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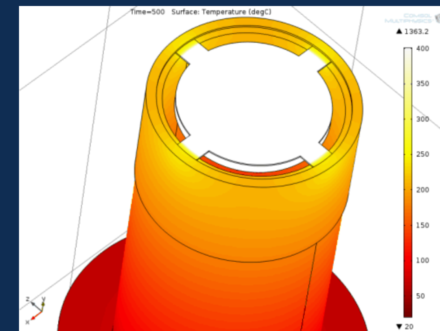

In-Situ Anode Heating and Its Effects on Atomic Constituents in the A-K Gap in Self-Magnetic Pinch (SMP) Experiments

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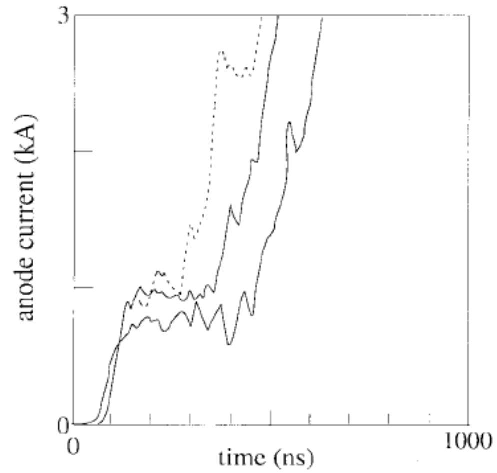
Outline:

- **Why In-Situ Heating?**
- **What Temperature to Clean Tantalum?**
- **Temperature Programmed Desorption (TPD) Results**
- **System Geometry**
- **Results:**
  - **Spectroscopic**
  - **Back-streaming Proton Currents**
  - **Radiographic Performance**
- **Summary**

Why In-Situ Heating?

- The Tantalum surface and bulk material consists of contaminants such as H, H_2O, CO, CO_2, N_2, and O_2
  - Monolayers form even in vacuum – requiring in-situ heating to remove contaminants with binding energies > 50 kJ/mol [3,4]
- AK Gap closure rates may be dependent on low-Z back-streaming ions
  - Thought to be dominated primarily by H and H_2O [7]
- Temperatures as low as 650 ºC can be used to remove most of the H and H_2O at pressures of ~10^{-6} torr
  - May improve pulse duration by drastically reducing the number of contaminants which contribute to A-K gap closure causing impedance collapse.[8]
- Understanding and controlling the overall surface and bulk contamination should:
  - Reduce risk of premature impedance collap
  - Improve reproducibility
  - Improve beam spot size
  - Extend the radiographic pulse
  - Increase the overall x-ray dose [4]



Delayed impedance collapse resulting from anode cleaning. Graphic from [8]

What Temperature to Clean Ta?

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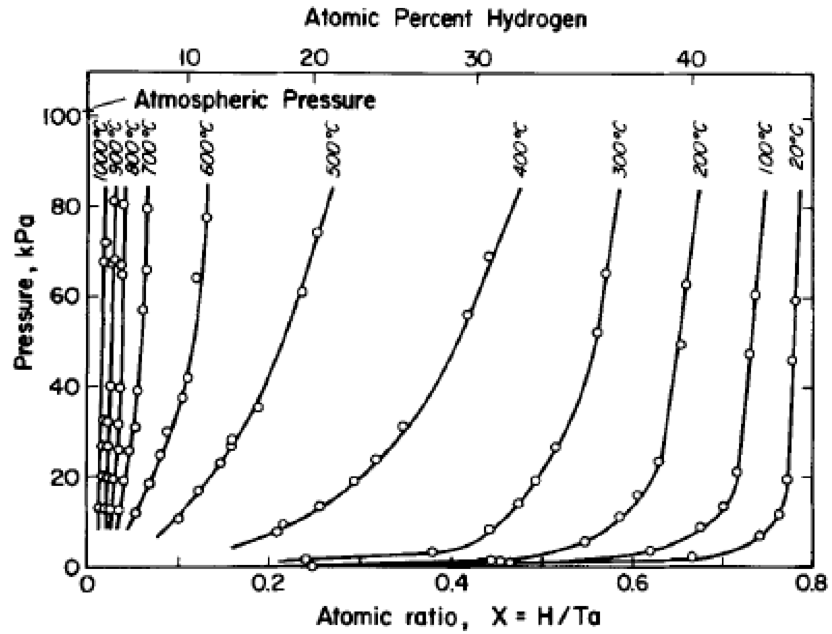
- **Isotherms for Ta-H composition indicate that an increase in T while in vacuum results in less H in/on the bulk Ta.**
- **H readily desorbs for T > 650 ºC [1]**
- **CO desorbs for T > 1600 ºC [1]**
- **O_2 and N_2 desorbs for T > 2000 ºC [1]**
- **Commercially available Boronitride heating elements can easily achieve 1200 ºC**

