Nickel Alloys as Fusion Reactor Plasma-Facing Materials

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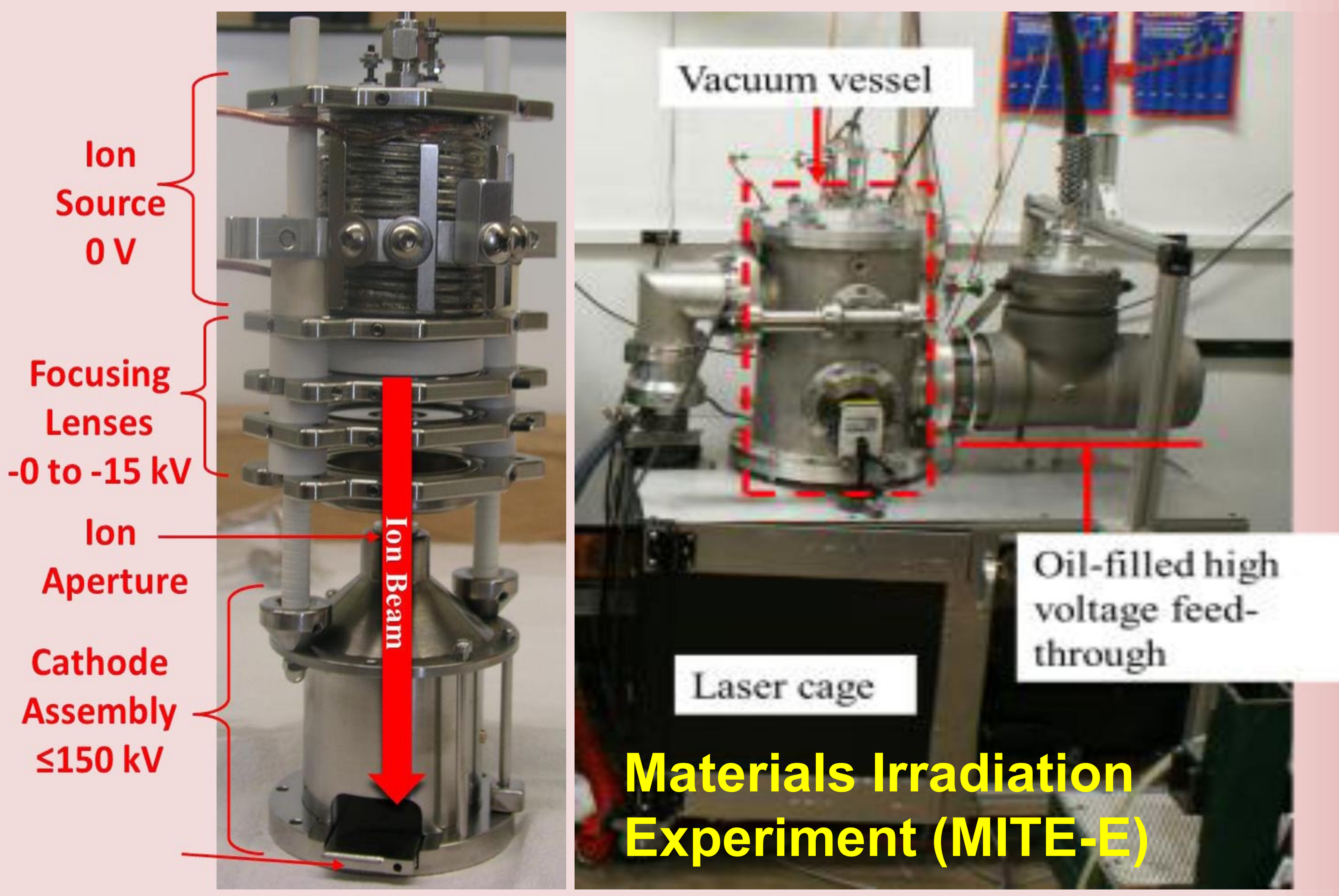
Motivation

- Metals used to confine hot plasmas are important to fusion reactor operation.
- Fuels used in fusion reactors will produce large amounts of energetic particles that will erode the plasma-facing material.
- Possible fusion reactor fuels producing energetic particles: DT, DD, D^3He, $p^{11}B$.
- Exploring the properties of nickel alloys will:
  - Define the operating temperature range for nickel alloys.
  - Resolve the maximum fluence of H and He allowed for nickel alloys as plasma-facing components.

