High Fluence Implantation of Helium in Tungsten

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HAPL Meeting-Rochester, NY

November 9th, 2005

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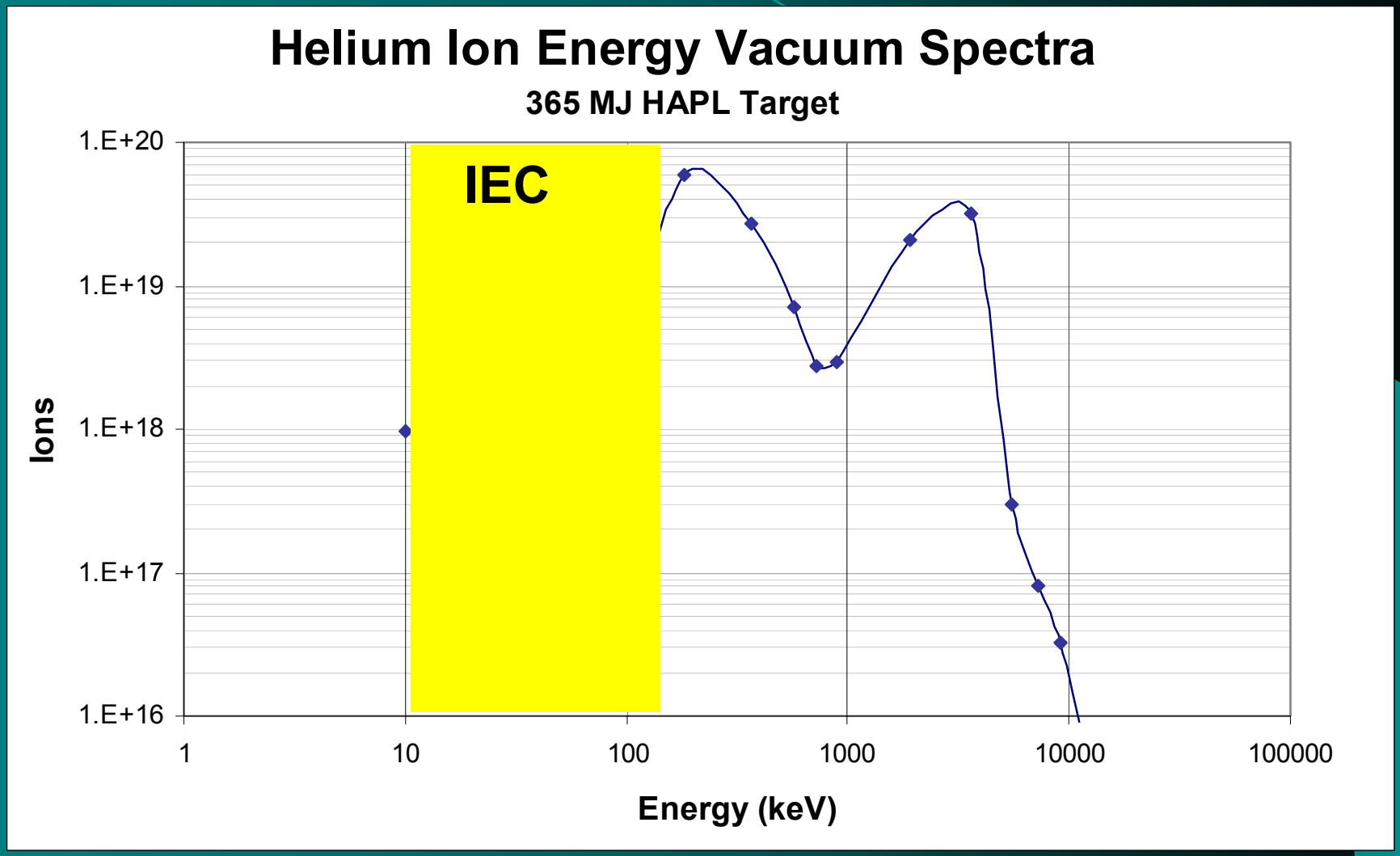
Progress Since the Last Meeting

