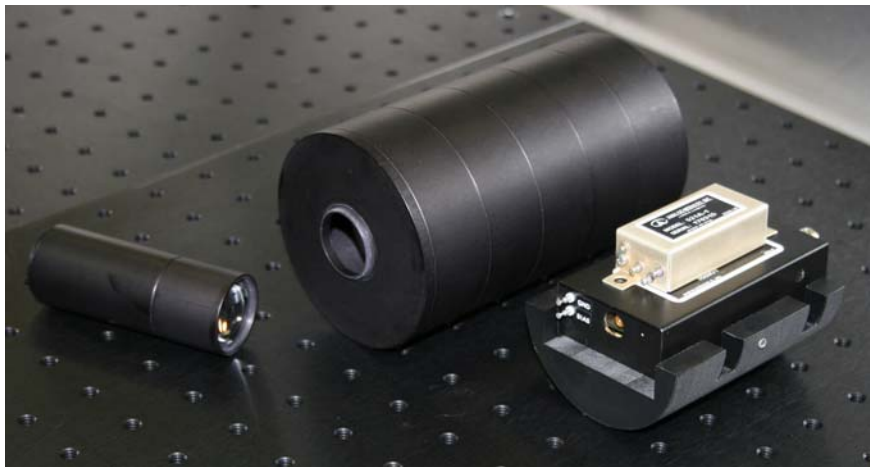
Detailed Design of a Six-Color Optical Pyrometer and Subsystem Testing Results



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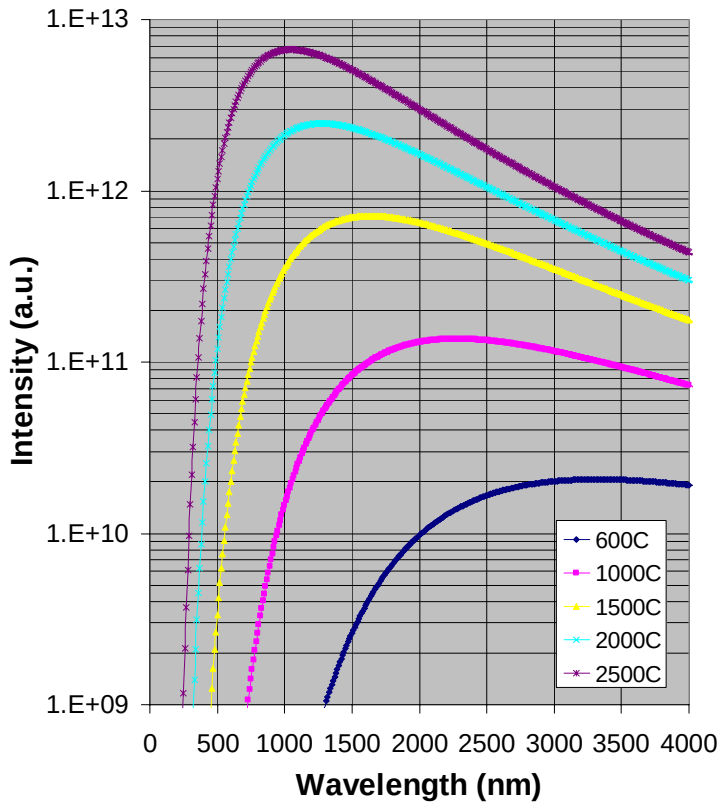
We have completed the final design of our new 6-color optical pyrometer

- Principles of operation
- Issues with 2-color thermometer
- Selection of detectors
- Selection of optics
- Final optical layout
- High-temperature furnace for calibration
- Schedule / future plans