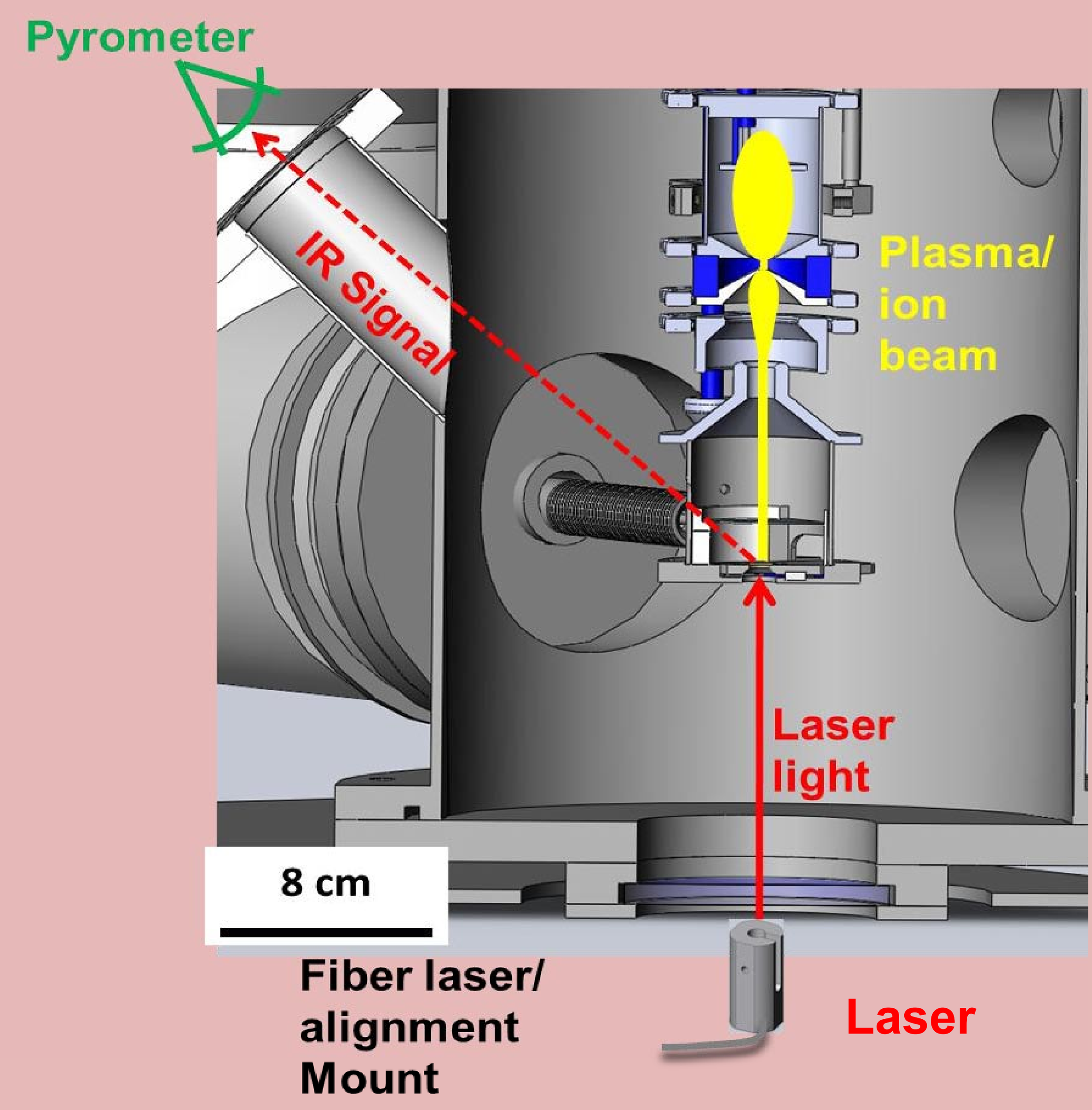


MITE-E ion gun and chamber.

Nickel Alloys Considered

- Inconel: Ni-Cr-Fe
- Incoloy: Ni-Cr-Fe-Cu

