Armor Simulation Experiments At Dragonfire Facility

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HAPL Meeting

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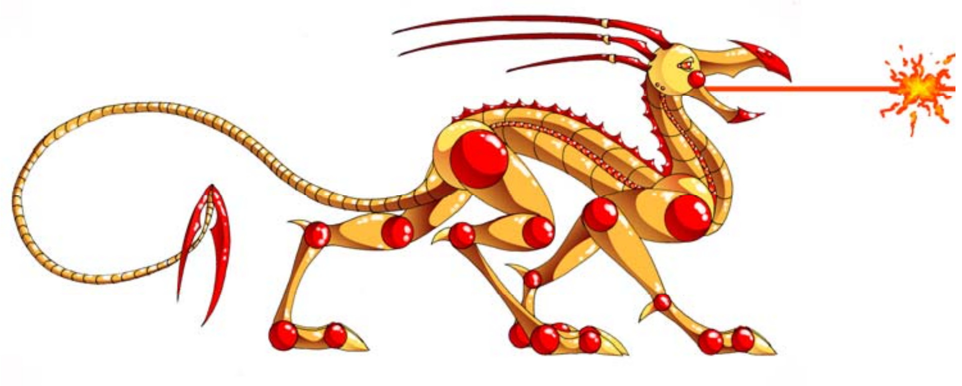


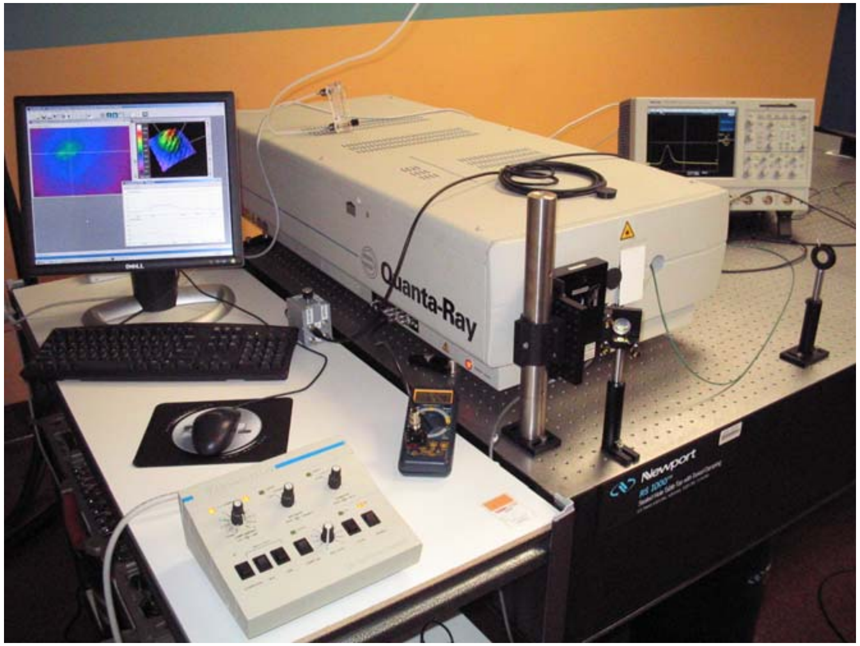
Electronic copy: http://aries.ucsd.edu/najmabadi/TALKS
UCSD IFE Web Site: http://aries.ucsd.edu/IFE

Armor Irradiation Test Matrix

Test matrix:	Initial Temp.	ΔT	No. of Shots
Sample 1A:	RT	2,000°C	10^3 (100s)
Sample 2A:	RT	2,000°C	10^4 (~16 mins)
Sample 1B:	RT	2,000°C	10^5 (~2.8 hr)
Sample 3A:	RT	2,500°C	10^3
Sample 2B:	RT	2,500°C	10^4
Sample 3B:	RT	2,500°C	10^5
Sample 4A:	500°C	2,000°C	10^3
Sample 5A:	500°C	2,000°C	10^4
Sample 4B:	500°C	2,000°C	10^5
Sample 6A:	500°C	2,500°C	10^3
Sample 5B:	500°C	2,500°C	10^4
Sample 6B:	500°C	2,500°C	10^5

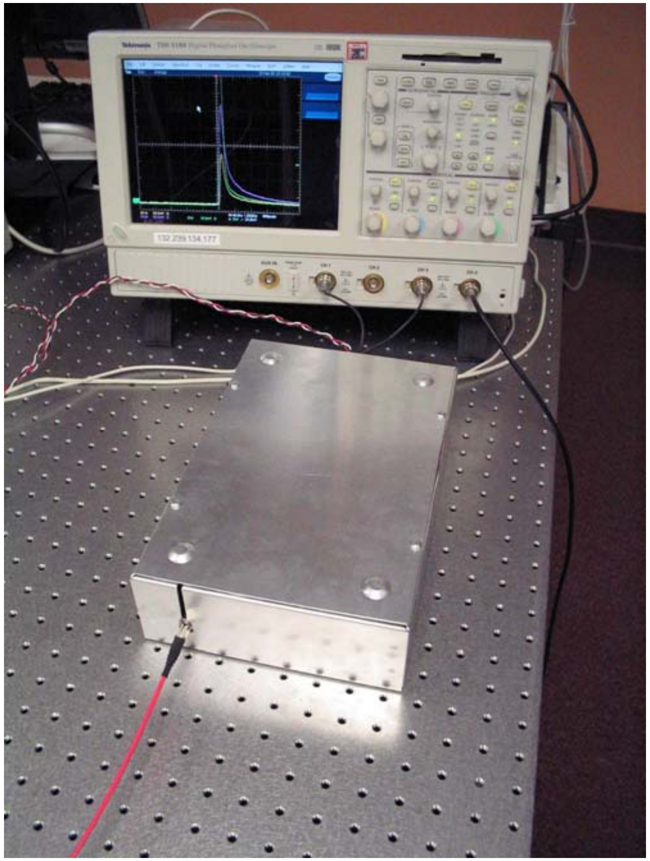
- **Samples:** Powder metallurgy tungsten samples from Lance Snead.

Our laser was repaired and tuned in December



- ➢ We now continuously monitor temporal profile and spatial profile of the laser.