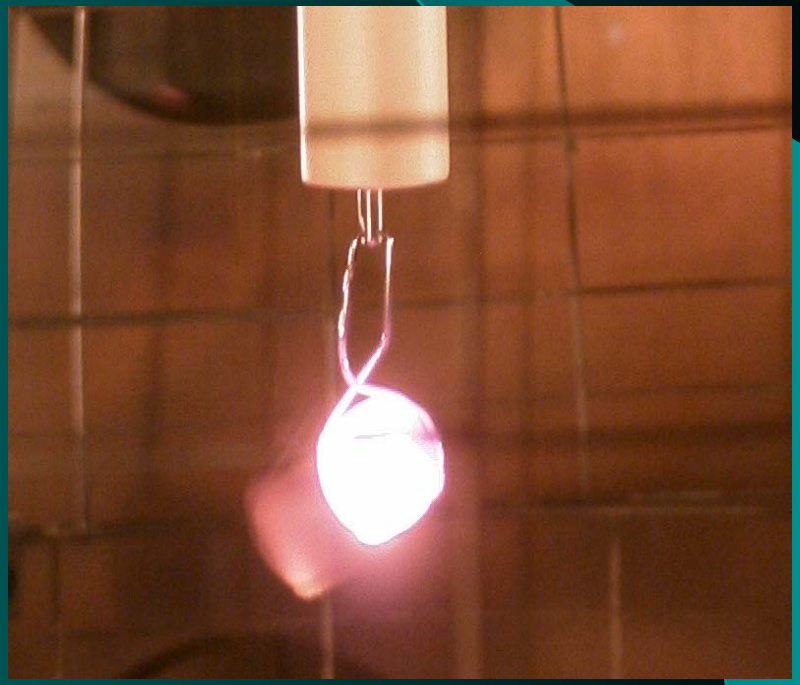
- Tungsten sample has been irradiated to 10 times previous levels with energetic helium ions
- Characterization of high fluence (10^{20} He^{+}/cm^{2}) irradiated sample has begun
- Work has begun on the development of pulsed IEC operation
- The He^{+} energy spectra on the first wall and the IEC sample temperatures were re-evaluated

The IEC Voltage Capability Covers Nearly 25% of the Ions at the First Wall



Tungsten Samples Have Been Irradiated in the IEC Device

- Powder metallurgy samples
- Obtained from Lance Snead, Oak Ridge
- Polished finish
- Spot-welded on to a W-Re wire loop