- **Our final design can achieve temperatures of ~850 - 1200 ºC**
  - **But what can be cleaned at these Temps?**

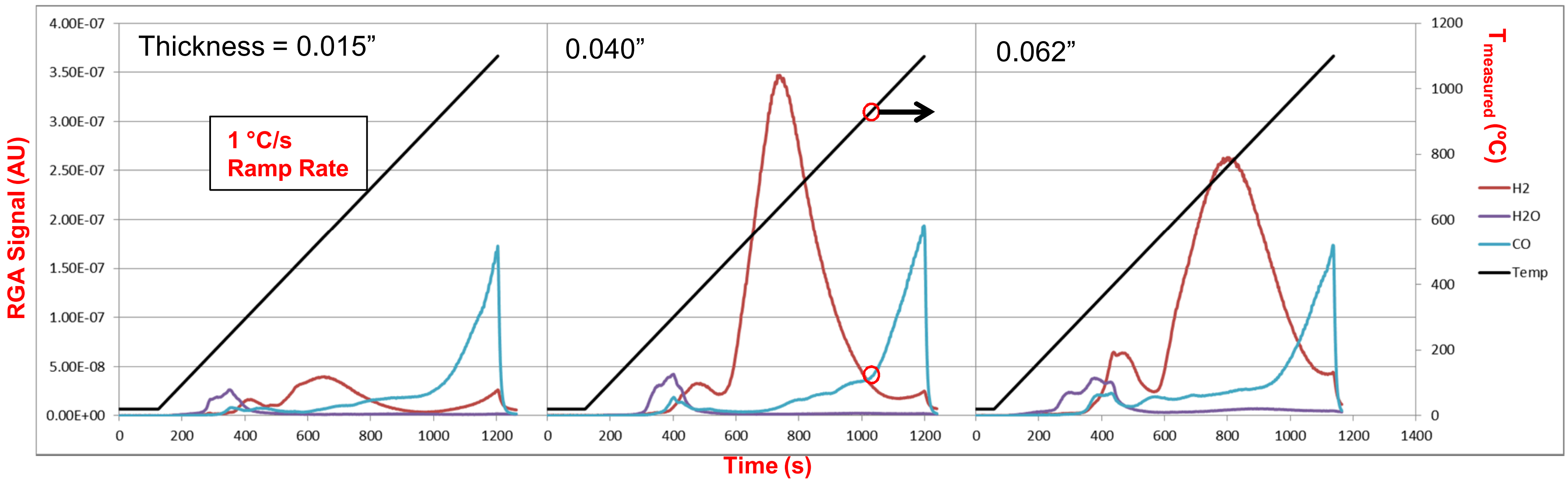


Ta-H Pressure Composition Isotherms

The H-Ta (Hydrogen-Tantalum) System,
A. San-Martin and F.D. Manchester
Journal of Phase Equilibria Vol. 12 No. 3 991

TPD Results for Varying Thicknesses of 1” dia. Ta

Partial Pressures for H_2, H_2O, and CO vs. Time

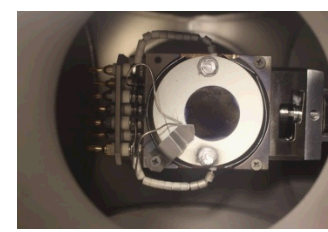


H_2 peak at T= 548 °C
H/Ta = 0.067
~.00119 mols of H

H_2 peak at T= 640 °C
H/Ta = 0.147
~.00696 mols of H

H_2 peak at T= 764 °C
H/Ta = 0.093
~.00683 mols of H

CO beginning to outgas at end of TPD ramp (~925 - 1100 °C)