Principles of operation

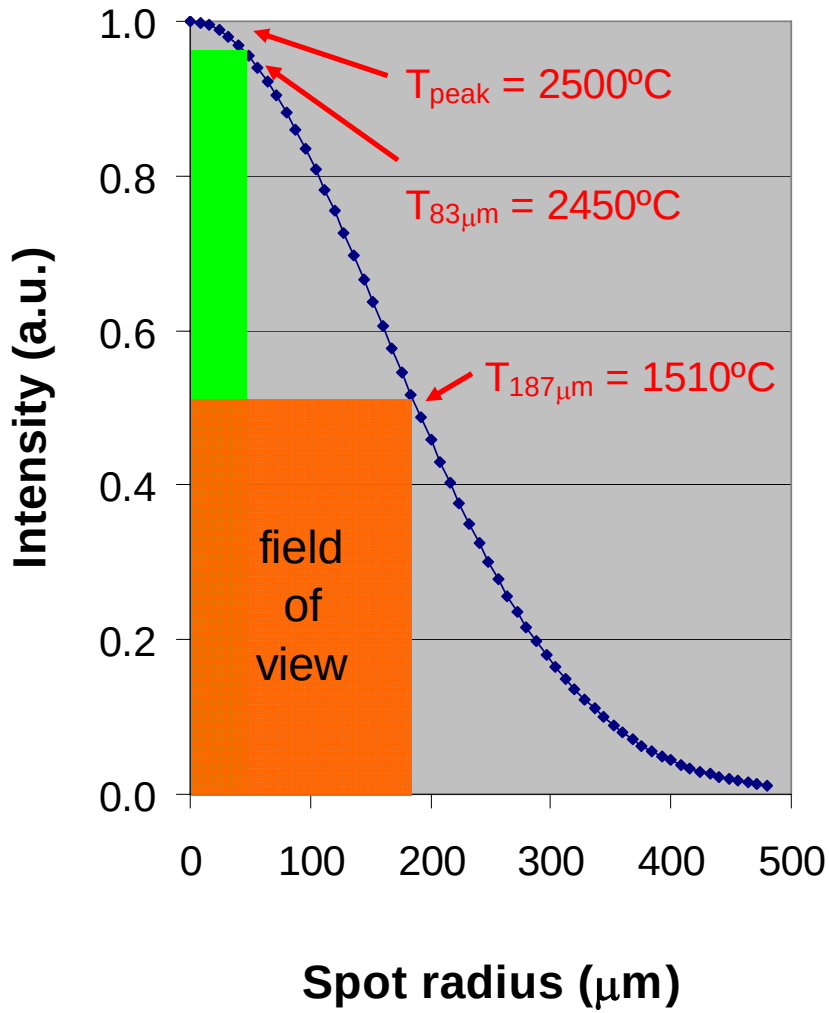
- Bodies emit radiation according to their temperature (Planck's law)
- If we had a blackbody or two closely spaced wavelengths, could neglect emissivity
- We cannot use a relatively slow broadband source (e.g., flashlamp) to measure ***in-situ***
- Approach is to measure in side chamber with steady-state furnace

$$I(\nu,T)=\frac{2h\nu^3}{c^2}\frac{1}{e^{\frac{h\nu}{kT}}-1}$$



Issues with 2-color thermometer

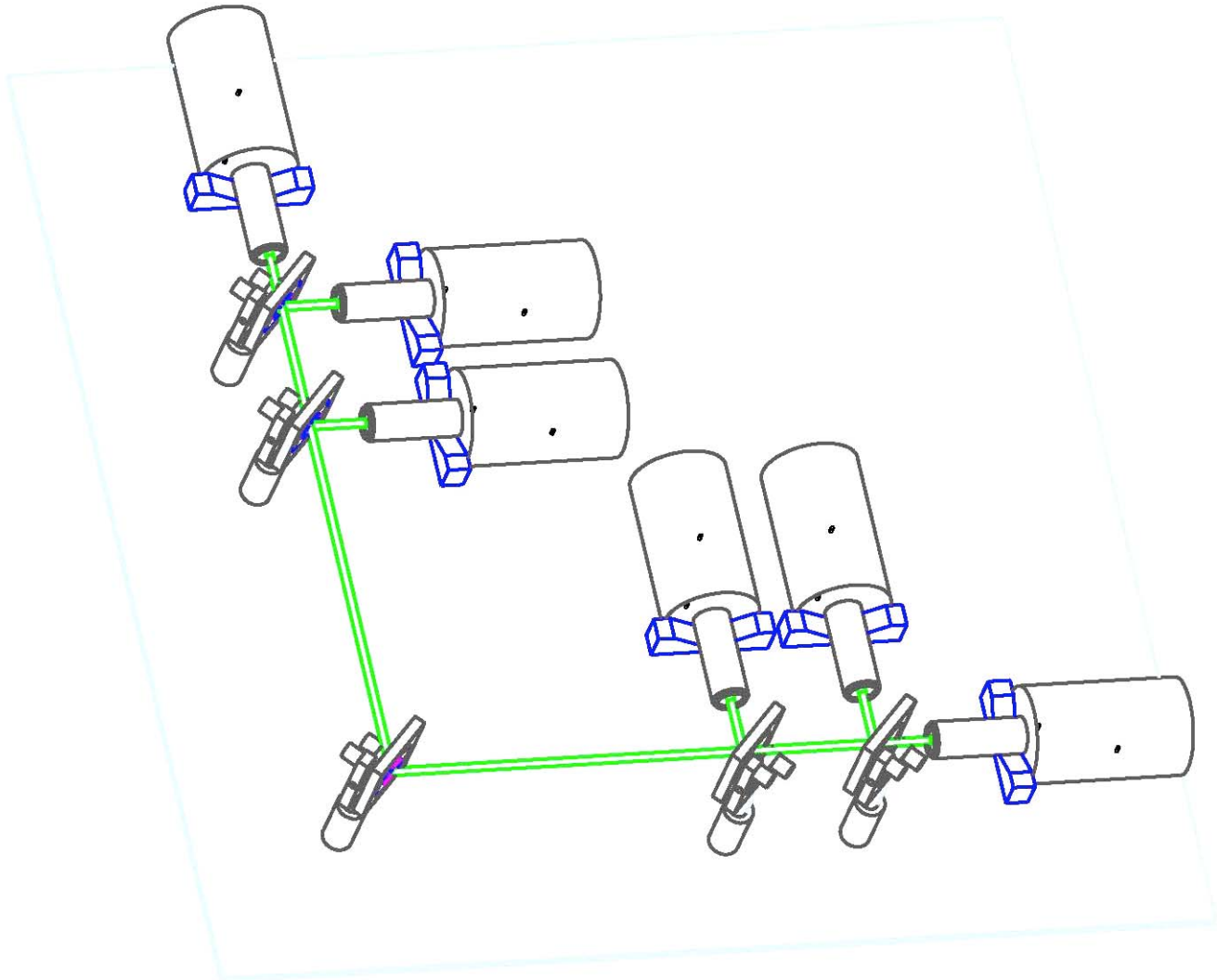
- Wavelengths (700, 800nm) poor match for our plasma
- Gain from PMTs insufficient given small spot size and plasma emission
- Putting it all together, dealing with <200 photons/ns in each channel → very challenging!
- Spot size was so large that we had significant temperature variation within the field of view