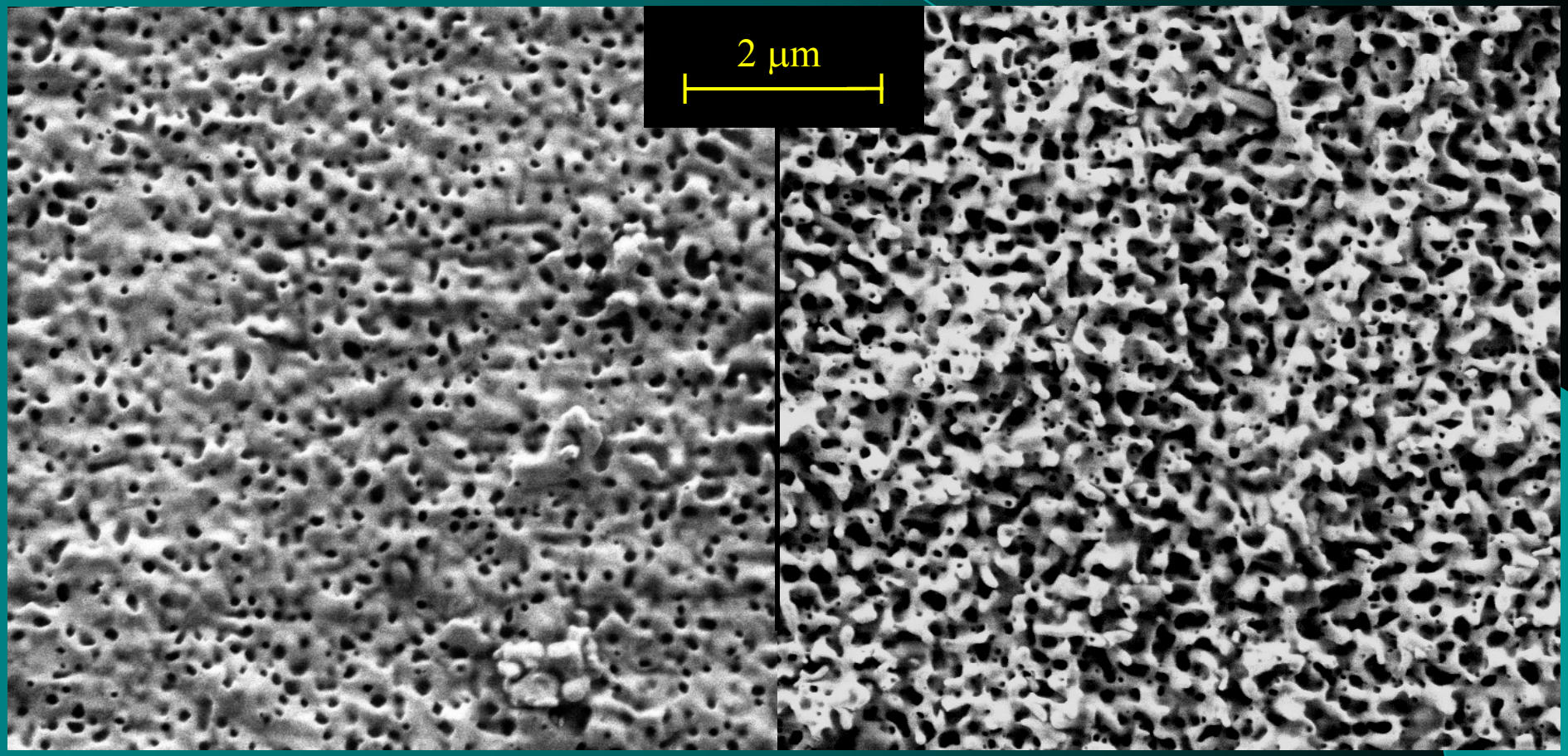
IEC Run Extended He^+ Implantation Database to 10^{20} Ions/cm^2

- Previous maximum fluence was 10^{19} He^+/cm^2
- Irradiation was performed at 30 kV, 6 mA, 0.5 mTorr, and 1150 °C
- This is equivalent to 20 effective full power days in the reference HAPL design (all helium energies)
- It is also equivalent to ~ 100 effective full power days in the reference HAPL design (10 keV < He^+ < 100 keV)