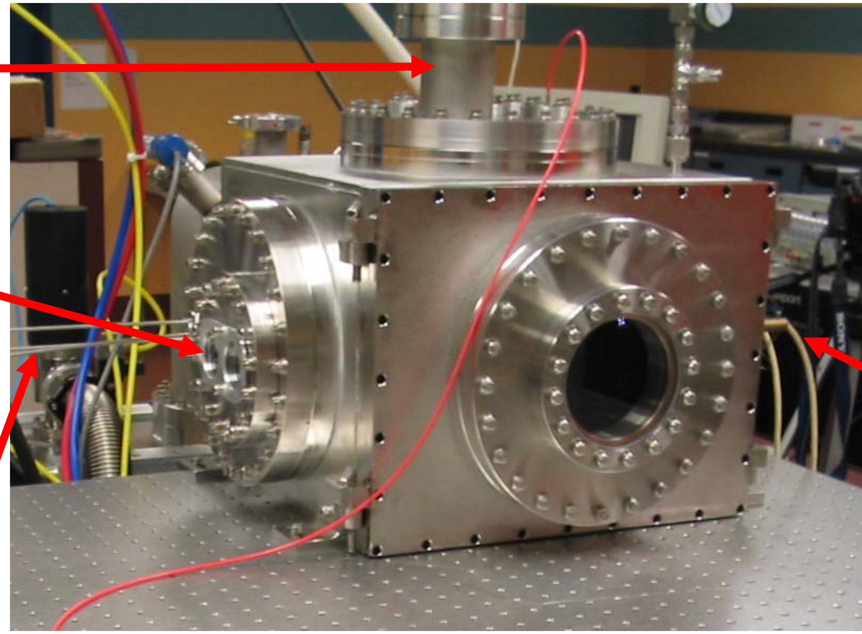
- ➢ Thermometer head and Scope.

