Comparison of Proposed First Wall Experiments

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Goal

- Assess the ability of various proposed experiments to mimic HAPL conditions

Comparing Experiments

- Which available experiments can be used to test materials for HAPL?
  - XAPPER
  - Z
  - RHEPP
  - UCSD Laser
  - Infrared
- Match surface peak temperature and then compare spatial distributions

Parameters

Experiment	Type	Energy (keV)	Max Fluence (J/cm^2)	Approx. Depth (microns)	Pulse Width (ns)
RHEPP	Ions	750	7	1-10	100
Z	X-Rays	0.8-1.2	3000	1-2	6
XAPPER	X-Rays	0.1-0.4	7	1-2	10-30
UCSD	Laser		0.7	0	8
Electra	electrons	500	2	100	100
Infrared	Infrared		q=10 MW/m^2	0	>10 ms

Initial Approach

- Consider three cases using analytical results
  - Surface heating
  - Volumetric heating which decays exponentially
  - Uniform volumetric heating over a fixed depth
  - Initial results are for semi-infinite solids, so the results are only valid for short pulses

Constant Fluence

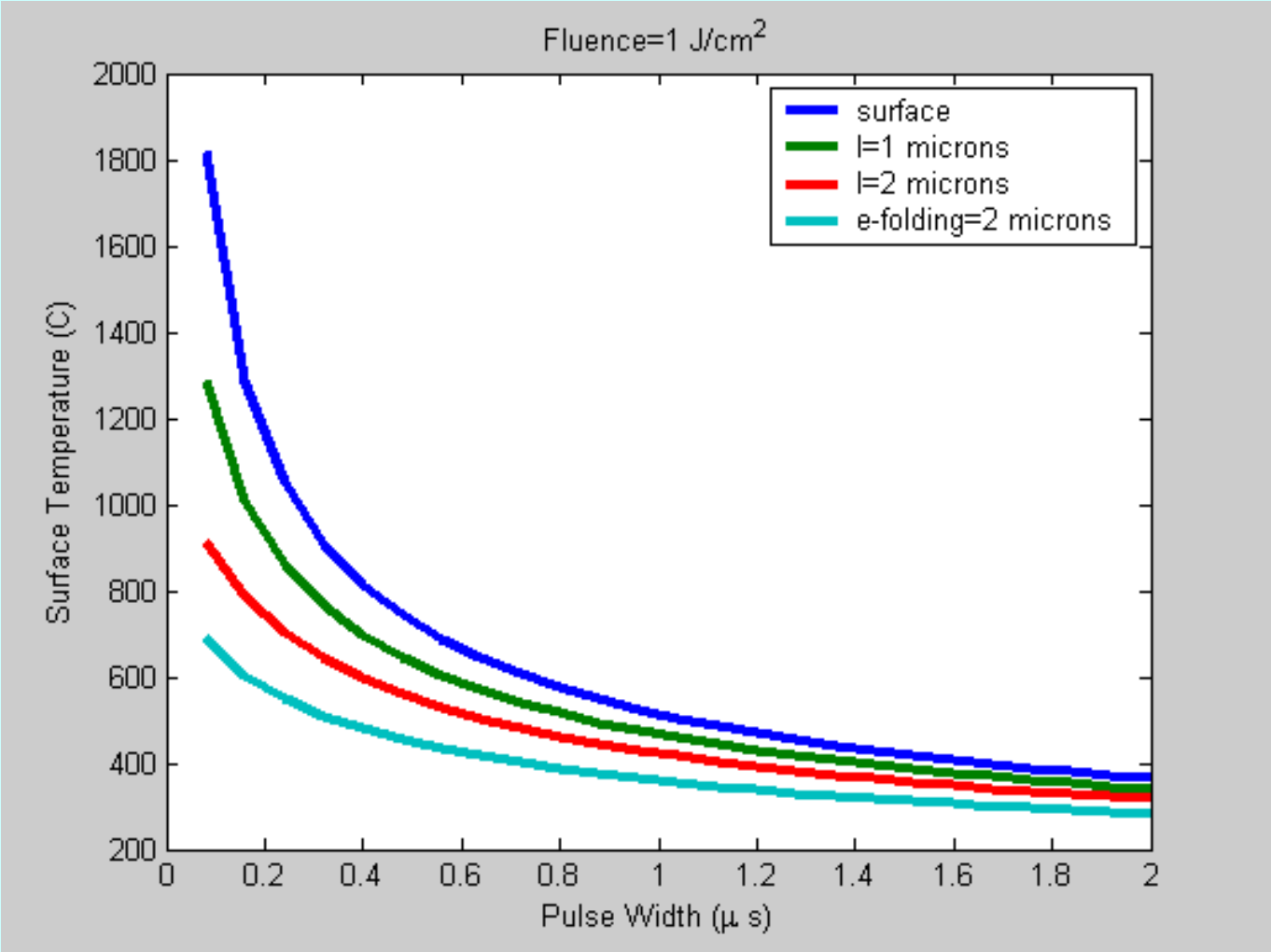
surface $$T_s = \frac{2F}{k}\sqrt{\frac{\kappa}{\pi t_p}}$$

