Helium Implantation in Tungsten

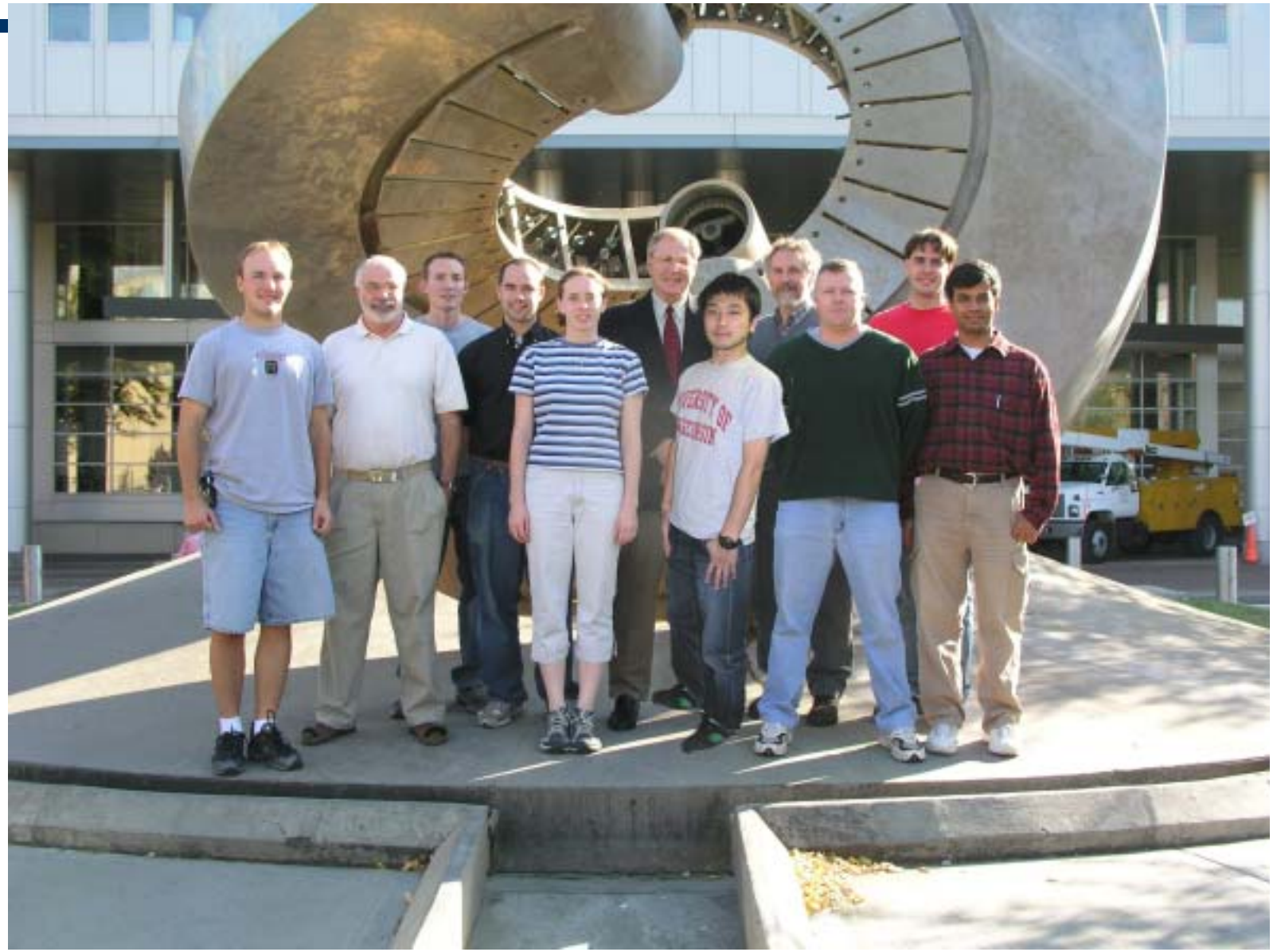
B.B. Cipiti & G.L. Kulcinski

February 6, 2004

Fusion Technology Institute

University of Wisconsin-Madison

The Wisconsin IEC Team

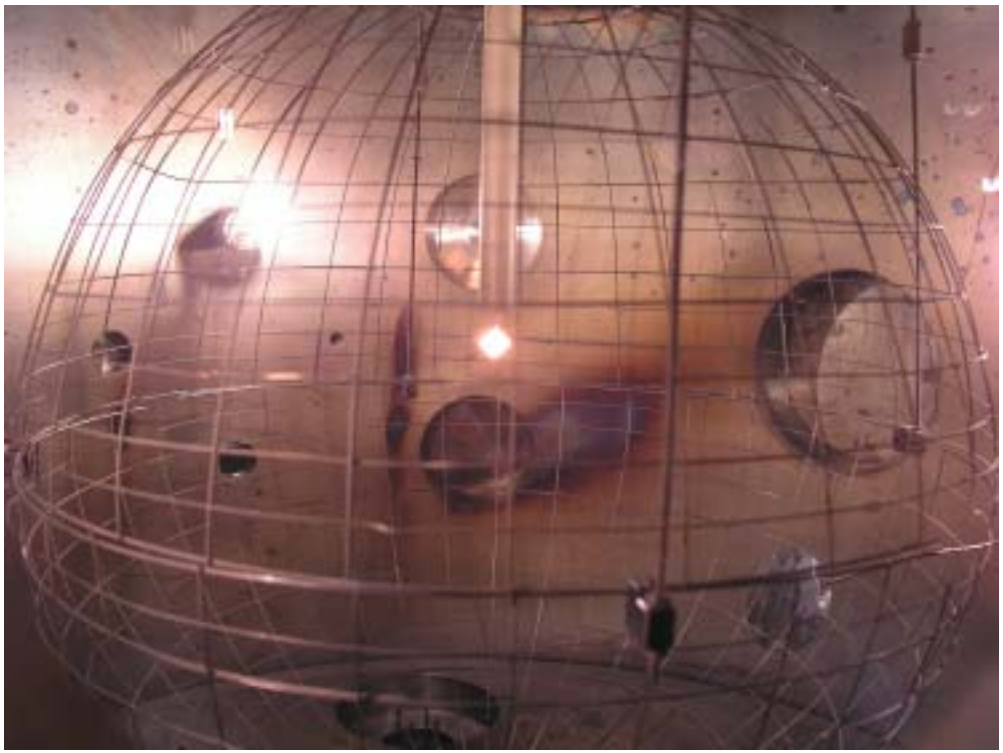


Helium Implantation in Tungsten at High Temperatures at the University of Wisconsin

- **Purpose:** To determine the effect of helium implantation on the surface morphology of tungsten at high temperatures
- **Why?** To see if tungsten can serve as a suitable material for the HAPL first wall
- **How?** Use high energy helium ions to bombard W while it is at temperatures typical of HAPL chamber