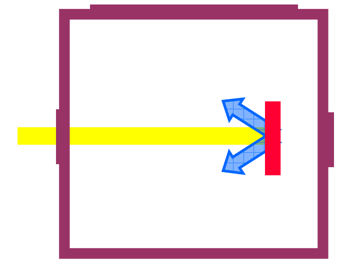


Experimental Setup

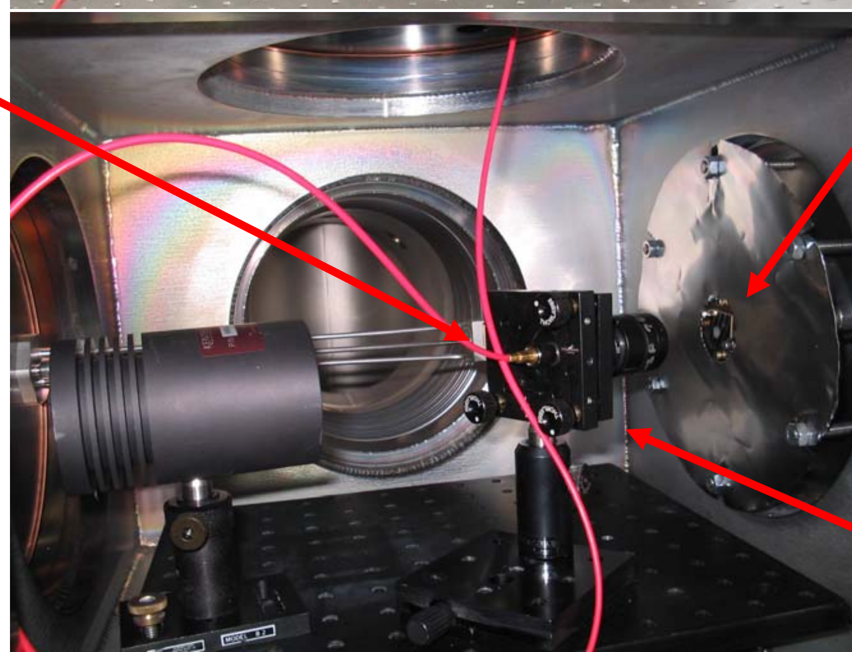
RGA

Laser entrance





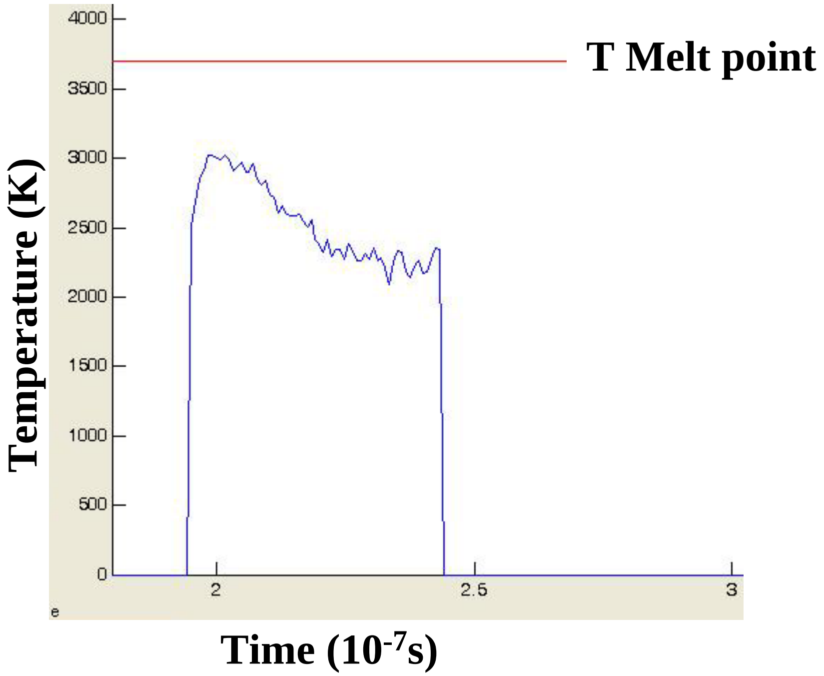
QCM

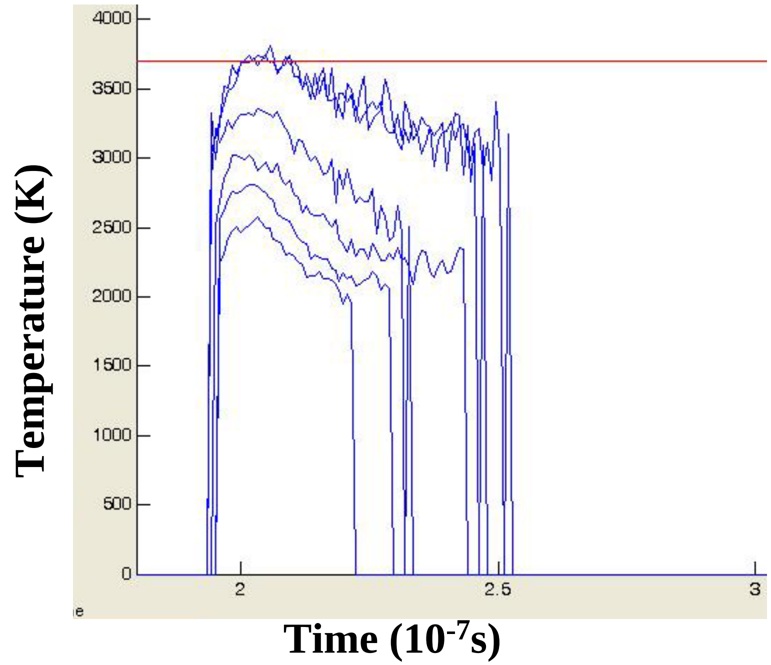


High-Temperature Sample holder

Thermometer head

A Variety of Measure has reduced the noise in thermometer signal considerably





- Little difference in thermometer signal when averaged over 4, 8, 16, and 32 shots.

- Thermometer is calibrated based on the melting point of tungsten

Sample tests were performed at a fixed laser energy (no feedback to fix ΔT)

Evolution of sample ΔT:

- ✓ During the first 10-100 shots, reflectivity of sample surface changes and there is a change in sample ΔT. Afterwards, ΔT remains creatively constant.
- ✓ For large shot rates, spatial profile of laser over the target varies (very slowly) leading to changes in ΔT (< 10%).

Sample equilibrium temperature

- ✓ Sample is cooled through conduction to the vacuum vessel.
- ✓ For heated samples, conduction cooling is large, power to the heating element is typically 10 times larger than laser energy. Sample temperature is easily maintained at the desired temperature.
- ✓ For RT samples, conduction cooling is negligible. For large shot rate, sample test temperature increases (from 28 to 132^{o}C for 10^5 shots).

Armor Irradiation Test Matrix

- **Test matrix:**

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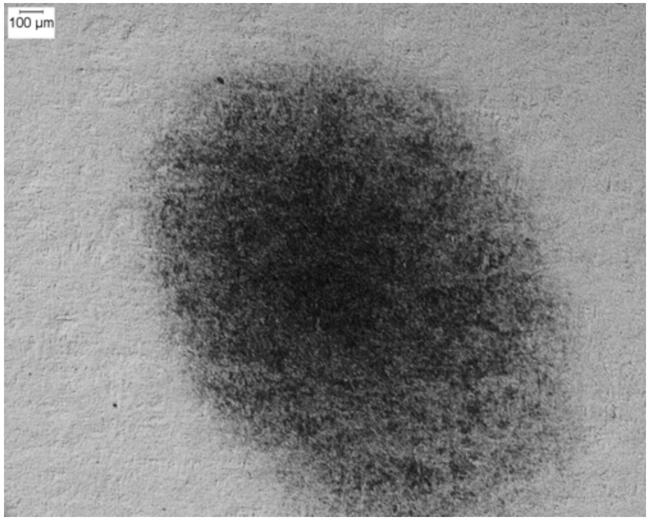
Sample 2B:	RT	2,500ºC	10^4
Sample 3B:	~ RT	2,500ºC	10^5
Sample 4A:	500ºC	2,000ºC	10^3
Sample 5A:	500ºC	2,000ºC	10^4
Sample 4B:	500ºC	2,000ºC	10^5
Sample 6A:	500ºC	2,500ºC	10^3
Sample 5B:	500ºC	2,500ºC	10^4
Sample 6B:	500ºC	2,500ºC	10^5

- **Samples:** Powder metallurgy tungsten samples from Lance Snead.

Powder Metallurgy Tungsten Samples After Laser Irradiation

- Samples are polished to a “mirror-like” finish.
- The “damaged” area has a “dull” finish.
- A brown background is placed in the photograph to enhance contrast.