exponential $$T_s = \frac{2F\sqrt{\kappa}}{k\sqrt{\pi t_p}} - \frac{F}{\beta k t_p}\left[1 - \exp\left(\beta^2 \kappa t_p\right) erfc\left(\beta\sqrt{\kappa t_p}\right)\right]$$

uniform $$T_s = \frac{F\kappa}{lk}\left\{1 - 4\, i^2 erfc\left(\frac{l}{2\sqrt{\kappa t_p}}\right)\right\}$$

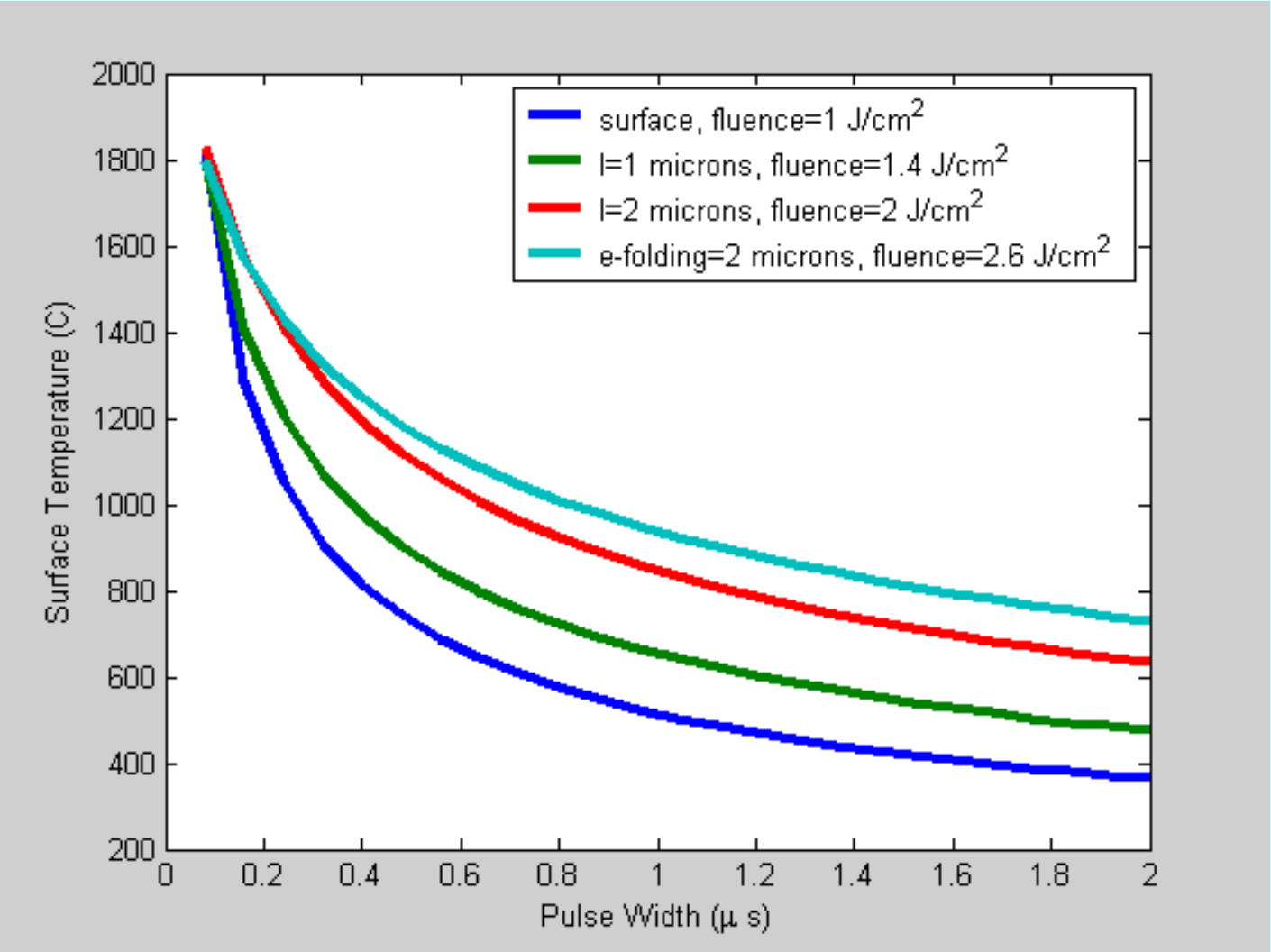