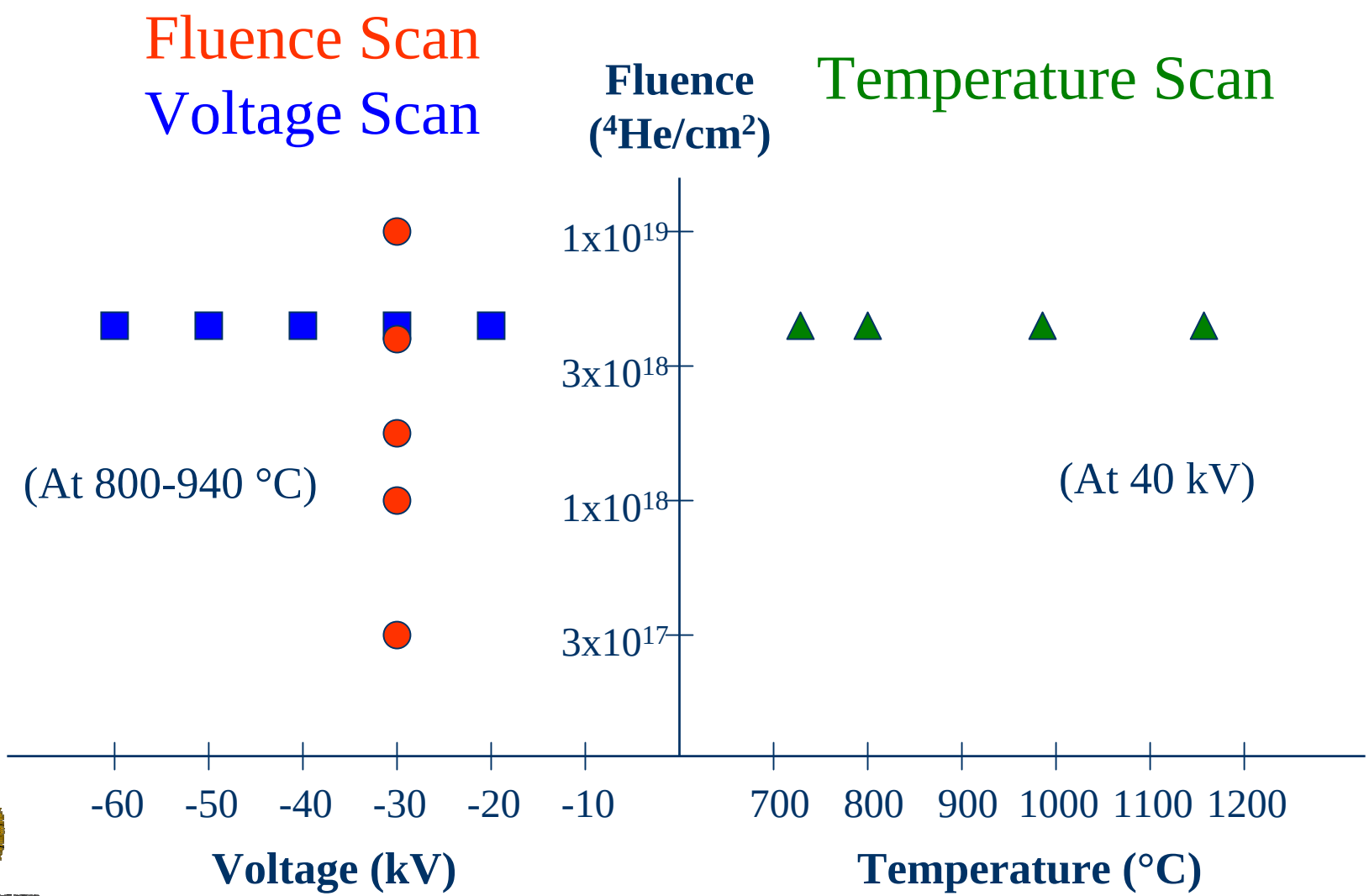
THE UNIVERSITY of WISCONSIN MADISON

UW IEC Chamber has Capability of High-Temperature Implantation at 10-150 kV



D^+, 20 kV, 5 mA
2 mtorr, 1100 °C