Higher Fluence Yielded Additional Pore Formation and Degradation of Surface

~1150 °C

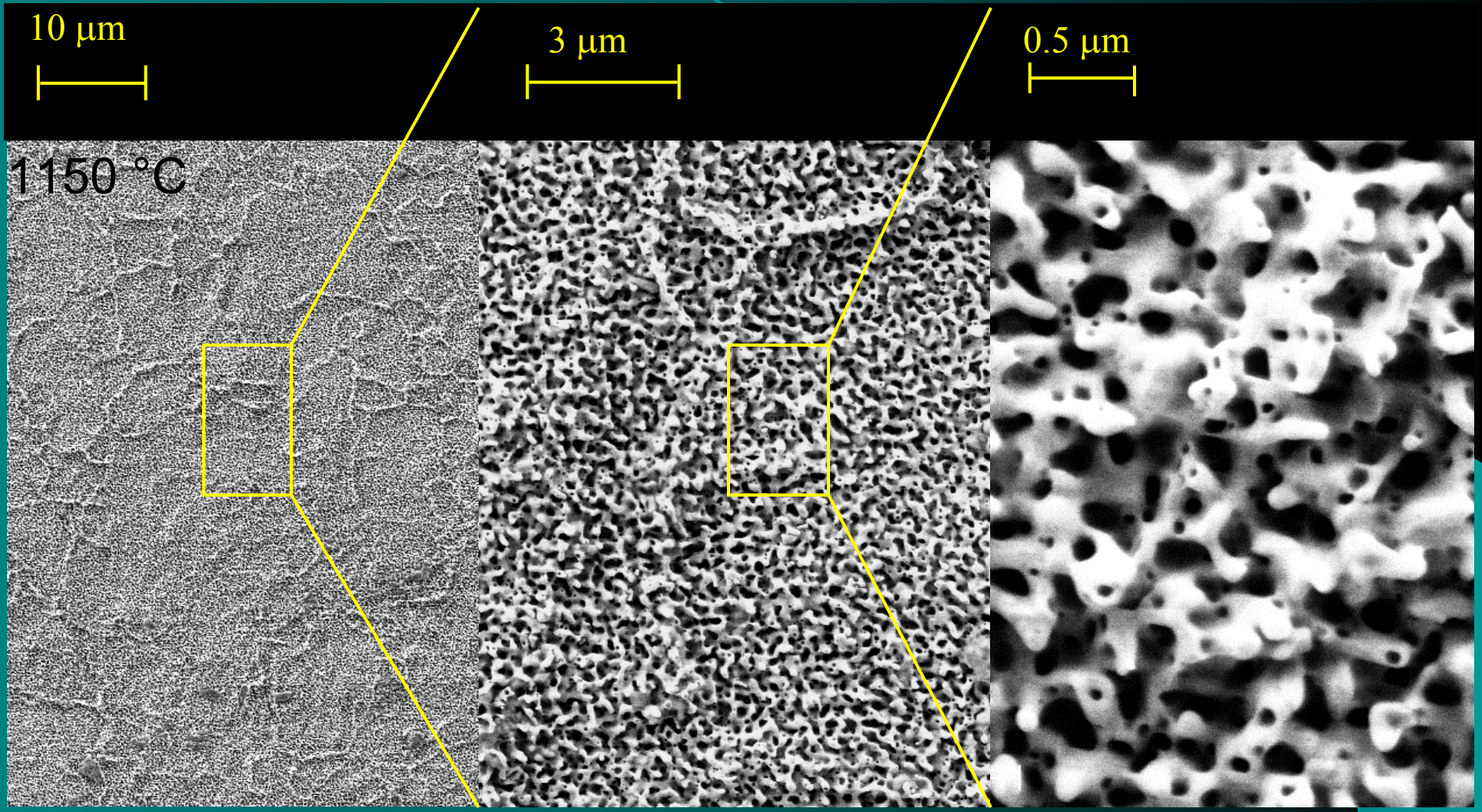
1150 °C



$1x10^{19}$ He^+/cm^2, 30 kV, 6mA

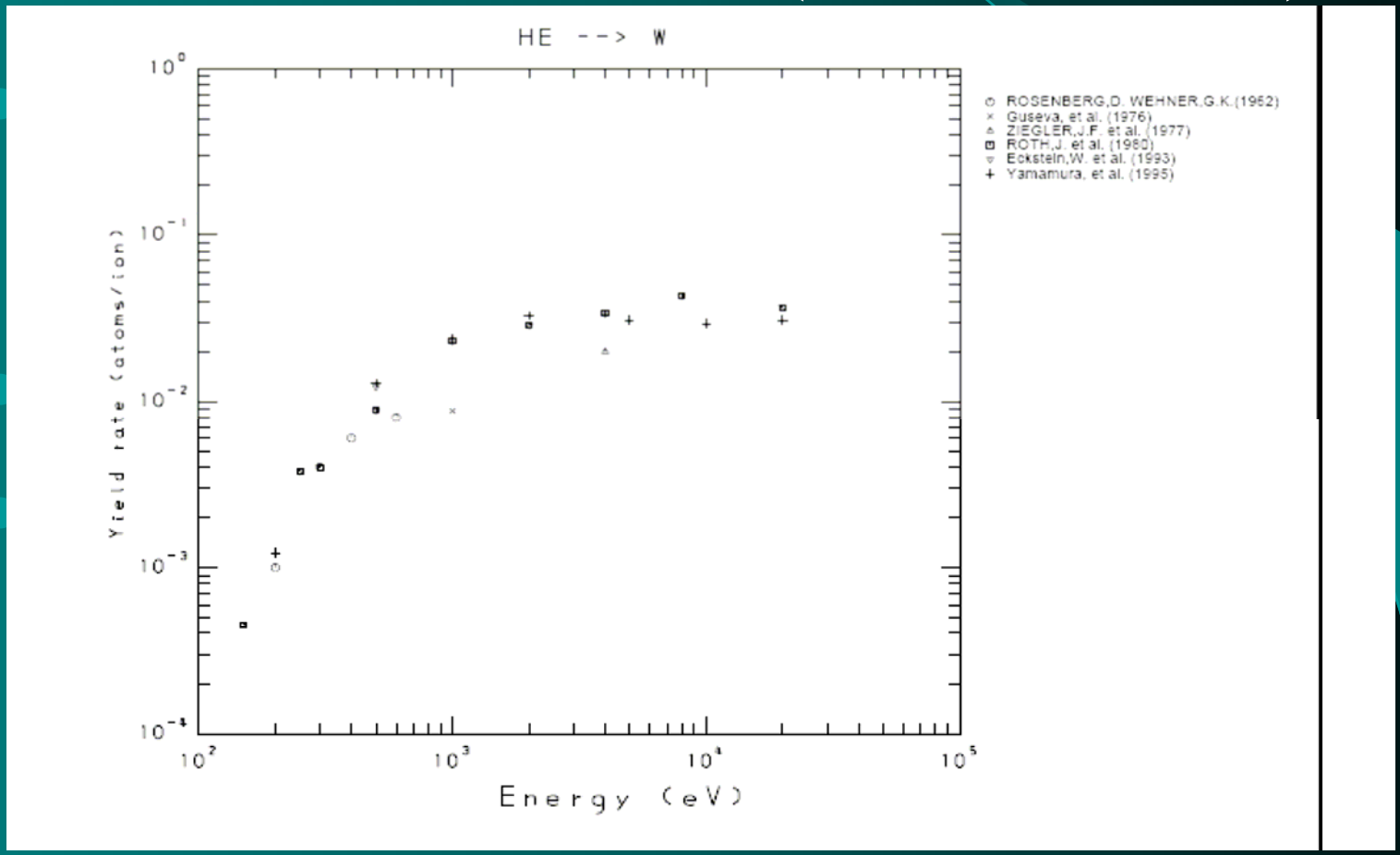
$1x10^{20}$ He^+/cm^2, 30 kV, 6mA

High Temperature Irradiation of Tungsten Produced Drastic Changes in the Surface Morphology



Measured Mass Loss was Observed at 5x the Calculated Physical Sputtering Rate

- Experimental sputtering yield is ~0.038 atoms/ion at 30 keV for ⊥ incidence (Roth, et. al.-1980)



Implications of Material Loss

- Reference HAPL chamber could lose 48 μm/FPY due to low energy He alone
- Physical sputtering from other light ions (H^+, D^+, T^+) could contribute another 6 μm/FPY
- Additional damage from carbon and heavier ions could further increase this loss
- These processes could result in the formation of a minimum of ~80 kg/FPY of radioactive dust in the chamber