Scaling of Temperatures

Surface Temperature vs. Pulse Width for Fixed Fluence

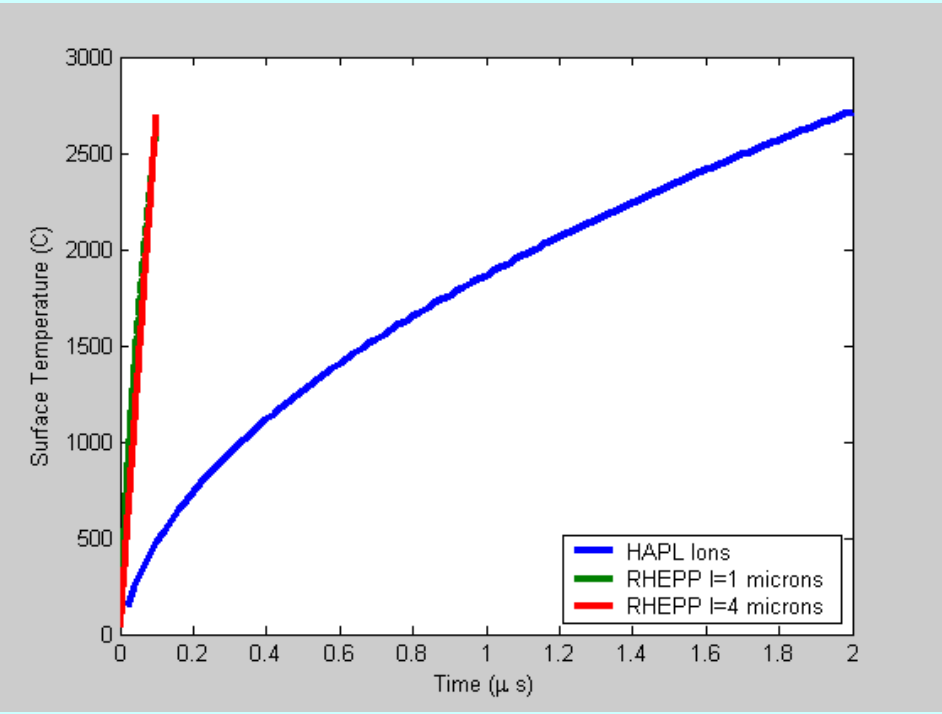


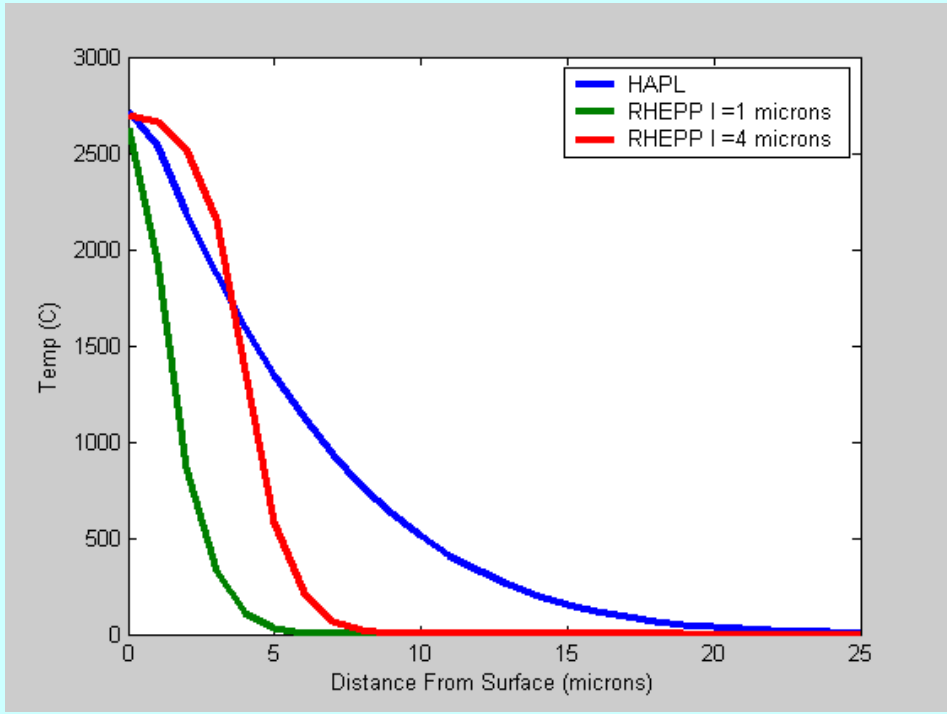
Scaling of Temperatures

Fix Surface Temperature at 80 ns Pulse Width



RHEPP





2.2 J/cm^2, 100 ns for 1 micron depth

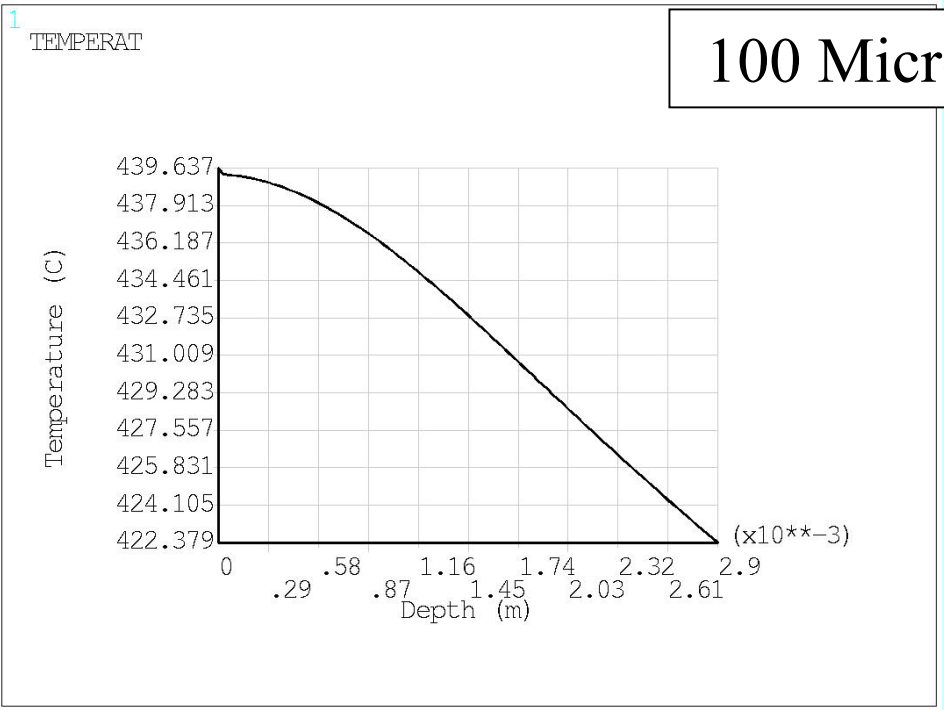