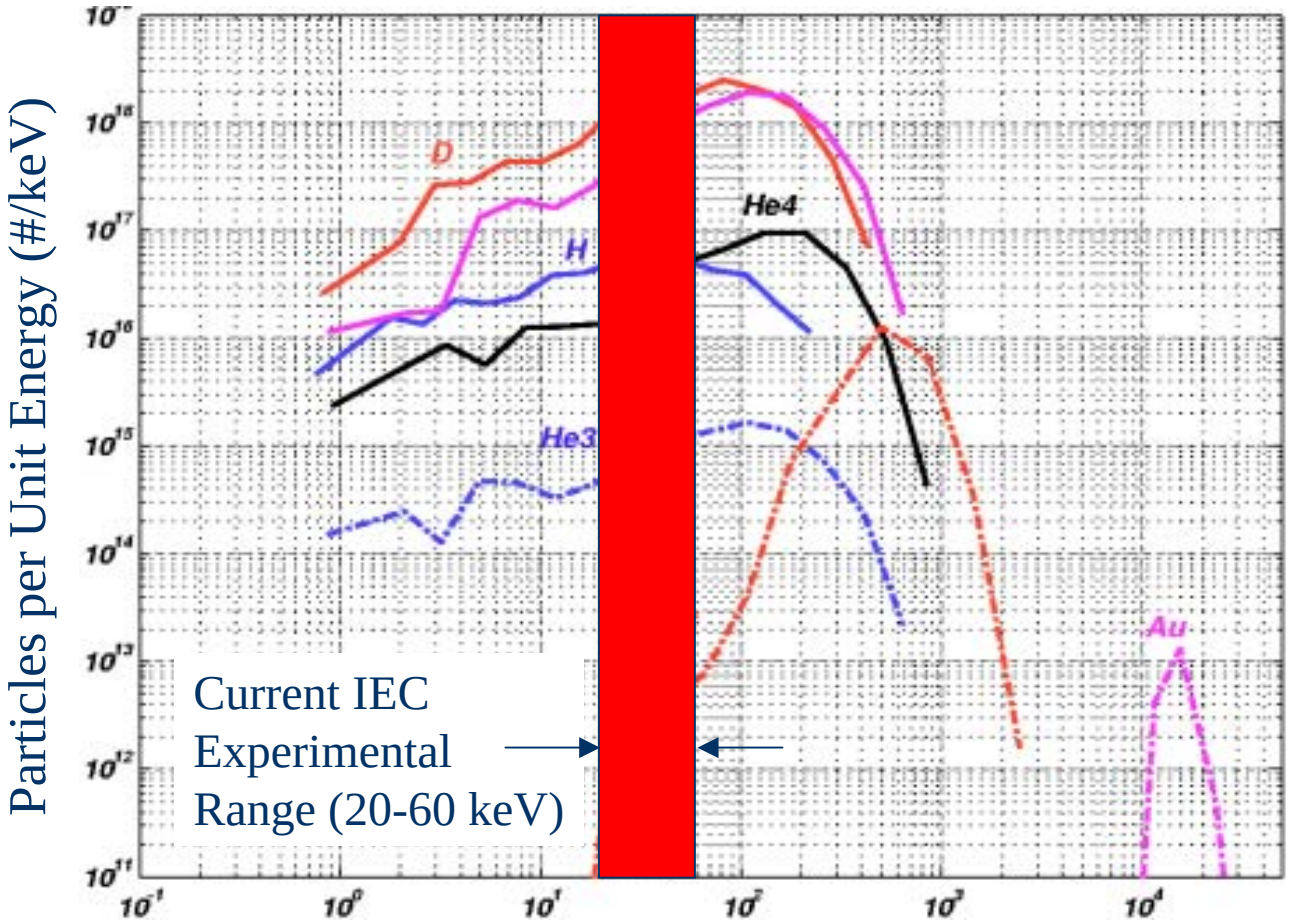
HAPL Implantation Experiments



THE UNIVERSITY of WISCONSIN MADISON

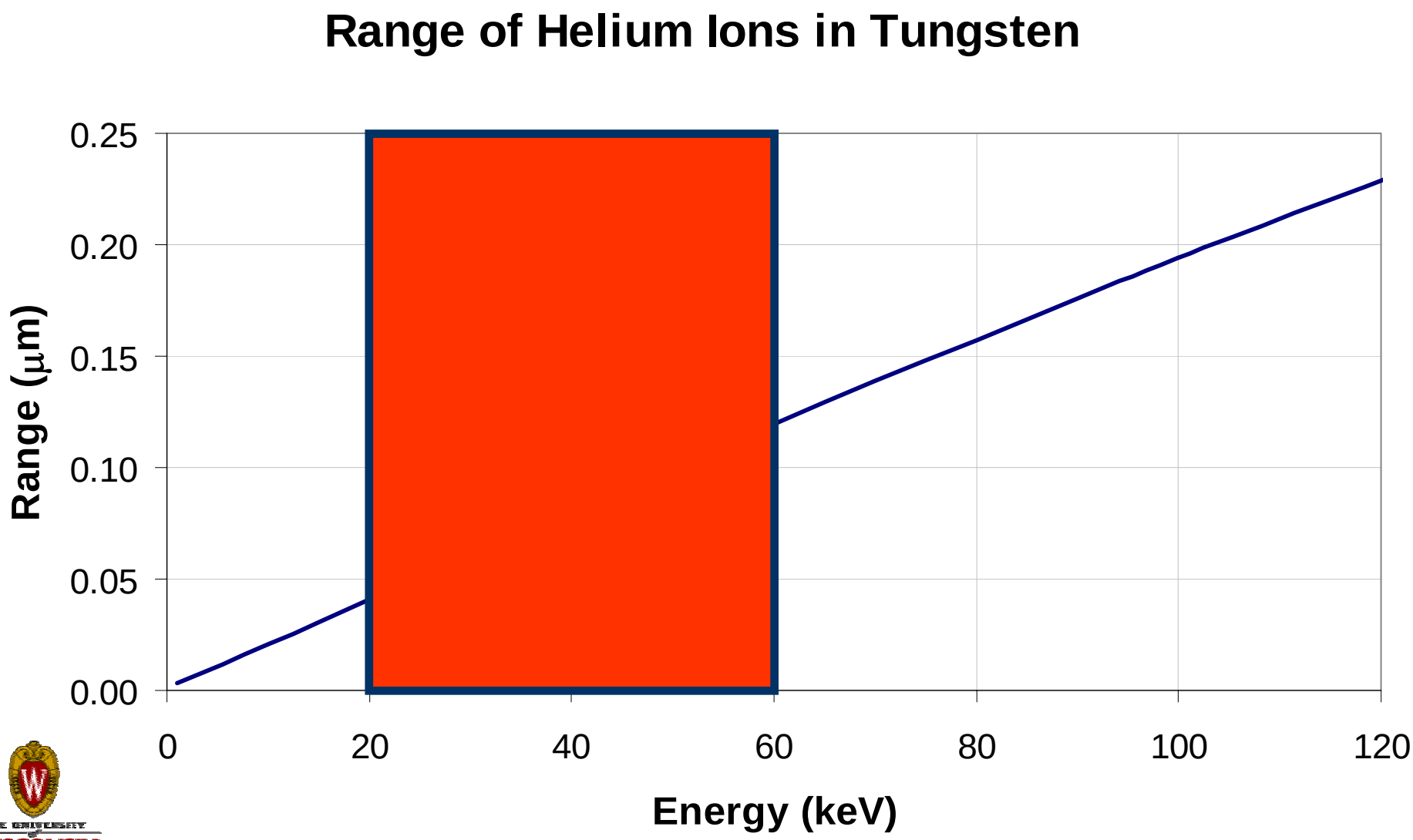
Early Implantation Studies Cover a Limited Range of the Helium Energy Spectrum