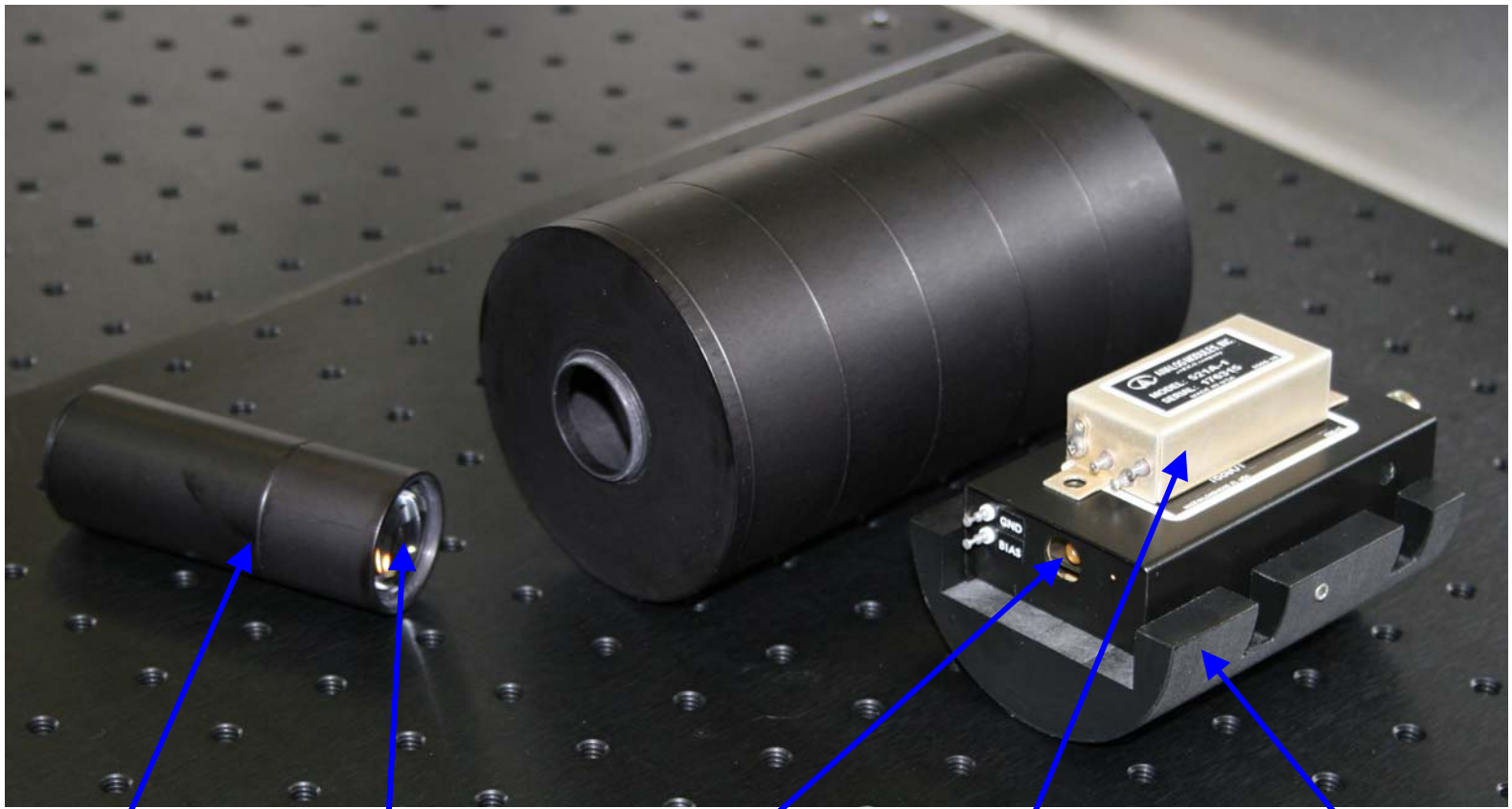
We selected detectors from Analog Modules, Inc.