5.25 J/cm^2, 100 ns for 4 micron depth

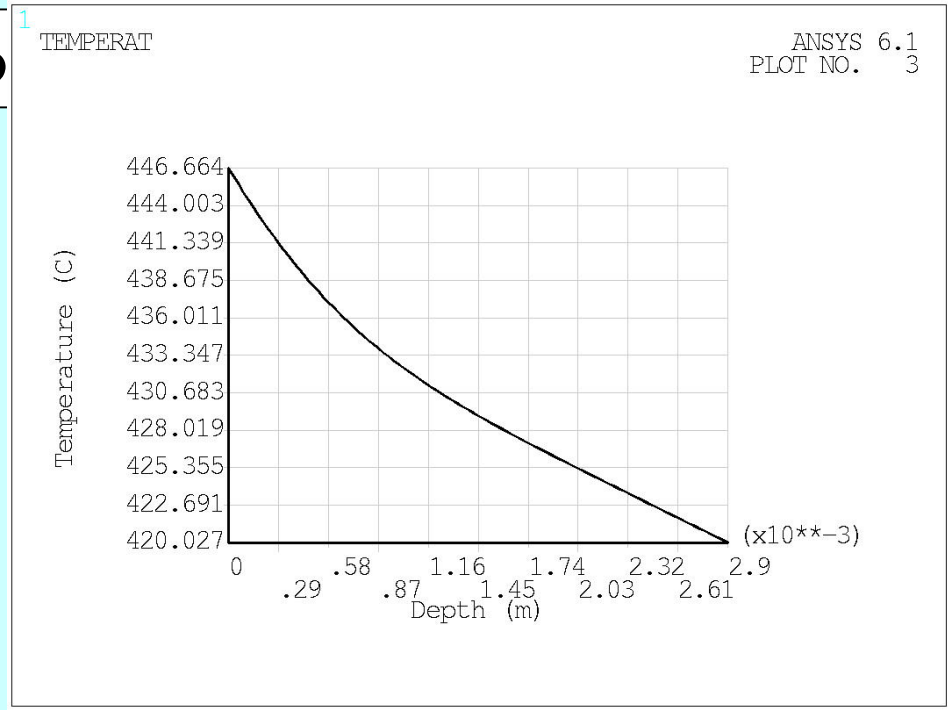
Infrared Tests

- Time scales are long for infrared tests, so analytical models are not appropriate
- Cases were re-rerun for 50 microns of tungsten on 3 mm of ferritic steel
- Metric is now surface temperature, temperature distribution, and stresses in steel