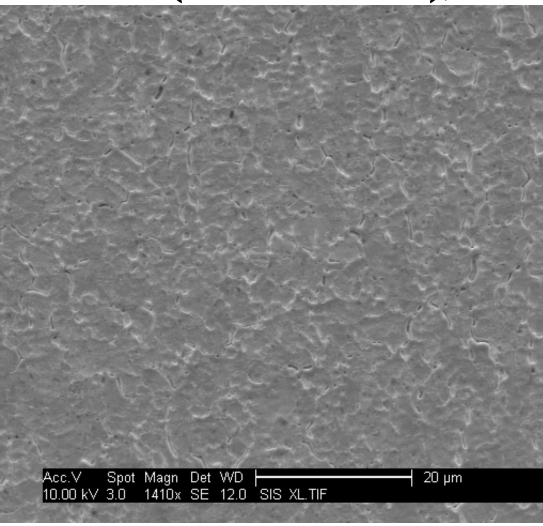
10,000 Shots

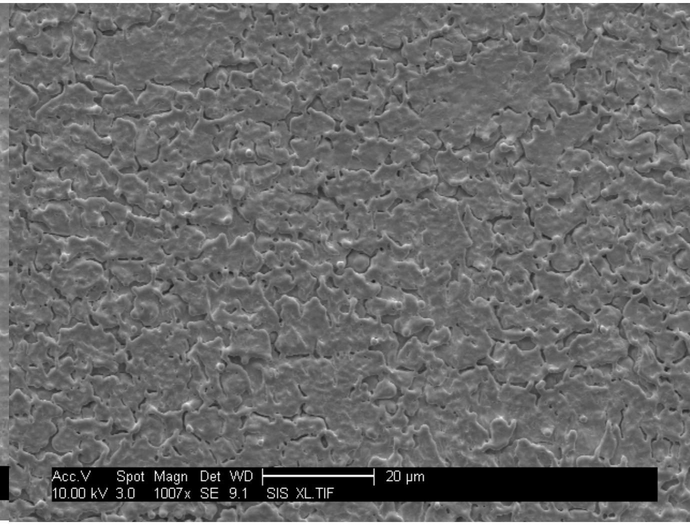


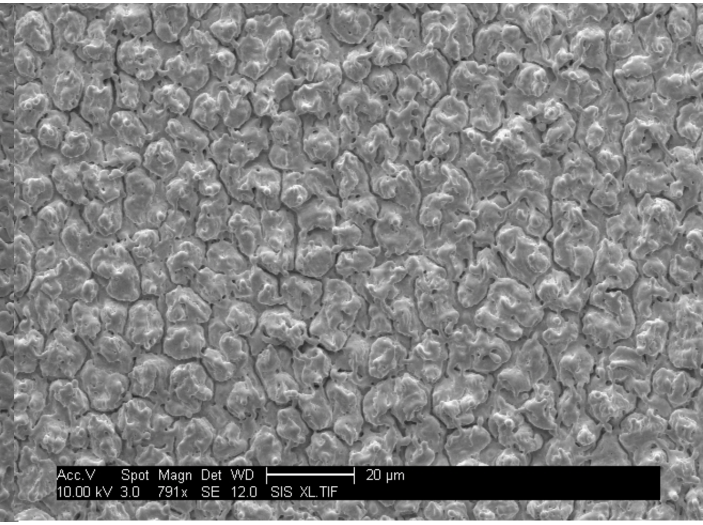
- Optical microscope at low resolution
- “Black” areas appear black because of the “dull finish” (they appear as whitish to the naked eye)

Effects of Shot Rate and Temperature Rise

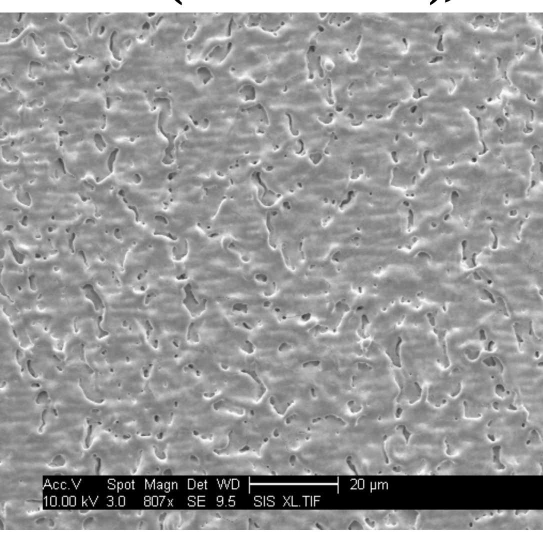
370mJ (~2000^{o}C ΔT), RT

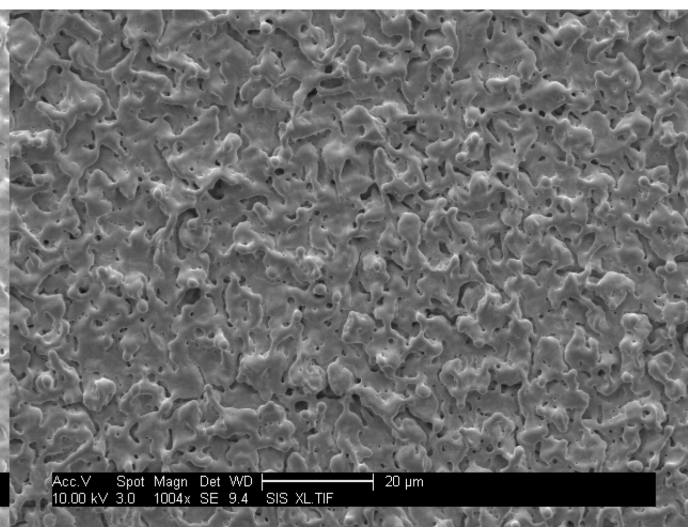


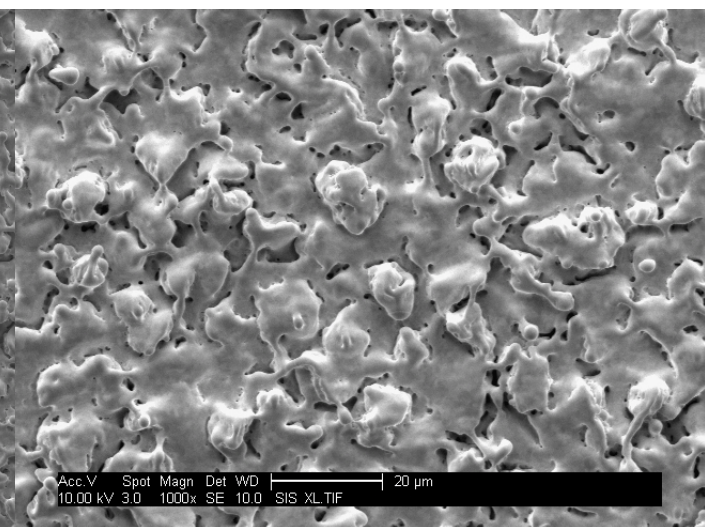




530mJ (~2500^{o}C ΔT), RT



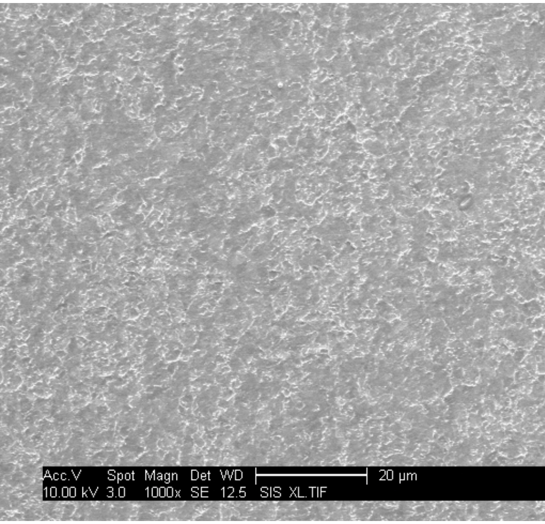




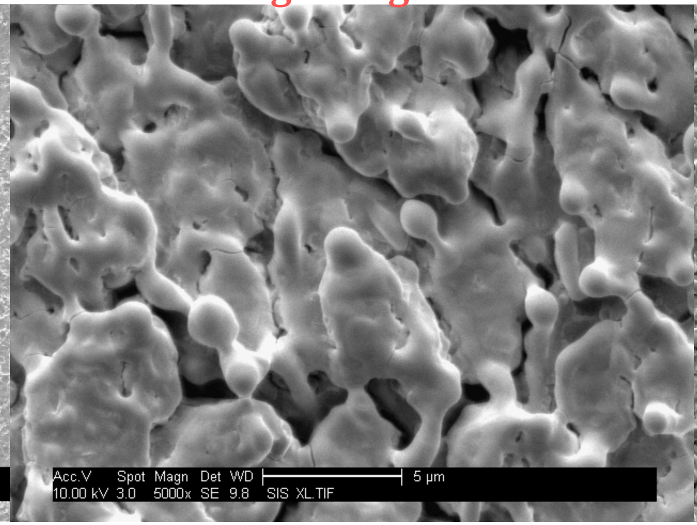
10^3 shots **10^4 shots** **10^5 shots**