(Only primary elemental components listed.)



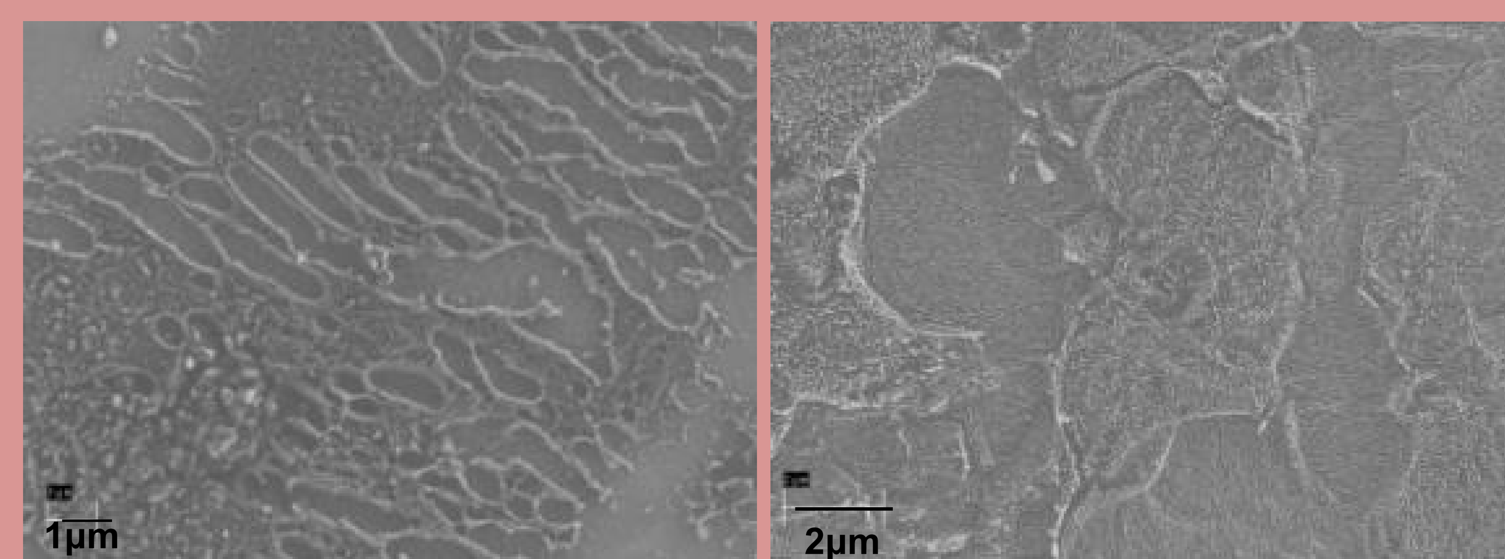
Solidworks™ model of the inside of the MITE-E vacuum vessel.