Temperature Distributions in Steel after last pulse – 150 MJ target

100 Micro





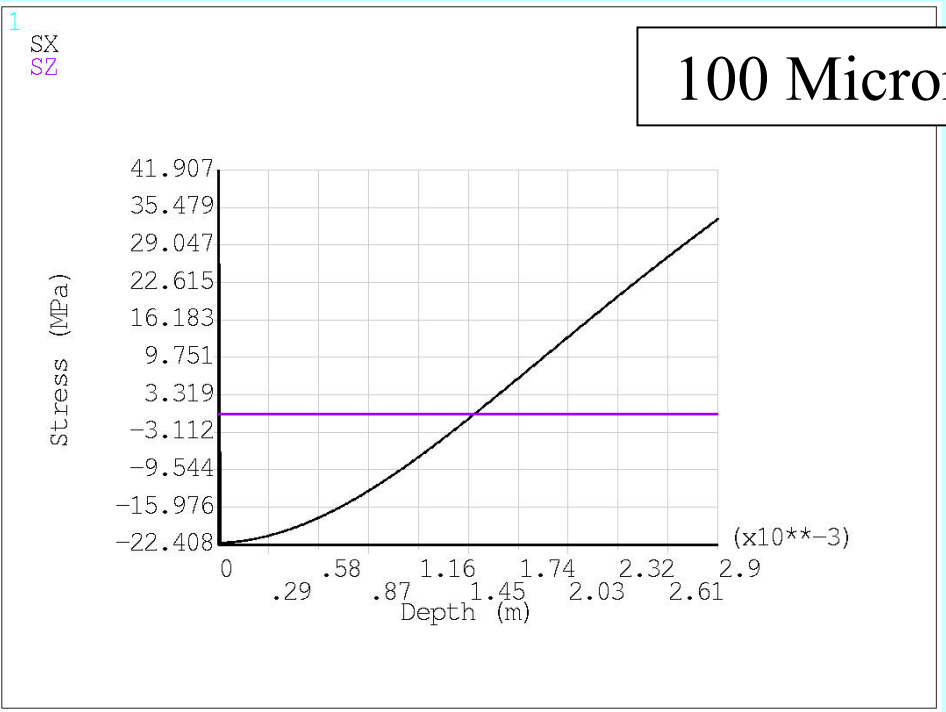
HAPL Low Yield

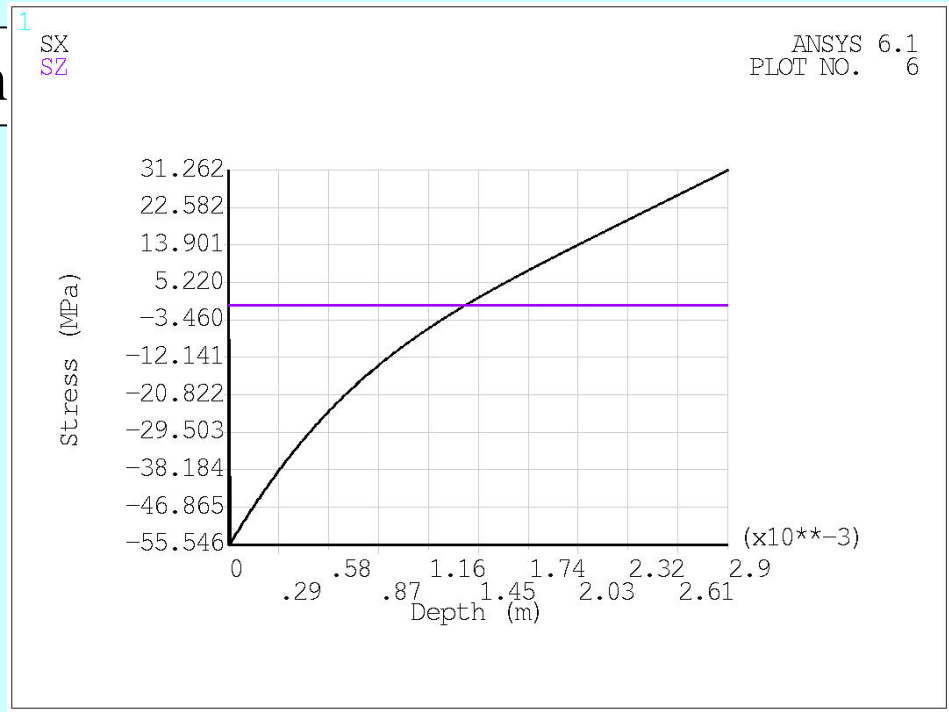
6.5 meter, no gas

IR Experiment – 0.7 MW/m^2

80 ms on, 160 ms off

Stress Distributions after last pulse for 150 MJ Target





HAPL Low Yield

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IR Experiment – 0.7 MW/m^2

80 ms on, 160 ms off

Ideal Experiment

- Preserve peak power and pulse width
- Preserve time-averaged power
- Preserve initial temperature
- Preserve gradients through steel (cool back of sample)

Conclusions

- Peak temperatures do not scale directly with inverse square root of pulse width
- RHEPP, Z, UCSD laser, and Xapper can simulate peak temperatures in HAPL walls, but with shorter times to peak and with sharper temperature distributions (Electra cannot)
- These effects are likely relatively unimportant
- IR can easily duplicate the important stress distributions throughout a duplex sample (this requires active cooling)
- It isn't clear that other options can mimic stress distributions in duplex samples (Electra might)

Future Work

- Monitor and model experiments
- Create design criteria from modeling
- Model cracking of tungsten (growth through tungsten and at steel interface)
- Model high cycle fatigue in steel
- Model castellation
- Put yield model into BUCKY