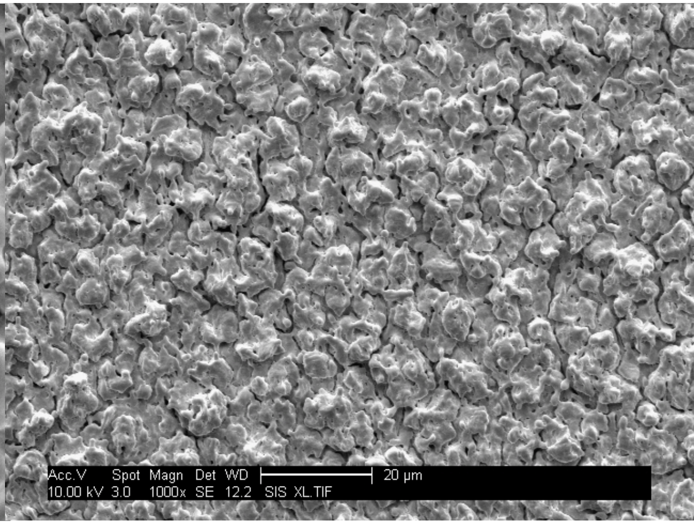
Effects of Shot Rate and Temperature Rise

370mJ (~2000^{o}C ΔT), 500^{o}C

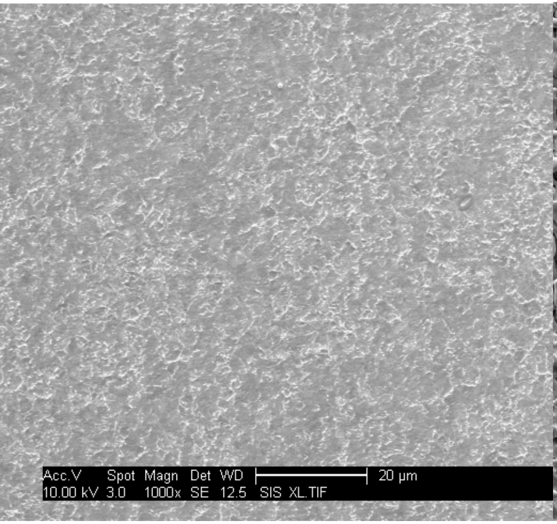


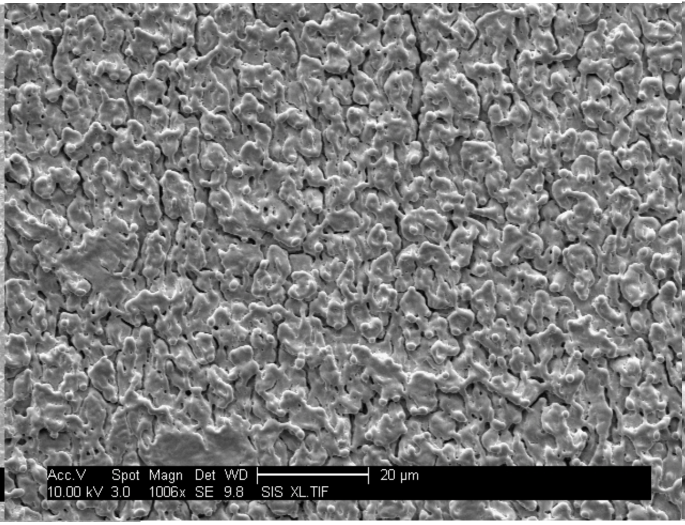
High Magnification

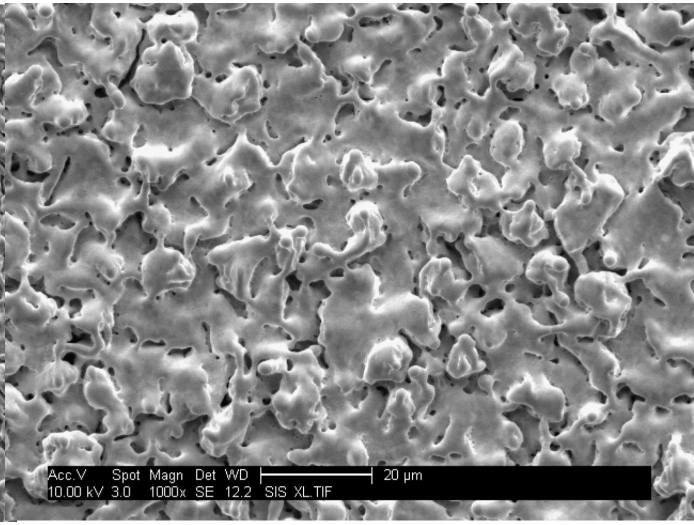




530mJ (~2500^{o}C ΔT), 500^{o}C



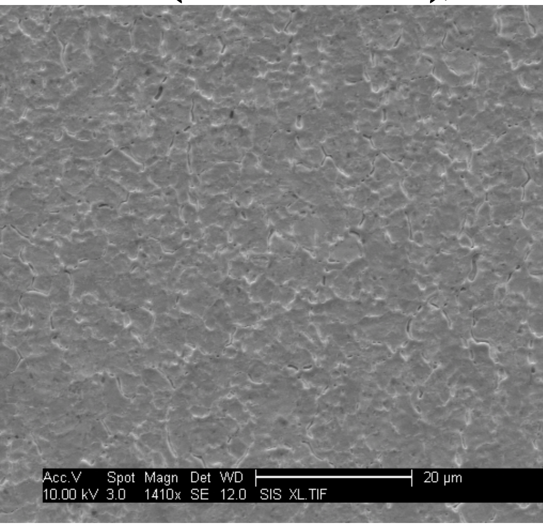


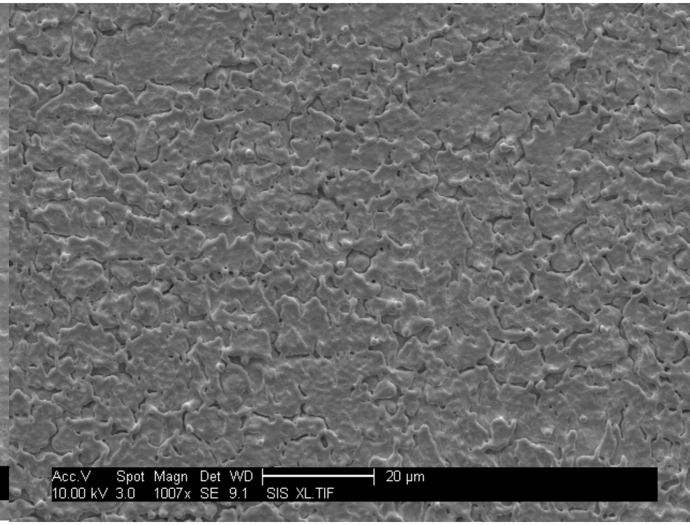


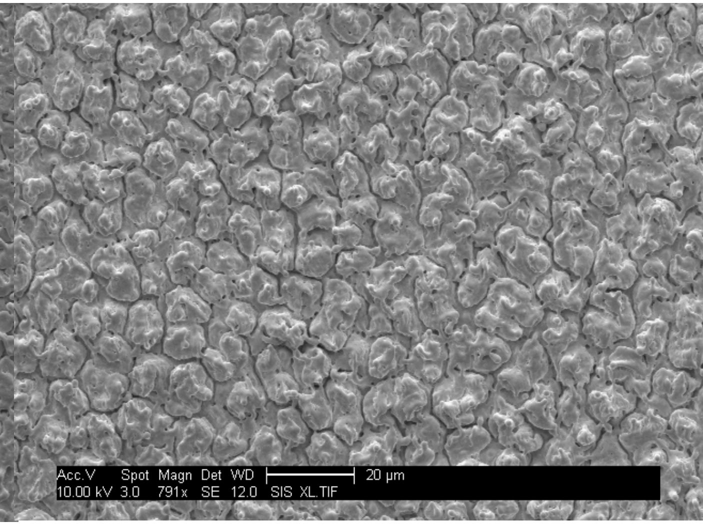
10^3 shots **10^4 shots** **10^5 shots**