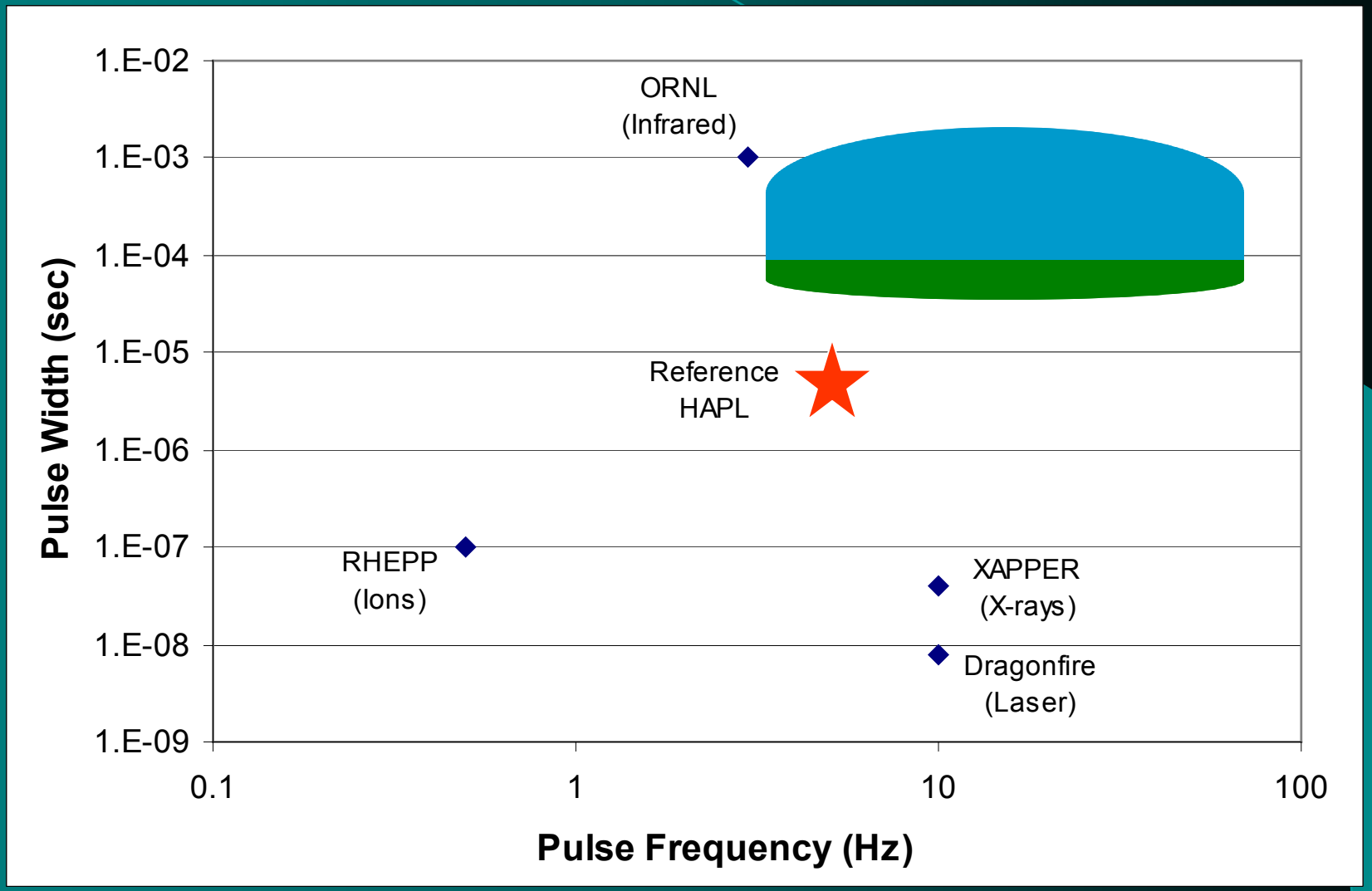
Systematic Pyrometer Malfunction Discovered

- Implication – Past quoted temperature of W samples were too low by 100 to 300 °C.
- Pyrometer repair brought measured temperatures closer to theoretically calculated temperatures
- Current corrections now result in secondary electron emission coefficients of ≈ 2-3 (more in line with measurements on other materials).
- These changes slightly affect temperatures quoted at PPPL (Fall ’04), NRL (Spring ’05), and LLNL (Summer ’05)

Work has Begun on Pulsed IEC Operation

- Steady-state experiments have limited ability to simulated pulsed HAPL operation
- A new campaign has begun to develop pulsed IEC operation
- Initial experiments have shown promising results