HAPL Debris Ion Energy Spectra



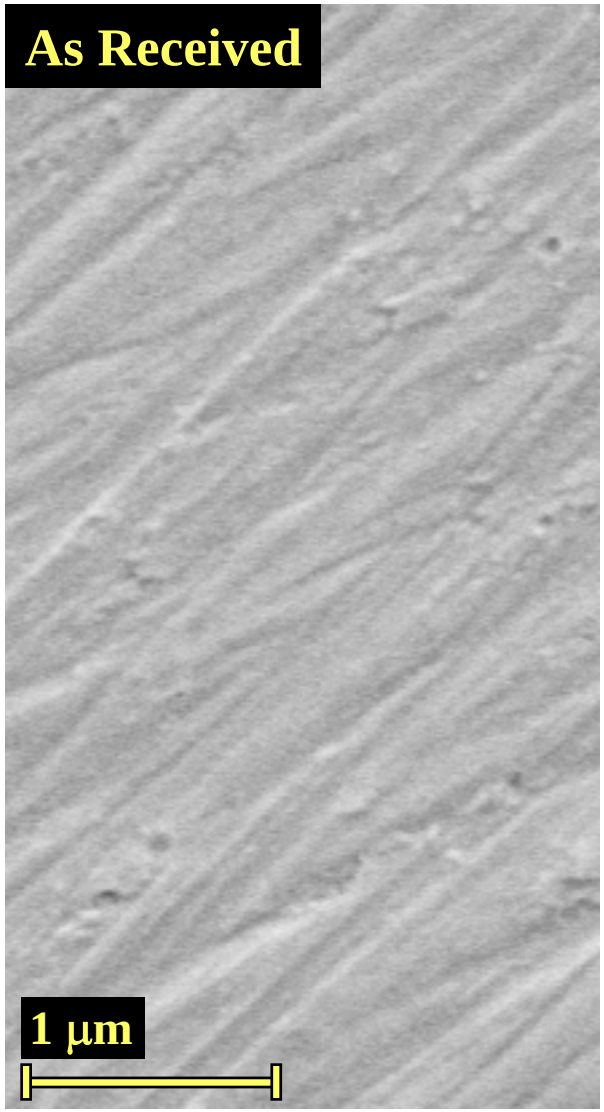
from.R. Raffray

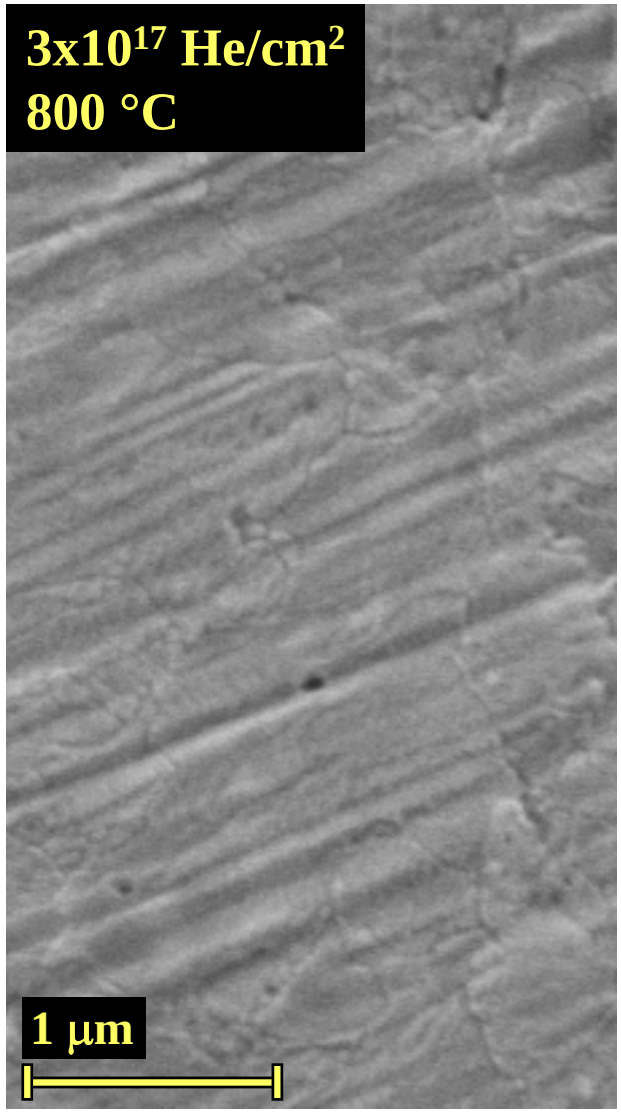
The Helium Ions from a HAPL Target Have a Short Range in W

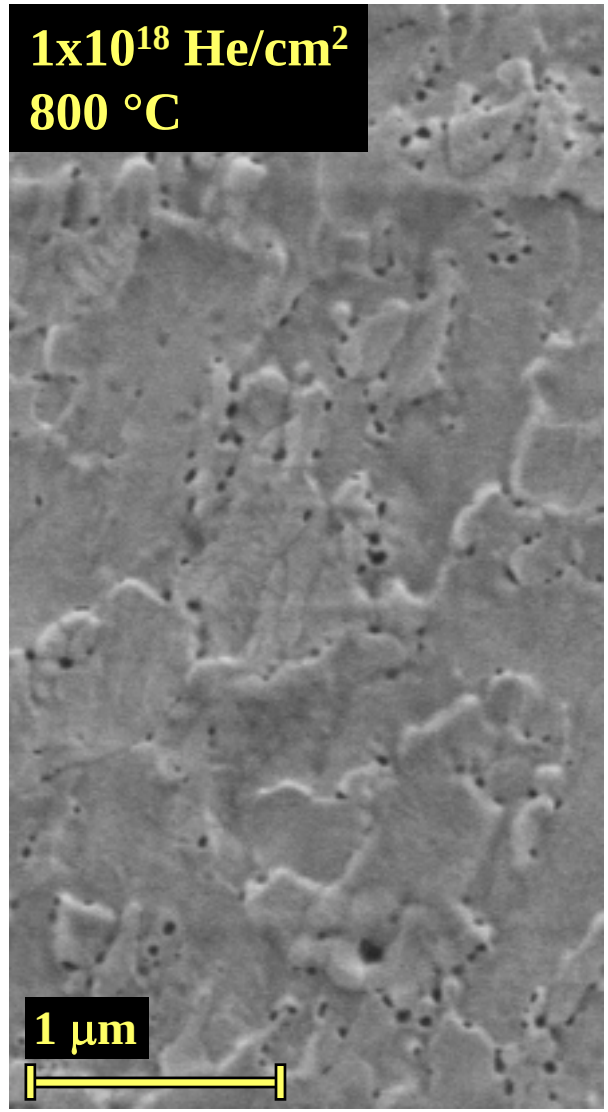


Threshold for Tungsten Pore Formation

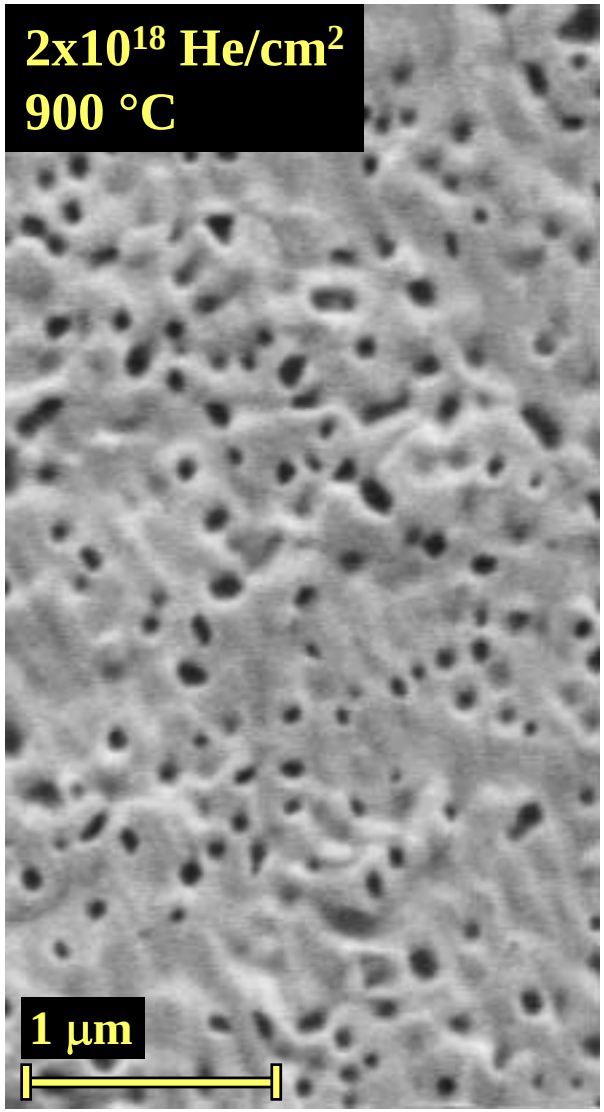
$<1x10^{18}$ He/cm^2 (30 keV He on W $7x10^{15}$ ions/cm^2-s)