- Avalanche photodiodes (APD) offer:
  - better speed & sensitivity than PINs
  - Higher quant eff. than PMTs
- Our APD specifications:
  - Si APD (0.6-1.0 μm):
    - ~1ns
    - 40-80 A/W at our λ's
  - InGaAs APD (1.1-1.7 μm):
    - ~3ns
    - 8-11 A/W at our λ's
- High bandwidth, low noise amplifiers (100fW/√Hz)

CAD model of pyrometer layout



Each detector is housed within an enclosure



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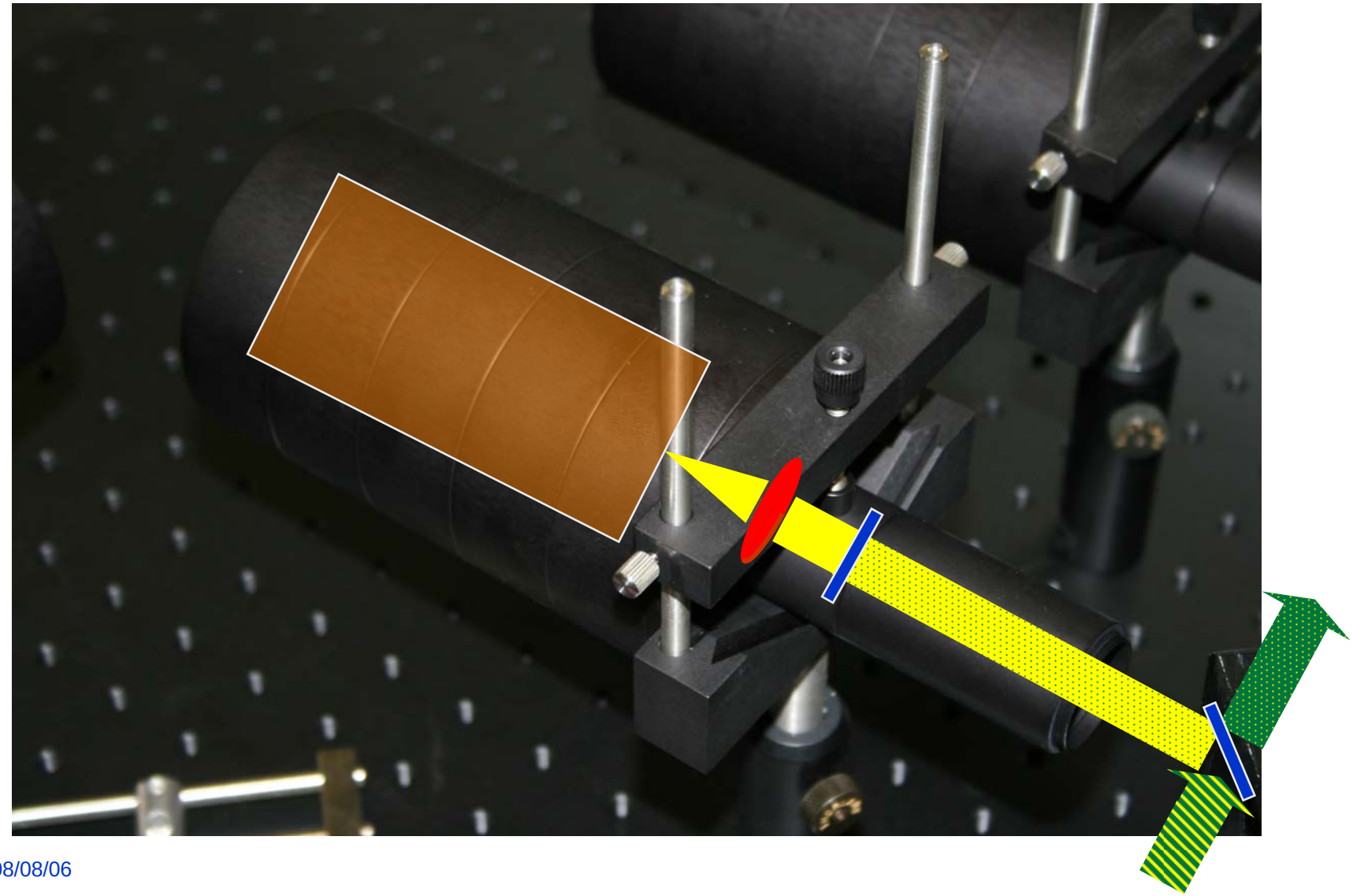
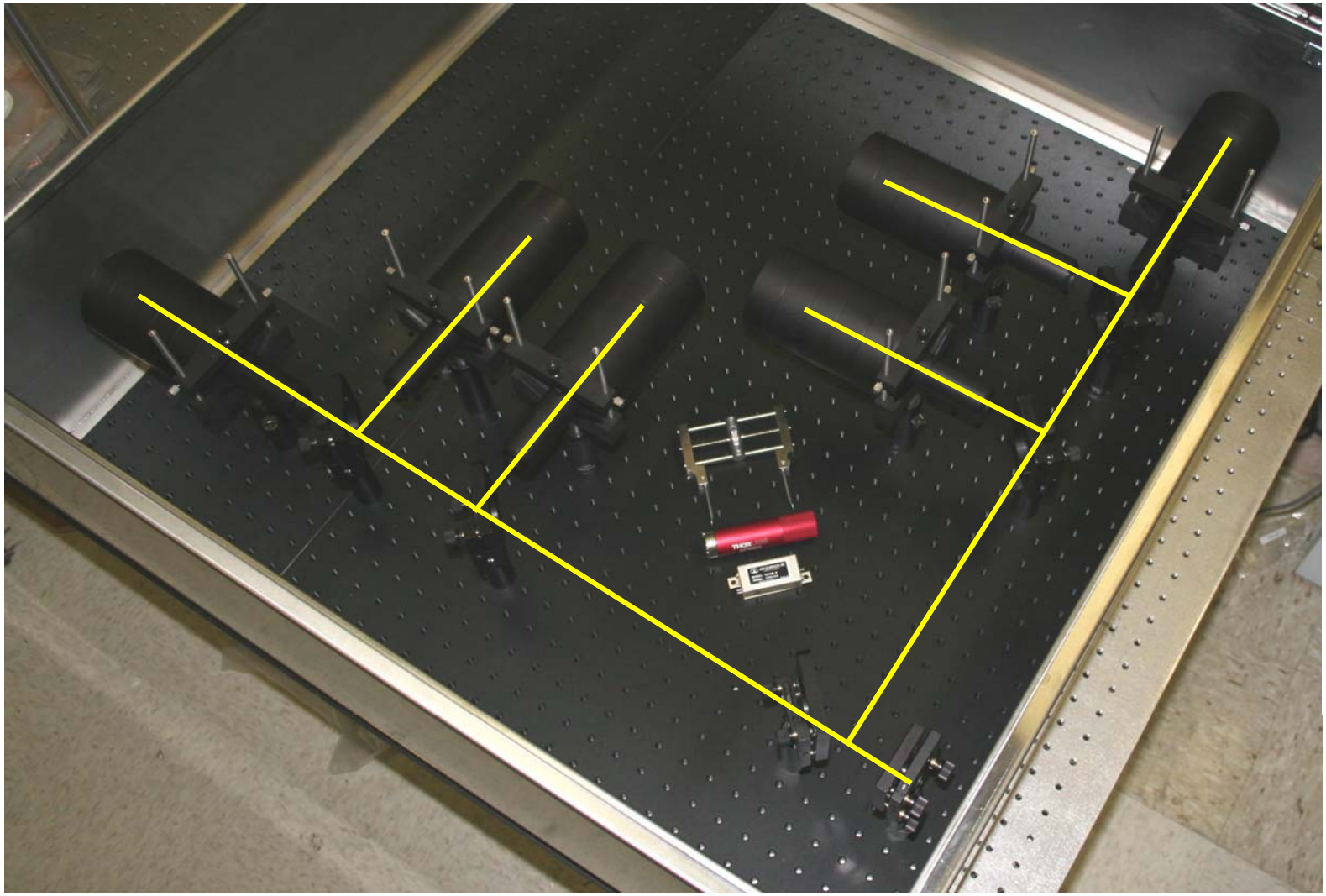