Pulsed Experiments Will Provide More Realistic Tungsten Damage



Initial Pulsed IEC Operation has Shown Promising Results

- High voltage pulsing circuit has been constructed and tested to 50 kV
- Pulses have been run as low as ~100 μs pulse width, 1-100 Hz frequency, and up to 300 mA peak current
- Video shows 30 kV operation at ~ 1Hz

Conclusions

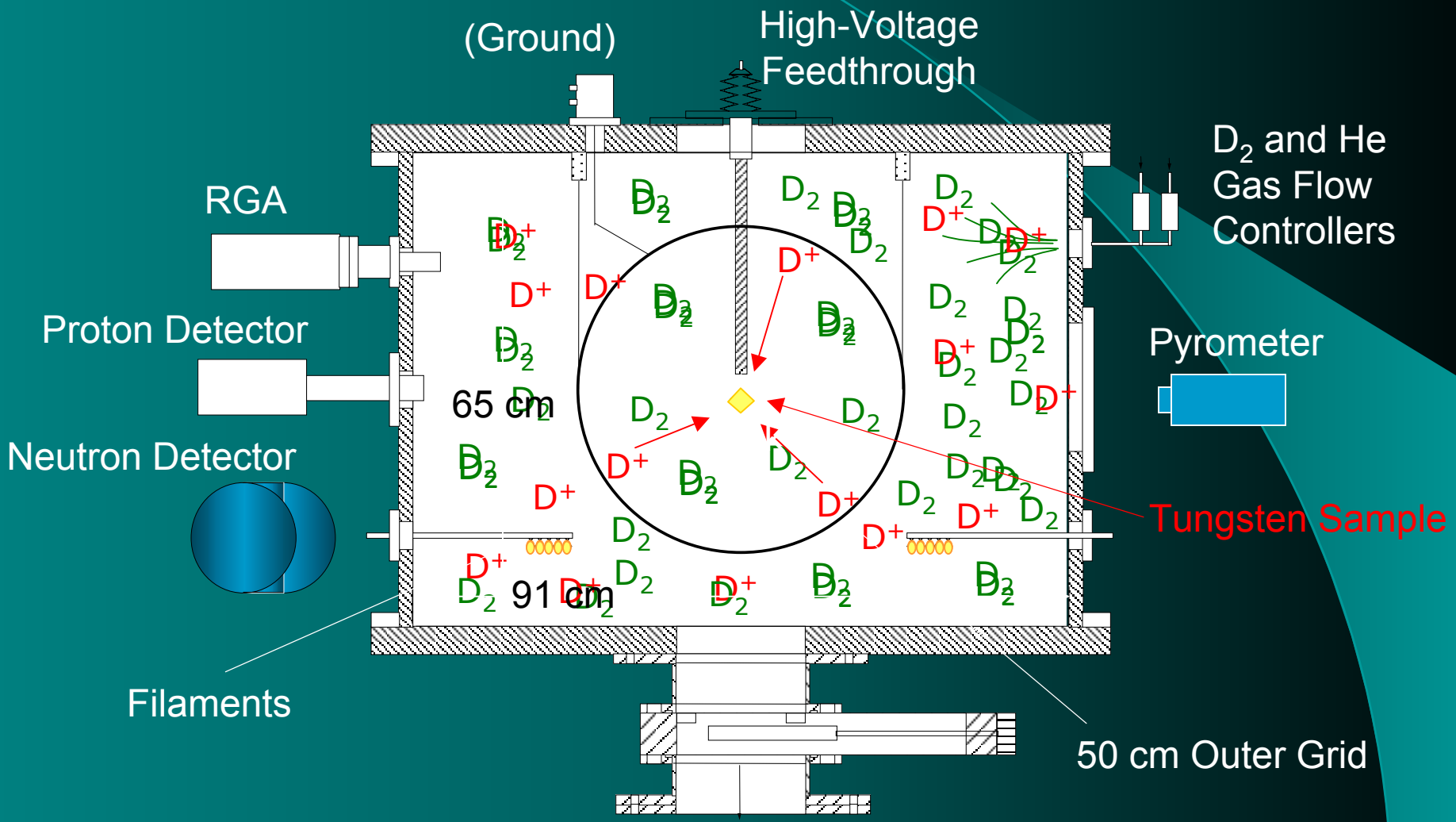
- Increasing the helium fluence from 10^{19} He^{+}/cm^{2} to 10^{20} He^{+}/cm^{2} resulted in an increased surface roughening
- Large fluences cause erosion of the tungsten first wall at 1150 °C beyond calculated physical sputtering values
- Pulsed IEC operation will allow irradiation at conditions closer to the reference HAPL design than previous experiments