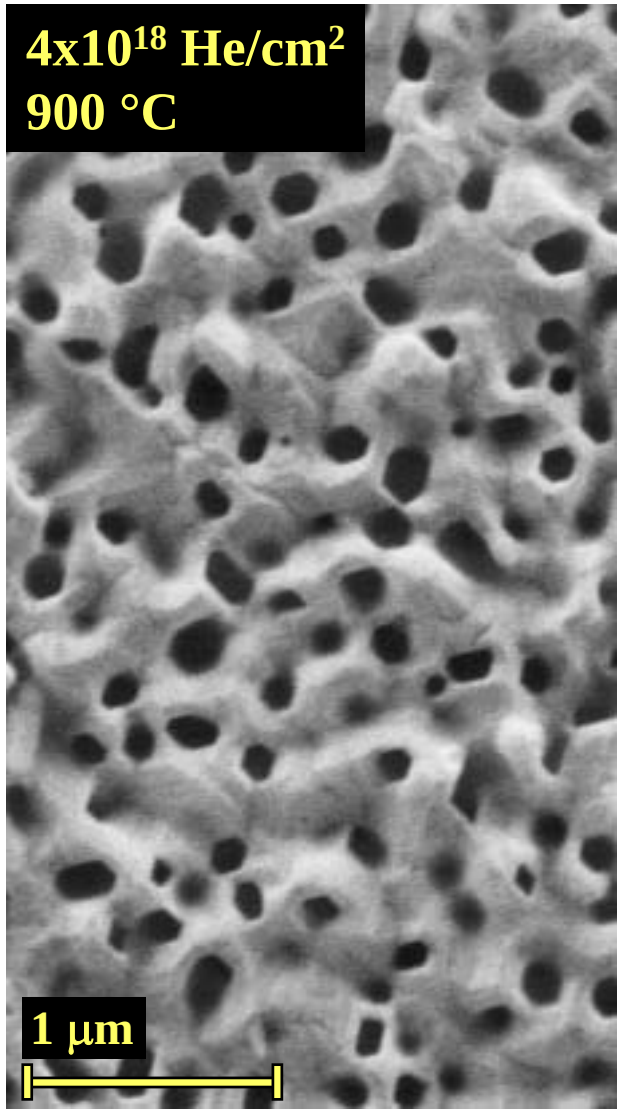


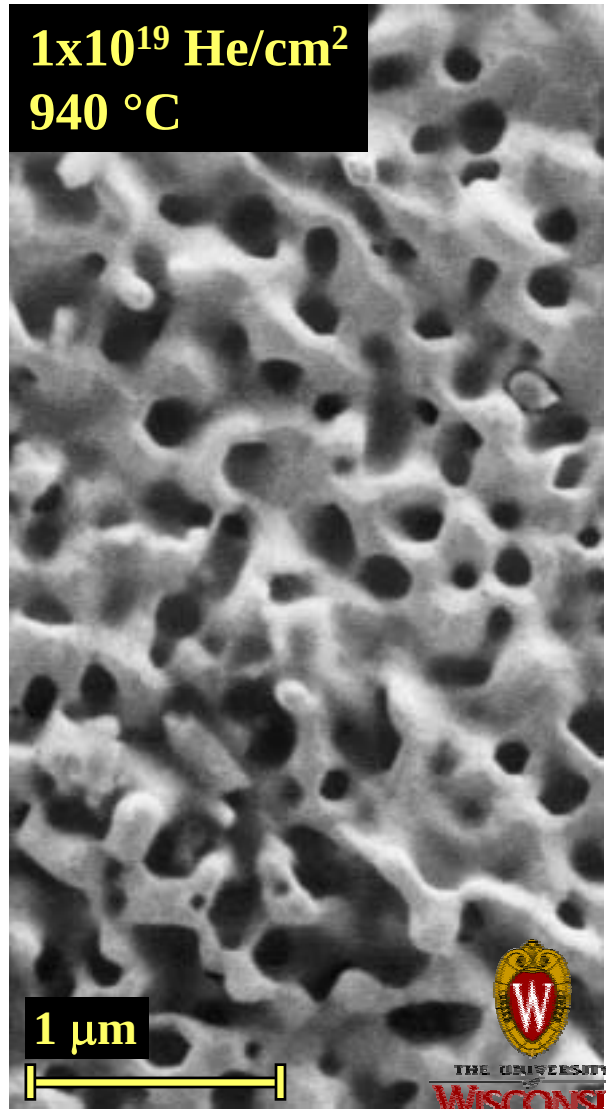




Tungsten Pore Structure Stabilizes at ~4x10^{18} He/cm^2 (30 keV He on W-7x10^{15}ions/cm^2-s)