Our layout will look something like this



Selection of optics

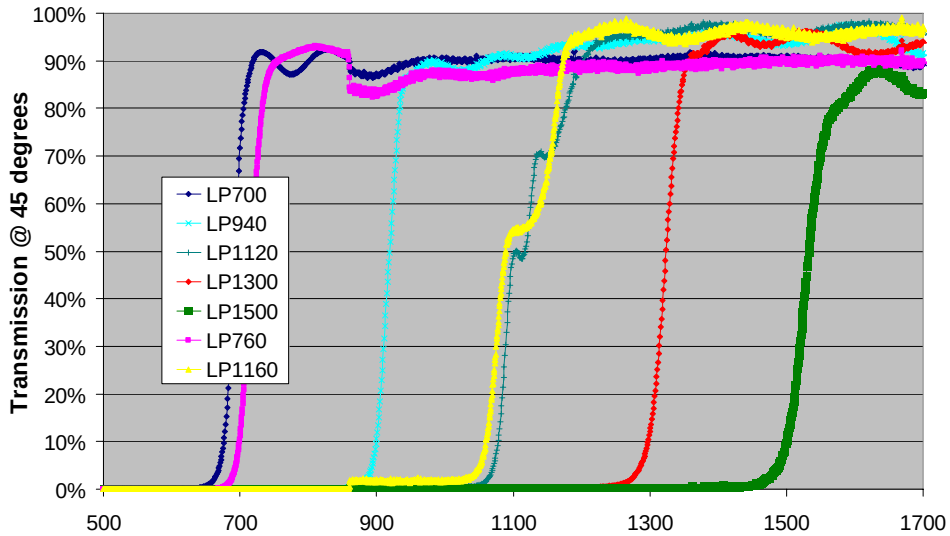
- Simple beamsplitters work, but with significant signal loss: three 50/50 splitters send only 12.5% to each detector

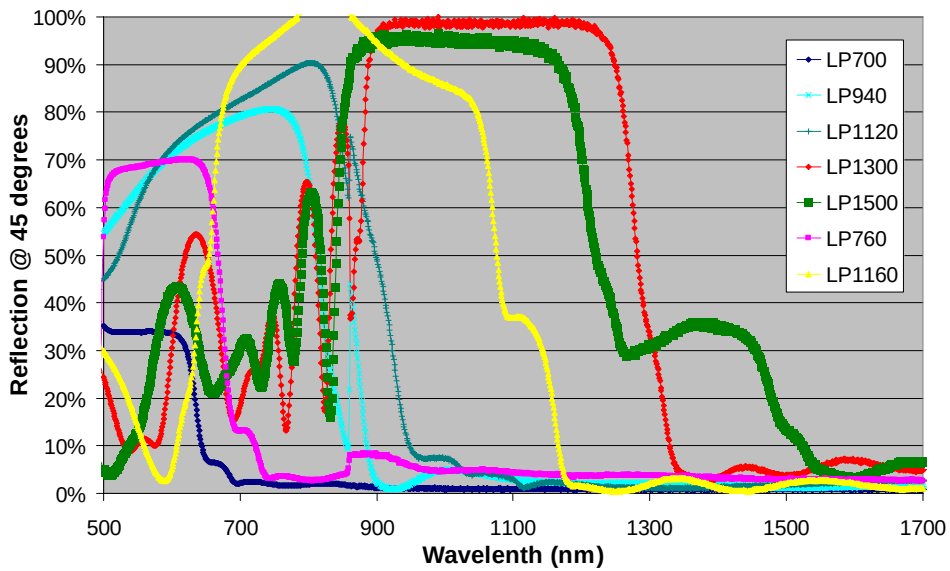
- Dichroics can separate the light more efficiently:
  - Difficult to find broadband dichroics that match our desired λ's
  - Custom runs can be done, but designs still difficult and expensive (quoted $2-3K for run producing ~10 parts or ~$15K for run producing 100's of parts)