Future Work

- Evaluate deuterium retention rates and profiles using Elastic Recoil Detection analysis
- Repeat D^+ and He^+ Irradiations to 10^{19} ions/cm^2 with pulsed operation


Questions?

IEC Device Provides Steady-State and Pulsed Operation



Secondary Election Coefficient on Tungsten

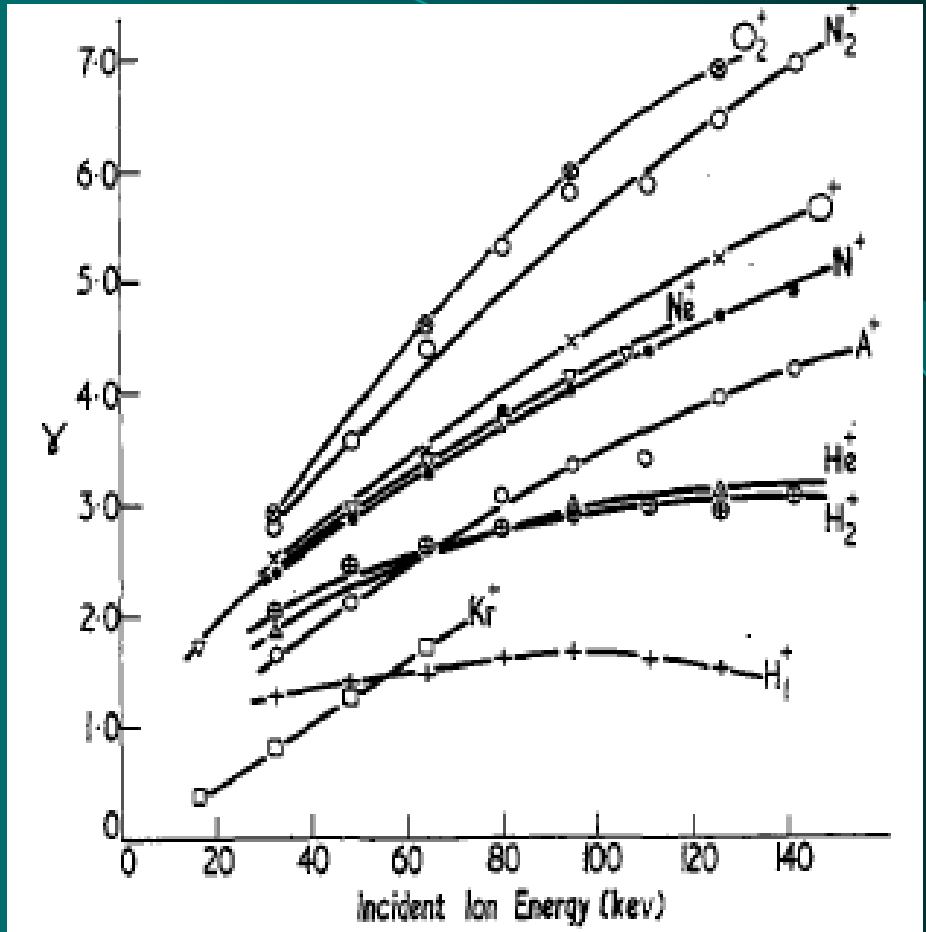


Figure 2. Variation of γ with incident ion energy.

Reference: Proc. Phys. Soc., 1963, vol. 81. "Secondary Electron Emission from a Clean Tungsten Surface Bombarded by various Positive Ions."

8 mTorr Xenon Backround Lowers Energy Spectrum