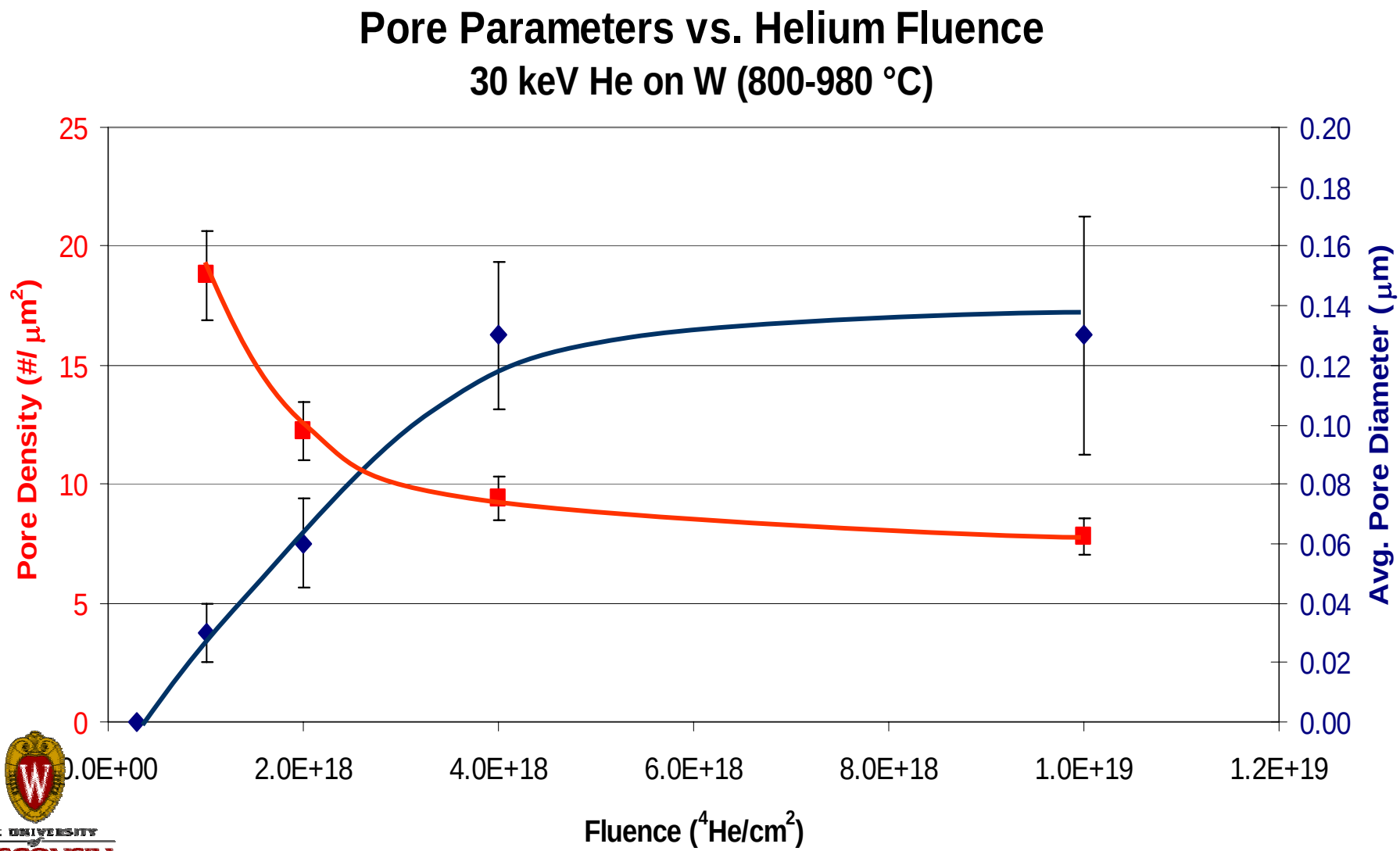






THE UNIVERSITY WISCONSIN MADISON

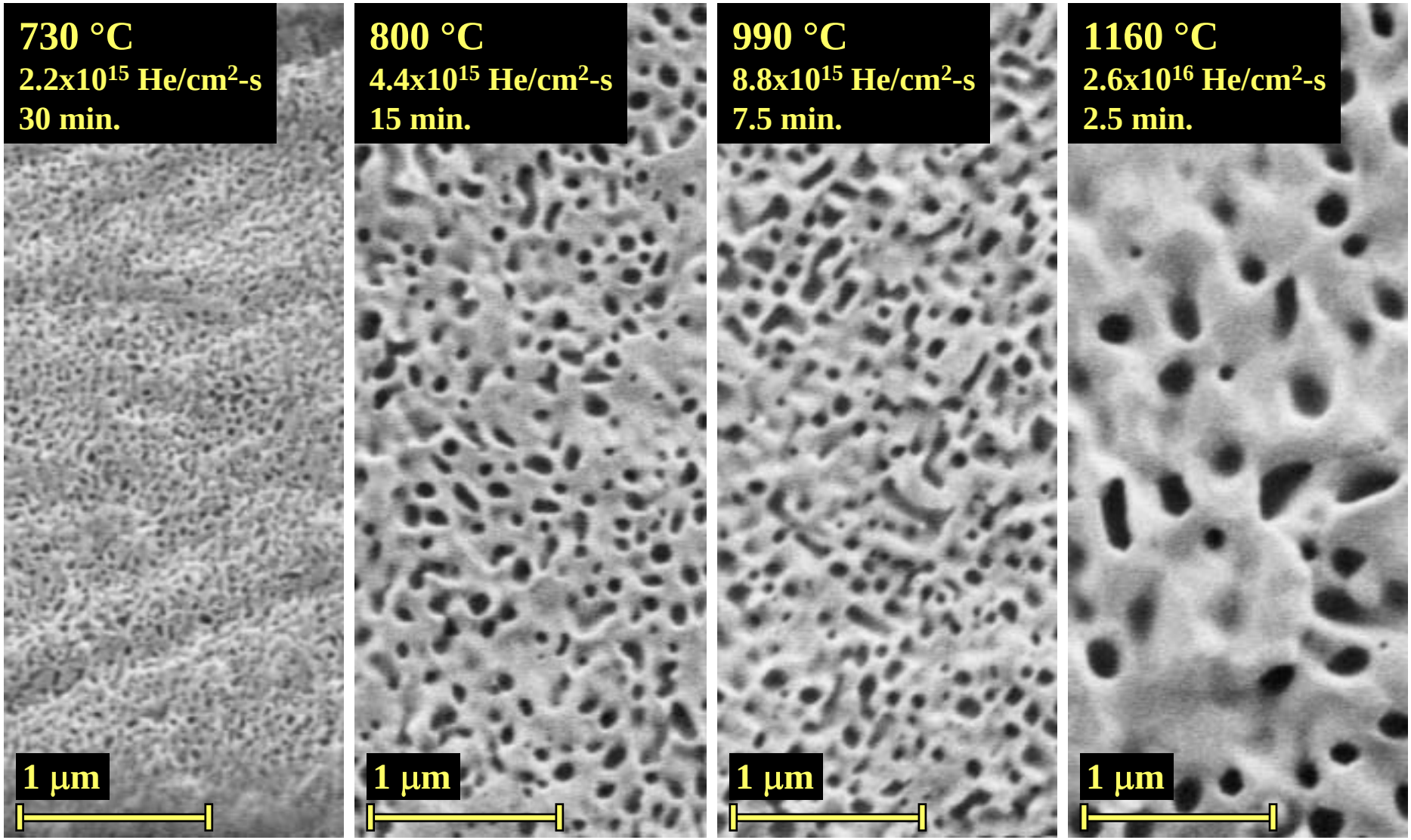
Pore Diameter Increases with Increasing Fluence while Pore Density Decreases