Material Testing

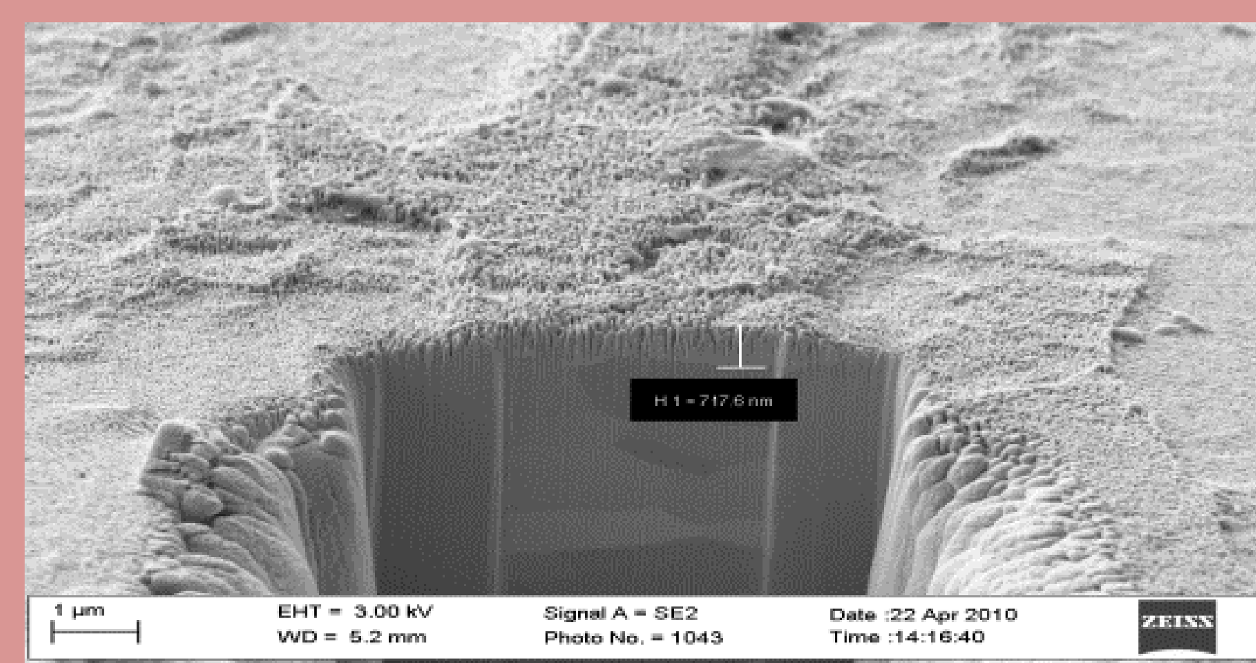
- MITE-E is used to simulate fusion reactor conditions by irradiating metal samples with He or D under specific conditions:
  - Temperature ranges from 500 to 1200 C.
  - Ion energies from 10 to 150 keV with ion currents of 75 3.8 μA, yielding a flux of 4.7×10^{14} ions/cm^{2}s.
  - Fluence range is 1.0×10^{17} to 1.0×10^{19} ions/cm^2.
- A variable power Nd:YAG laser provides additional sample heating.
- Sample sizes must be ~ 1cm x 1cm x 1mm.
- Physical changes in a sample are analyzed with the Focused-Ion Beam, Scanning Electron Microscope, mass loss measurements, and other techniques.

Conclusions

- Simulating a reactor setting will help evaluate first-wall use of a nickel alloy.
- It can be deduced from studying W that a reactor plasma-facing material will encounter severe damage.
- Severe damage in W occurs around 900 C and 6.0×10^{18} ions/cm^2.
- It is desired for plasma-facing materials to have a lifetime of 1 year or more due to expense so a suitable material must be found.
- Future work will include analyzing several nickel alloys at 900 C up to a fluence of 1.0×10^{18} ions/cm^2 to demonstrate the effects of He and H on the material.



SEM results for fluences of 1.0×10^{17} (left) and 1.0×10^{19} ions/cm^2 (right) at 900 C.



FIB results for a fluence of 1.0×10^{17} ions/cm^2 at 900 C.

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