Effects of Shot Rate and Base Temperature

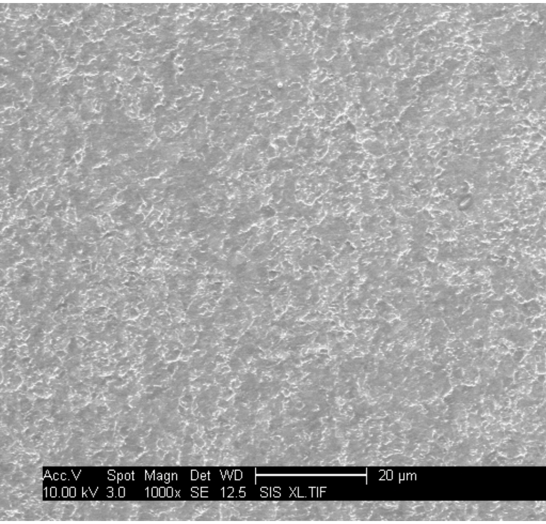
370mJ (~2000^{o}C ΔT), RT



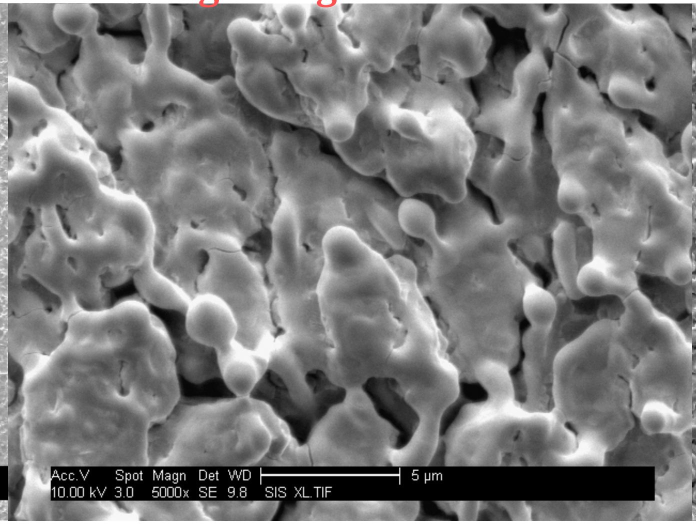


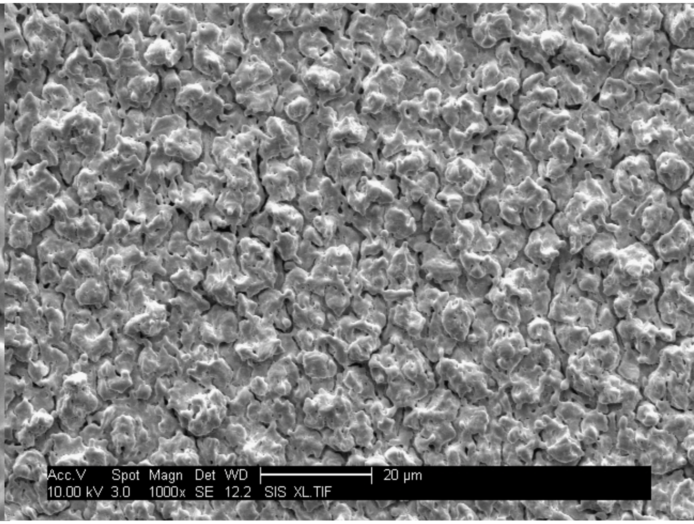


370mJ (~2000^{o}C ΔT), 500^{o}C



High Magnification

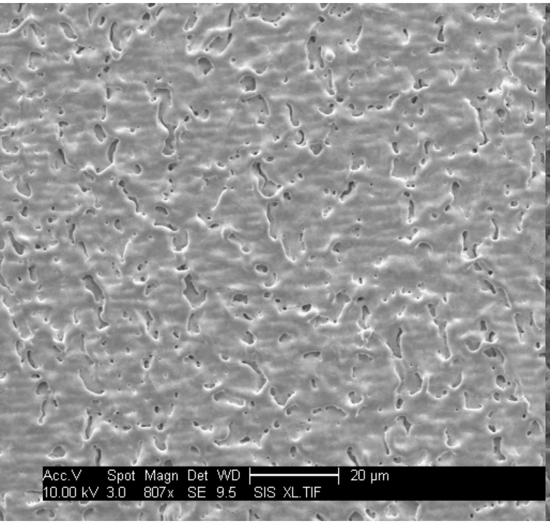


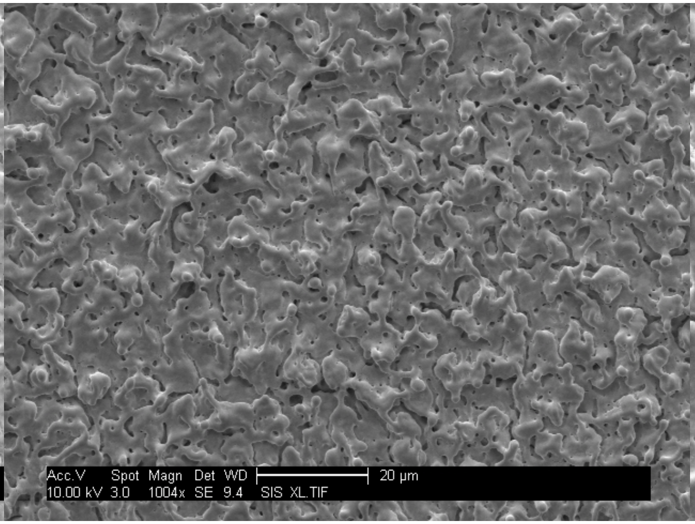


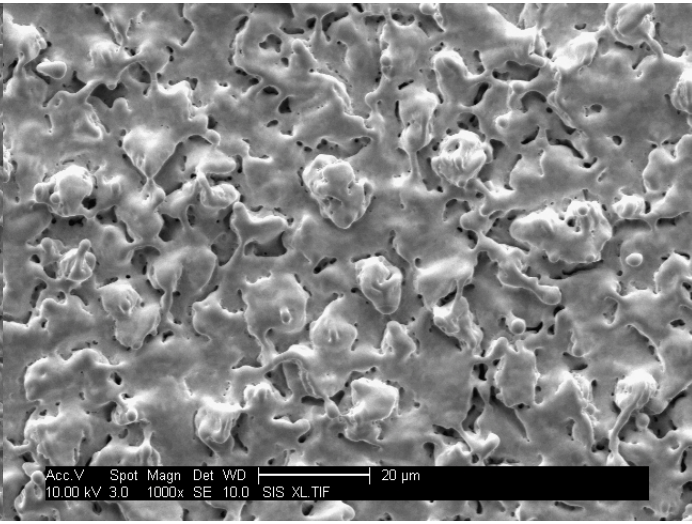
10^3 shots **10^4 shots** **10^5 shots**

