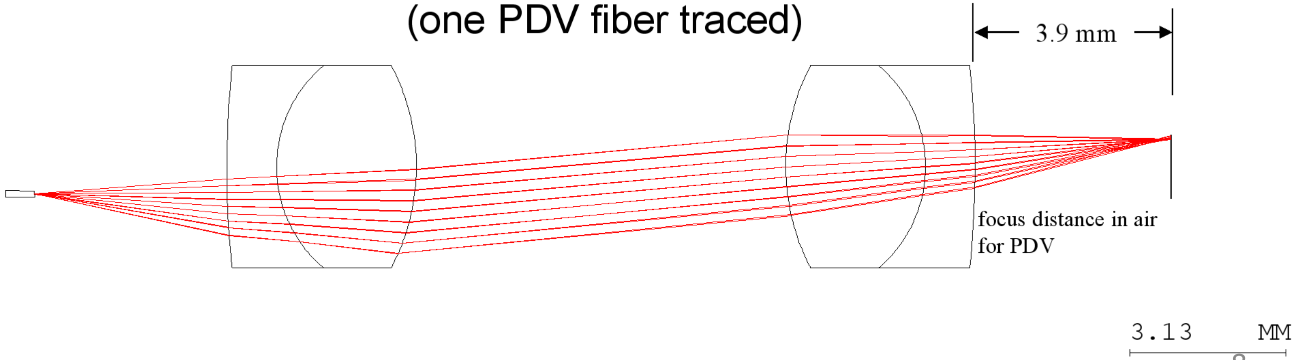
- Seven radiance fibers
  - 300 um core
  - Low-OH silica
  - Connected to 200 um runs
- Three PDV fibers
  - 8° polish
  - Must be optimized (imperfect)
- No VISAR at this time
  - Wrong configuration
  - Avoid ~kW stray light



(one PDV and two Radiometry fibers traced)



(one PDV fiber traced)



Diagnostic overview

- InGaAs avalanche photodiodes
  - 400 MHz bandwidth
- Standard bands
  - 50 nm FWHM
  - Centered at 1125/1225/1325/1425 nm
  - OD 8 blocking
- 10+ bit digitizers
  - ~1 GHz bandwidth
- Capacity
  - 8 channels standard
  - 16+ channels w/ LANL support
- Blackbody radiance calibration (!)

Infrared pyrometry fielded next to VISAR (might move to SVS)
Each channel gets its own fiber

Maximum working pressure is unknown

- Sample viewed through window and glue
  - Both have to remain transparent and cannot emit light of their own

- Lithium fluoride windows transparent to ~150 GPa shock
  - Light emission unknown

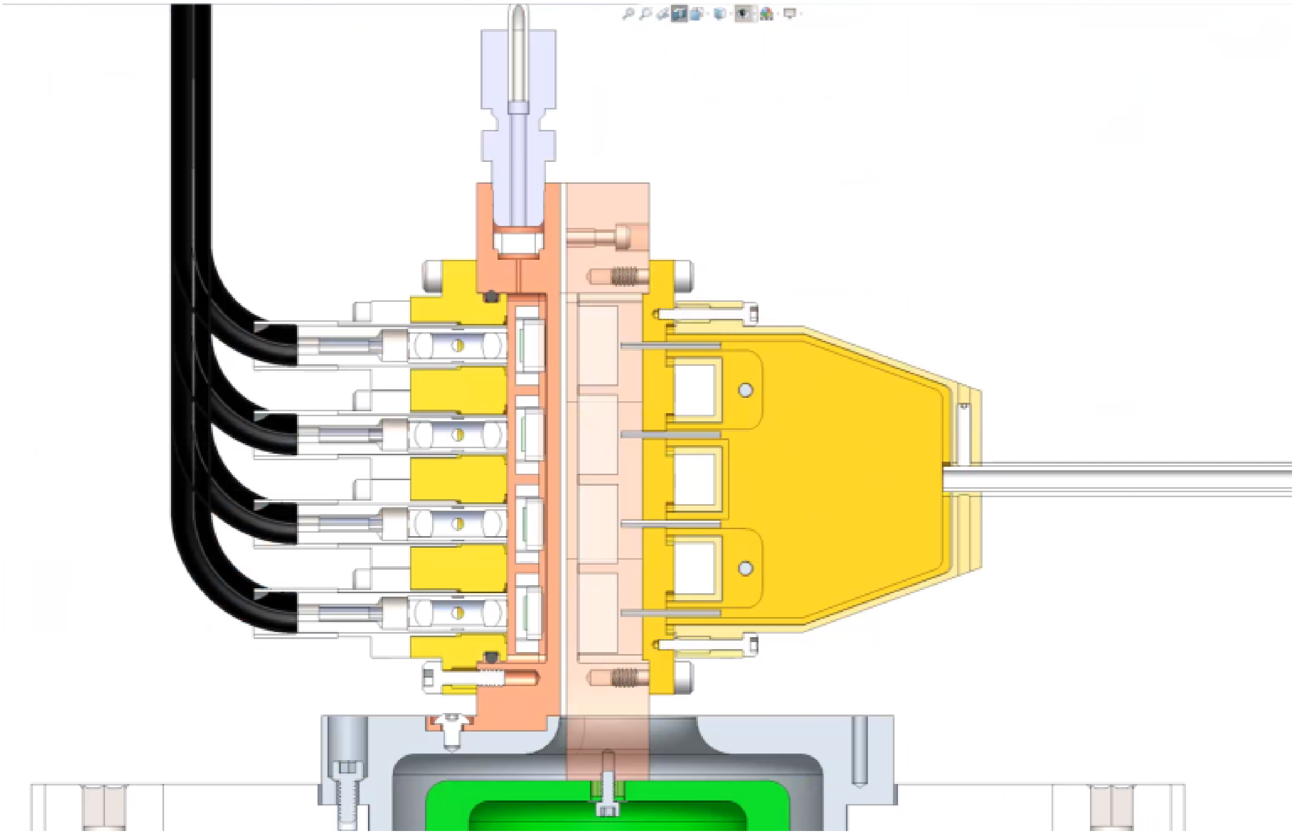
- Glue limits are unknown
  - LANL knows that Loctite 326 is OK to 45 GPa
  - LLNL reports emission (600-700 nm) at 73 GPa
  - Adhesive emission is poorly understood

Work in progress

- Background mitigation
  - Visible light generated in fiber
    - Fluorescence or Cherenkov?
  - Strip line probably worse
  - In situ null measurements

- First dedicated strip line shot (A1028a, October 2021)

- Reflectance ratio measurements
  - Constrain emissivity



Summary

- Infrared pyrometry can measure <2000 K temperatures on Z
  - Strict target and diagnostic restrictions
  - Non-standard target assembly (masking, painting, glue)
  - Custom fiber feed throughs, probe build/optimization
  - Equipment has to be moved in/out of DAS
  - Time-consuming radiance calibration (~3 hours on shot day)

- Diagnostic cannot be added to a shot request by simply checking a box!
  - Discussion must begin before final design submission
  - Limited MSTS diagnostic support in FY22