- Working with Spectrogon, Inc. and using some of their longpass and shortpass filters: luckily, rejection mode is often by reflection, not absorption

Selection of optics

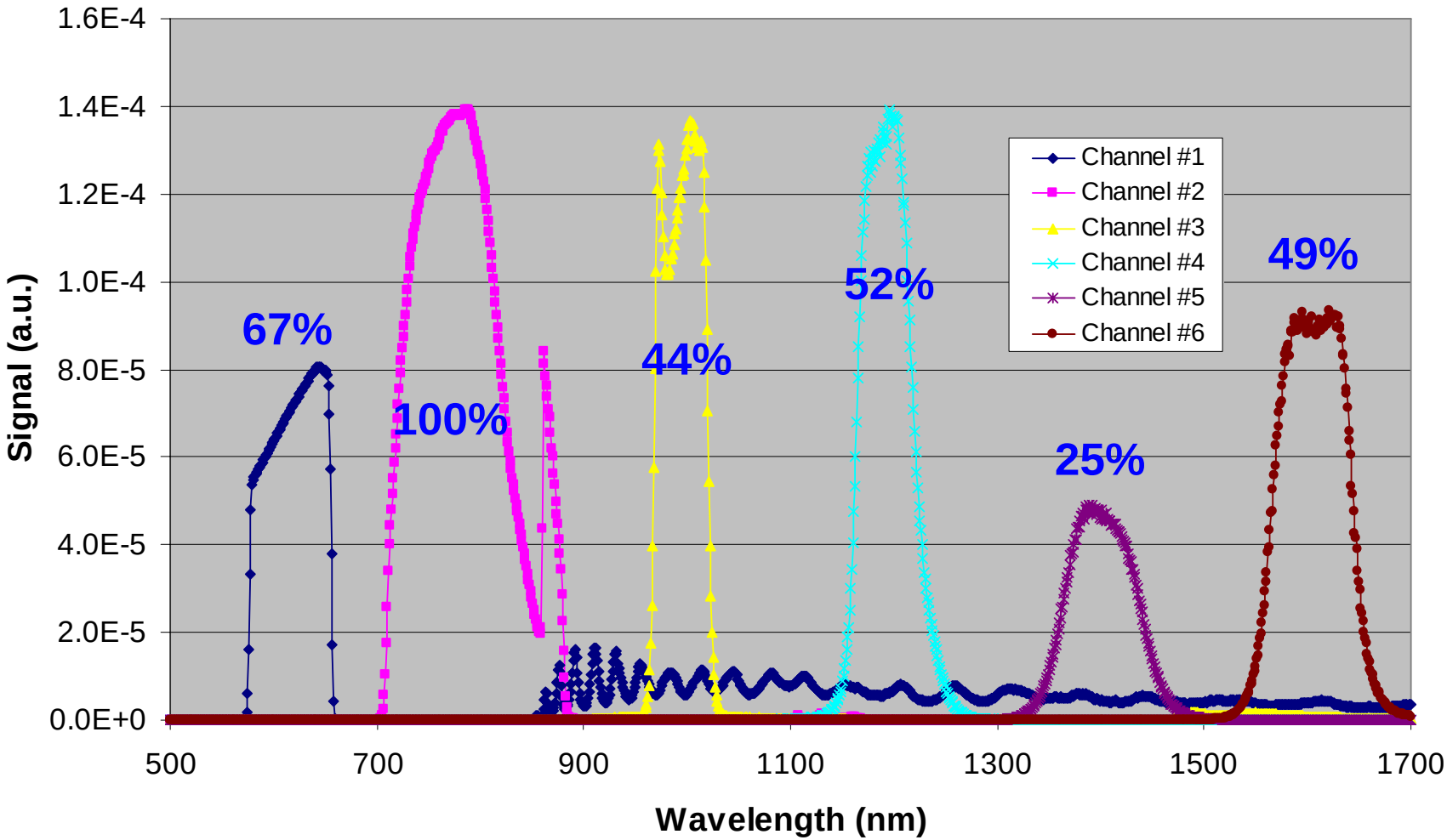
- We purchased 11 longpass and shortpass filters from Spectrogon (total cost ~$2K) for testing as dichroics
- Omega, Spectrogon, and Semrock bandpass filters evaluated
- Layout manually determined to give acceptable performance
- System optimization program is being tested – may alter final layout