Effects of Shot Rate and Temperature Rise

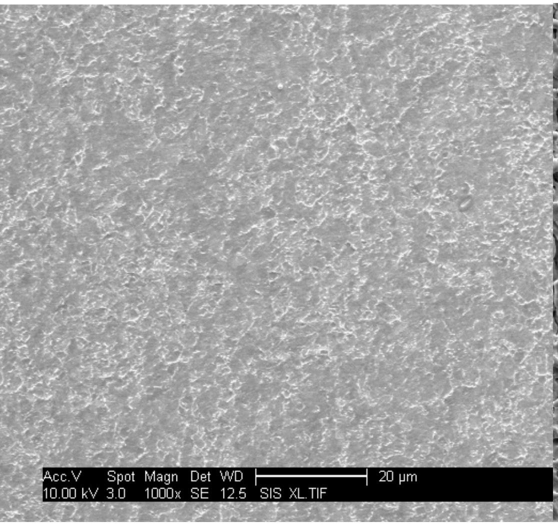
530mJ (~2500^{o}C ΔT), RT

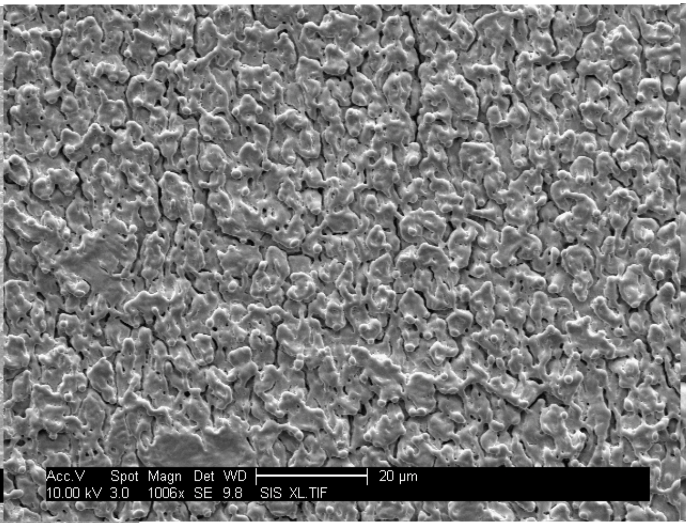


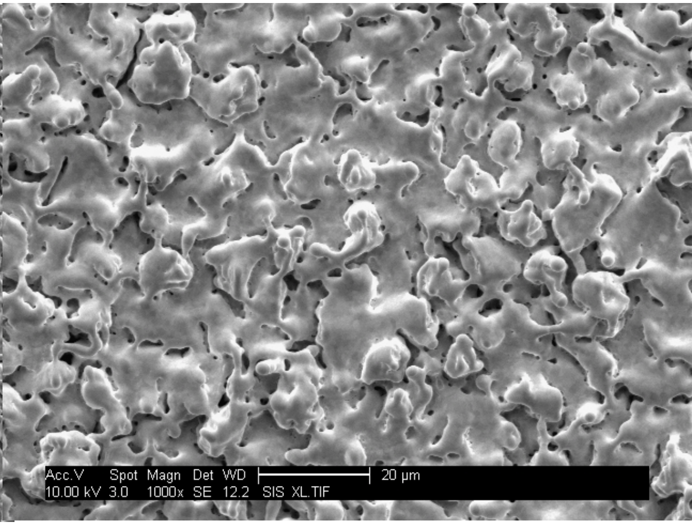




530mJ (~2500^{o}C ΔT), 500^{o}C



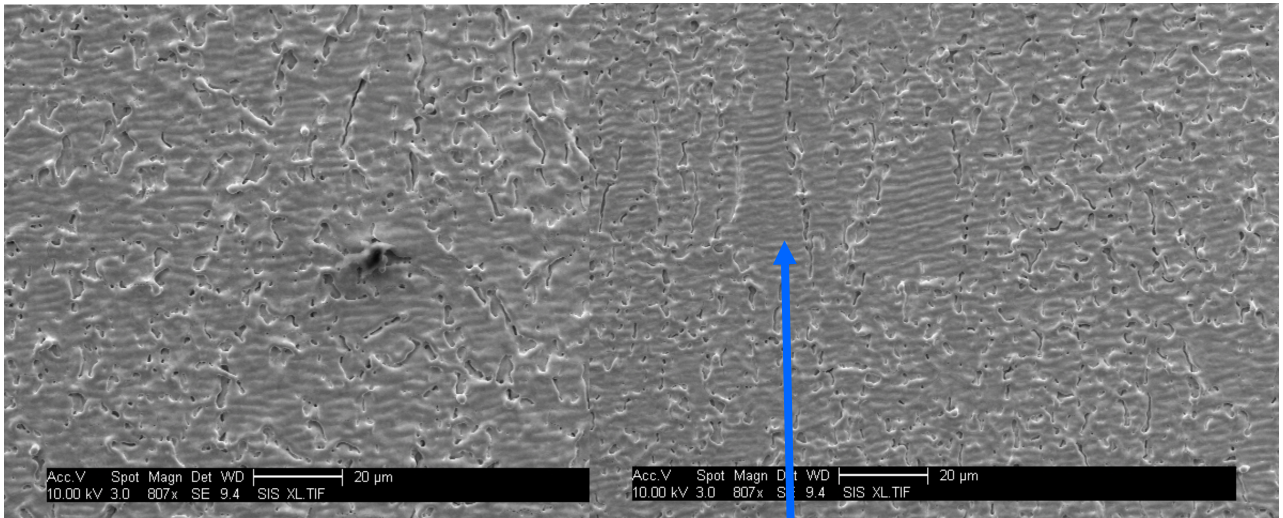




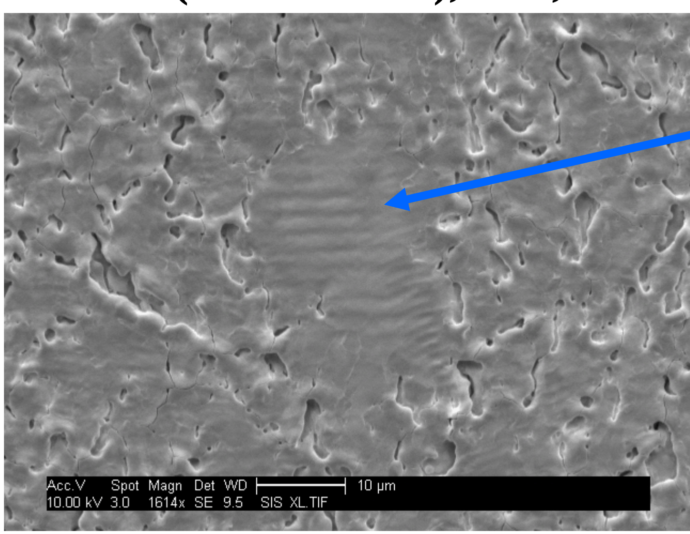
10^3 shots | **10^4 shots** | **10^5 shots**

Interesting Features

370mJ (~2000^{o}C ΔT), RT, 1000 shots

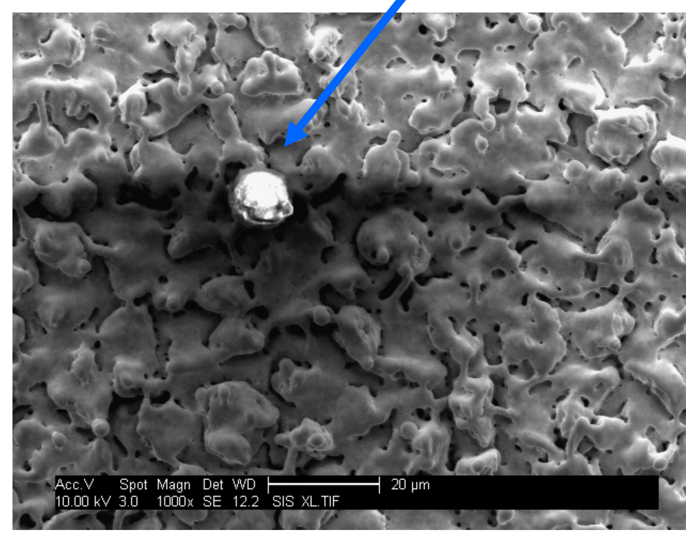


550mJ (~2500^{o}C ΔT), RT , 1000 shots



Slip planes?

Impurities?



Material Response: At First Glance

- It appears that samples evolves at two different time scales:
  - ✓ Low shot count: Defect planes appear,
  - ✓ High shot count: Individual “nuggets” form (are we seeing the powder constituents breaking apart?)

- Higher equilibrium temperature leads to less damage
  - ✓ Highly visible in low shot counts, For example, 1,000 shots at $\Delta T \sim 2{,}500^{o}C$ with $500^{o}C$ sample is “almost” damage free while the corresponding RT sample shows damage.
  - ✓ At high shot count, samples with higher equilibrium temperature also show “slightly” less damage.

Towards 10^6 shots on Dragonfire

- It would be difficult to take 10^6 shots continuously:
  - ✓ 10^6 shots would take about 28 hours.

- Can we beak 10^6 shots into three days of ~9 hour shooting?
- As a test, we have shot a sample at 10^5 shots in two series: (half of the shots in the morning and half in the afternoon)
  - ✓ Sample ΔT was different in afternoon series compared to morning series (by 15%).
  - ✓ Not clear if this was due to changes in laser profile or material response.

- We plan to repeat this experiment and compare with a sample shot continuously for 10^5 shots.