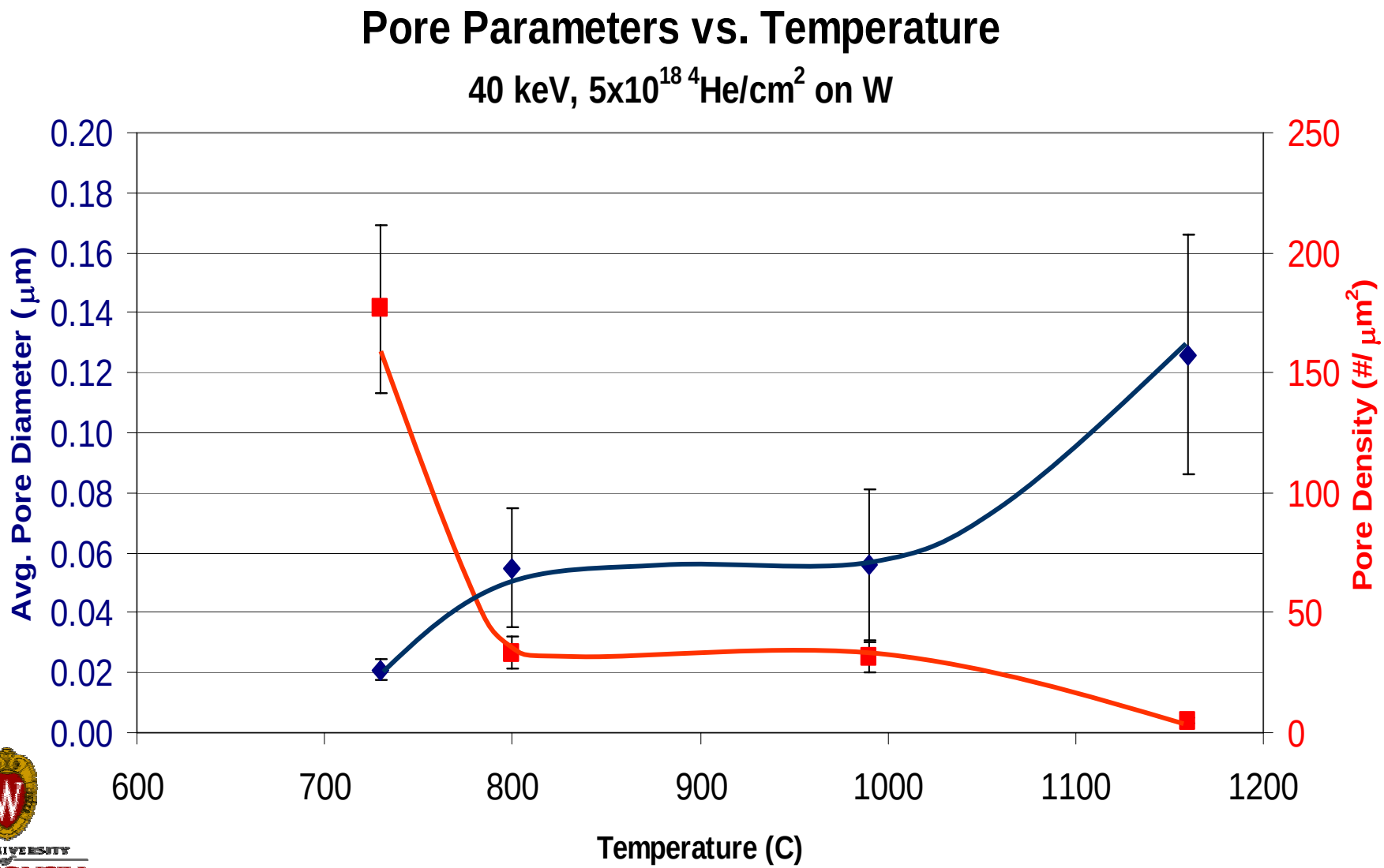
THE UNIVERSITY of WISCONSIN MADISON

Pore Size Increases with Temperature

(40 keV He on W $5x10^{18}$ ions/cm^2)



Pore Diameter Increases with Increasing Temperature while Pore Density Decreases



THE UNIVERSITY of WISCONSIN MADISON

Conclusions

- Threshold for pore formation in tungsten at 800 °C is < $1x10^{18}$ He/cm^2 (30 keV)
- Pore diameter saturates at 0.15 μm and density saturates at 7 pores/μm^2 for 30 keV implantation at ~ $5x10^{18}$ He/cm^2
  - It might suggest that by $5x10^{18}$ @ HAPL wall temperatures, an equilibrium surface condition will be attained
- Pore diameter increases by a factor of 6 and density decreases by factor of 35 when temperature increases from 730 to 1160 °C at 40 keV implantation
- Implantation energies from 20 to 60 keV showed no substantial difference in surface structure

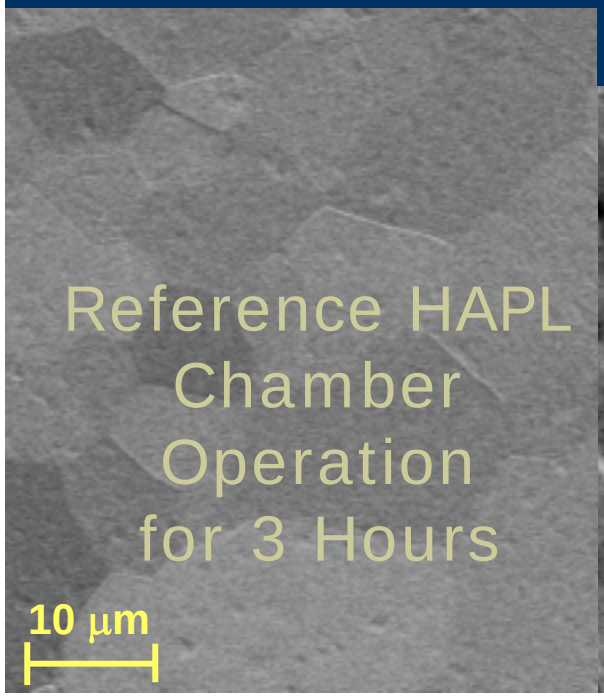
Future Work

- Repeat experiments with simultaneous deuterium implantation
- Determine density depth profile of helium in tungsten using elastic recoil detection
- Push towards higher energies (~100 keV)
- Consider implantation in W-Re alloy

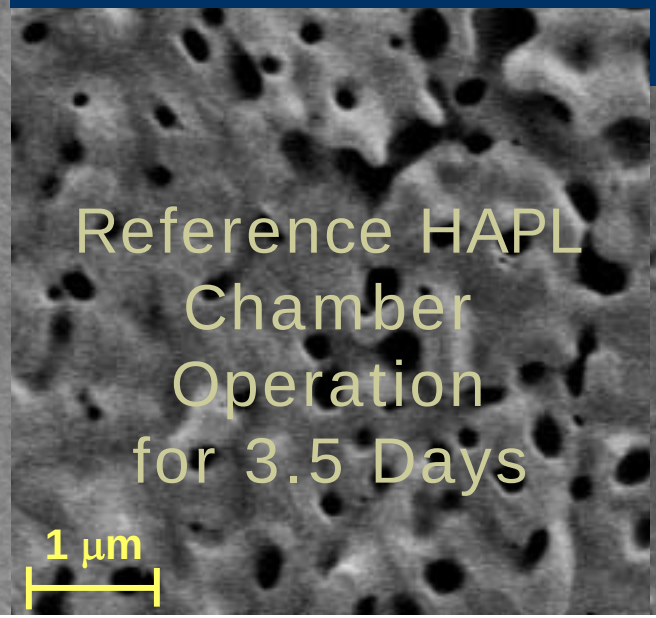
End of Talk

Preliminary Conclusions

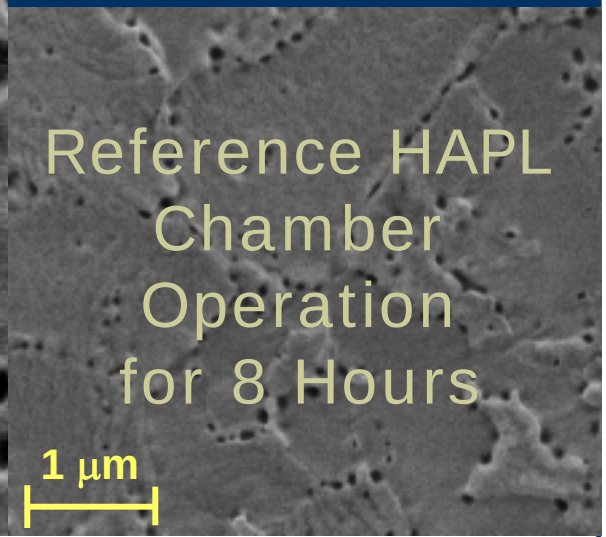
At 1100-1300 °C, $2x10^{19}$ D^+/cm^2 implantation produced no blistering