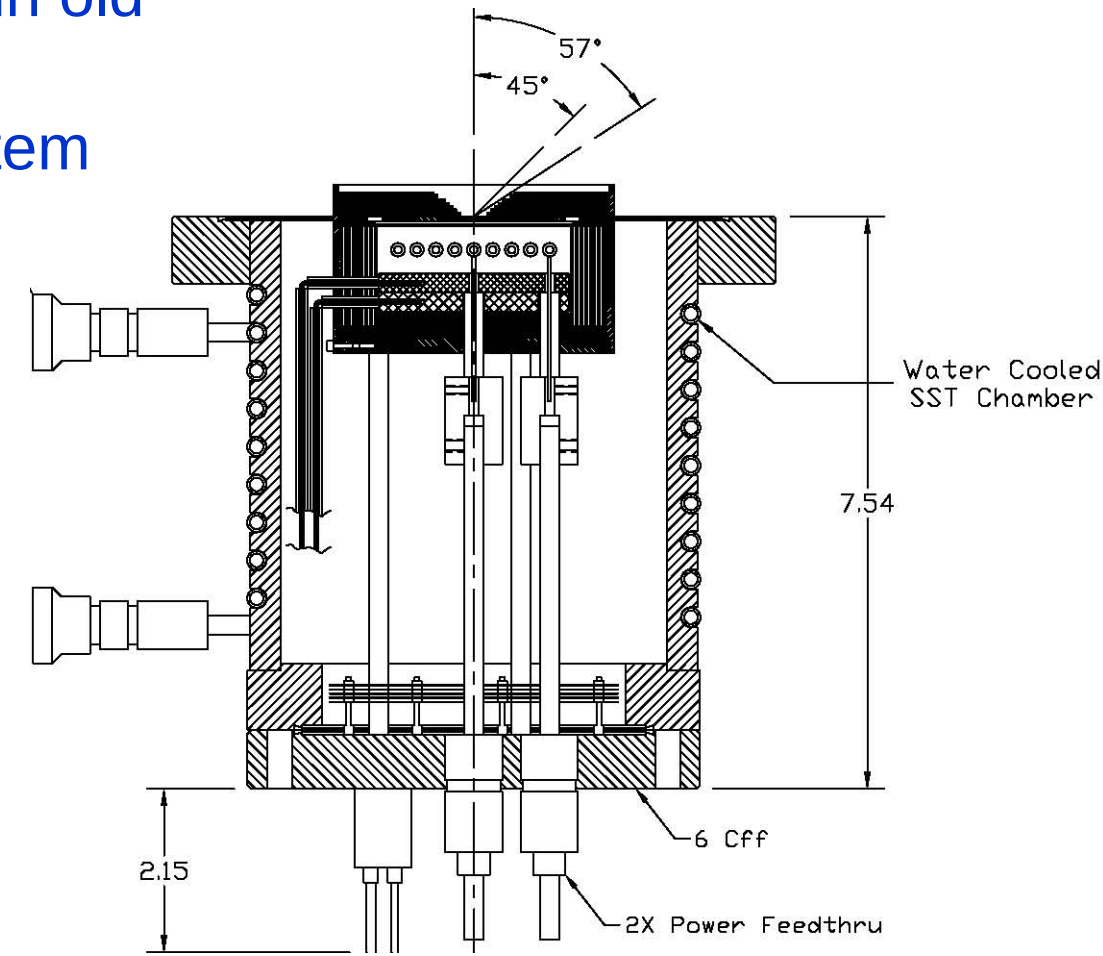
A placeholder design has been determined

Relative signal strengths of the six channels



HeatWave Labs is building us a high temperature furnace

- Furnace will be used within old XAPPER chamber as a pyrometer calibration system
- Capable of holding 1” sample at **2500°C**
- Provides viewing of the sample at up to 57°
- Due for delivery at end of August (revised)



High temperature furnace, (Cont'd.)

- The actual tungsten sample will be viewed within the calibration chamber
- Will use the pyrometer head and collect calibration data
- After cooling, sample moved to XAPPER chamber along with pyrometer head for time-dependent measurements

Schedule / Future plans

- Design optimization underway – completed in mid-August
- Final layout to be mounted 3rd week of August
- Sample furnace due for delivery end of August
- First light (furnace) 2nd week of September
- First data runs end of September
- Spend October hitting samples