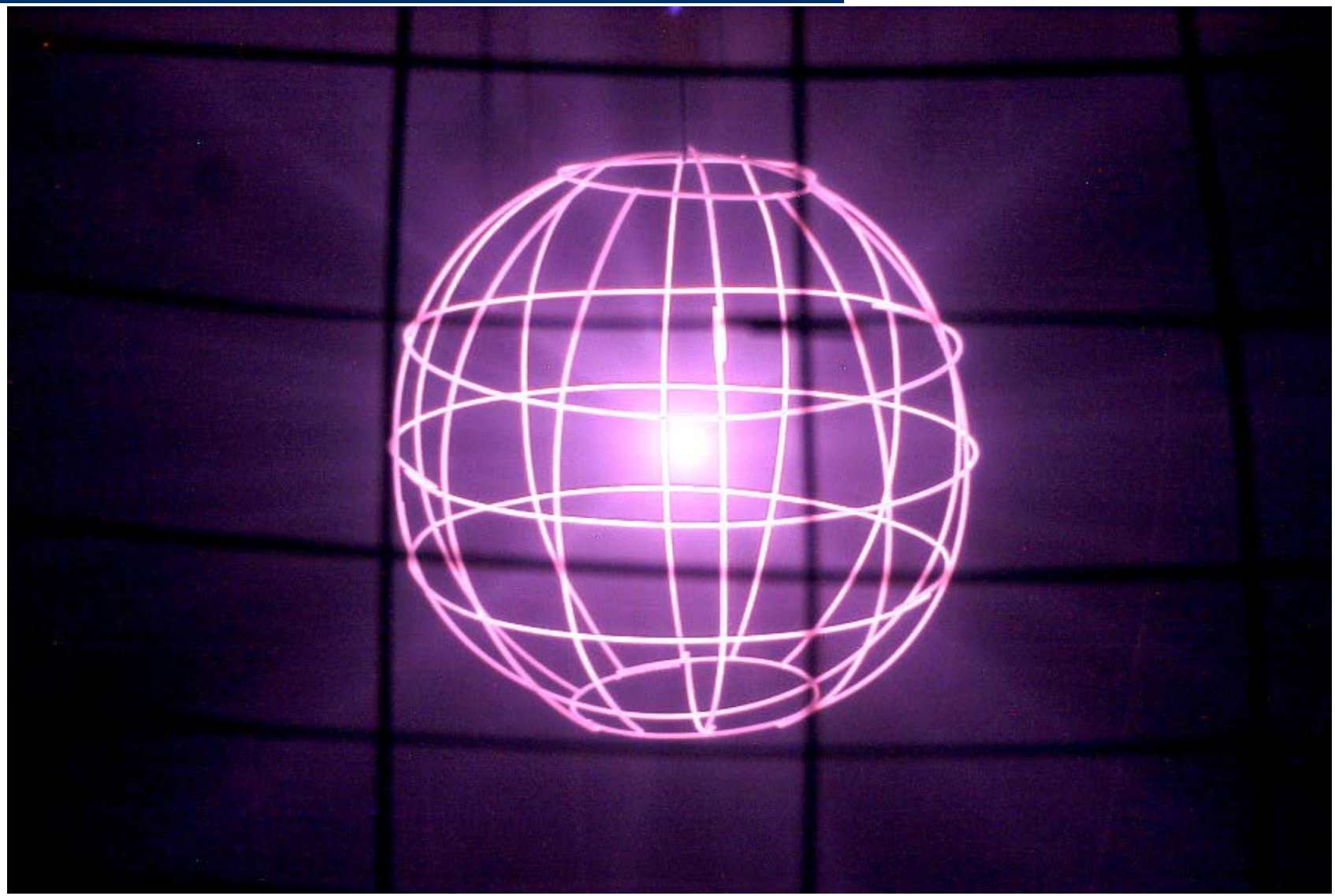
At 1200 °C, $6x10^{18}$ He^+/cm^2 implantation produced "pinhole" porous surface structure



At 1100 °C, $6x10^{17}$ He^+/cm^2 implantation produced helium bubbles that decorate the grain boundaries

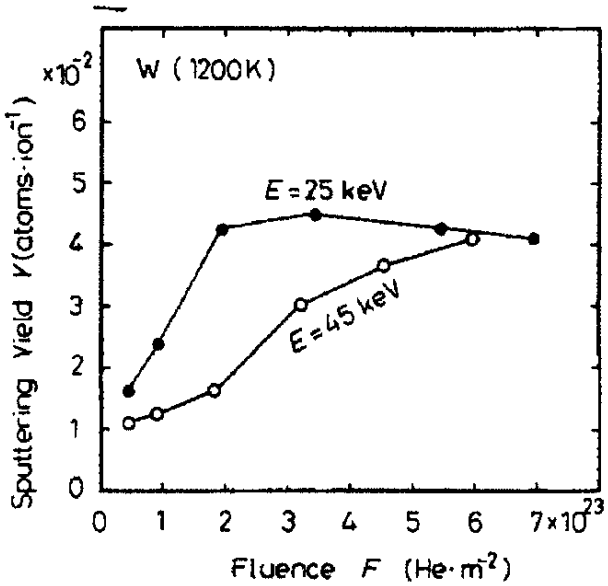


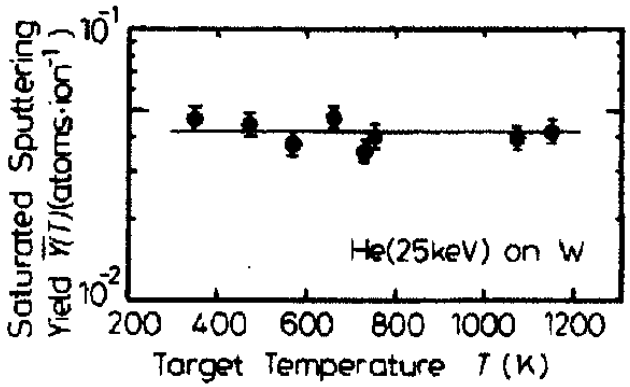
Steady State D-^{3}He Fusion in the UW IEC Device



Helium Sputtering Yield on Tungsten

- Sputtering yield saturates at ~ 0.04 for 25 keV helium on tungsten at 1200 K
- Saturated yield is constant with temperature
- Assuming 1.7×10^{18} $^4He/cm^2/day$ (on the HAPL chamber), a sputtering yield of 0.04 would result in a loss of 3.9 μm/year (This is only due to the helium)





M. Tomita & K. Masumori, *Nuclear Instruments & Methods in Physics Research.* (1989) **B39,** 95

Helium Implantation in Tungsten

B.B. Cipiti & G.L. Kulcinski

February 6, 2004

Fusion Technology Institute
University of Wisconsin-Madison