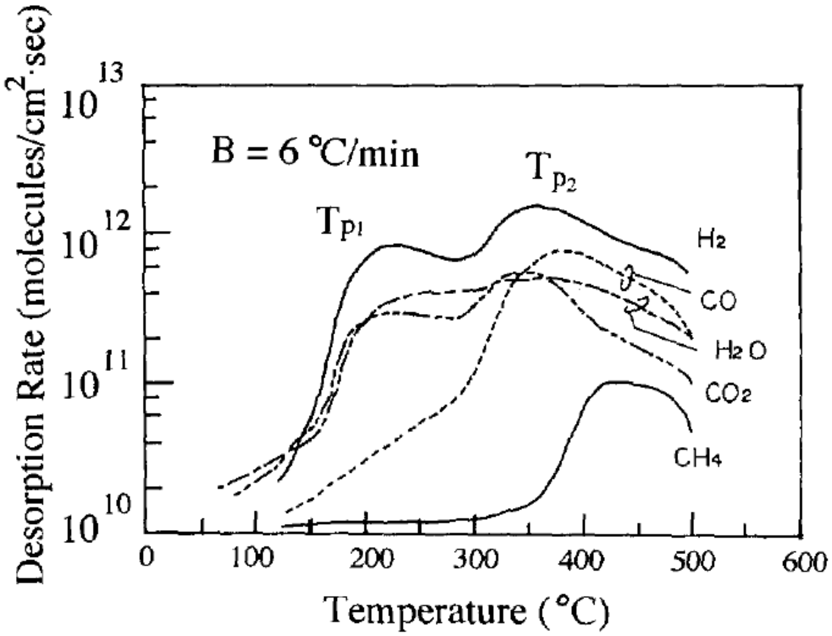


- First H_2 peak may be surface reactions[10] corresponding to monolayers, or desorption of β-phase Ta-H
  - Both of which have lower binding energies
- Nearly equivalent H_2O and CO curves indicates these are evolving from the surface
- CO starts to desorb fairly rapidly for T > 925 °C
  - Desorption of CO may be responsible for the increase of H at t = 1000 s as the CO reacts with the H_2O on the chamber walls releasing CO_2 and H_2

TPD Results for Aluminum

- Al Foils and Al coated Ta targets used on RITS
  - Foils are 99% pure Al
  - Al Coated Targets should be of higher purity but have not been analyzed
- Based on [10], most contaminants rapidly desorb by 450 °C
  - Need to characterize our materials
- Al Coated Ta and Al Foils should be cleaner than bare Ta

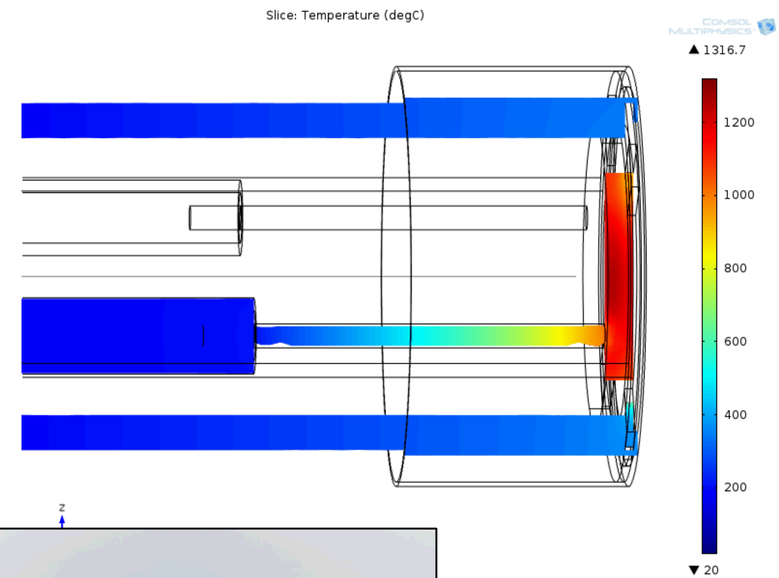
Thermal Desorption Curve of Pure Aluminum[10]

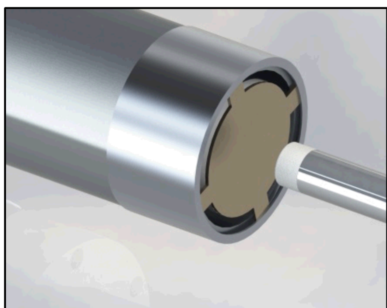


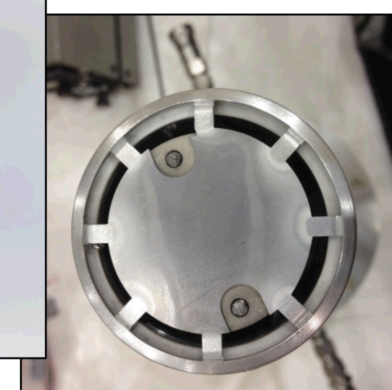
[10] Y. Hirohata, *et al*, *Hydrogen Desorption Behavior of Aluminum Materials Used for Extremely High Vacuum Chamber,* J. Vac. Sci. Technol. A, Vol. 11, No. 5, Sep/Oct 1993

System Geometry

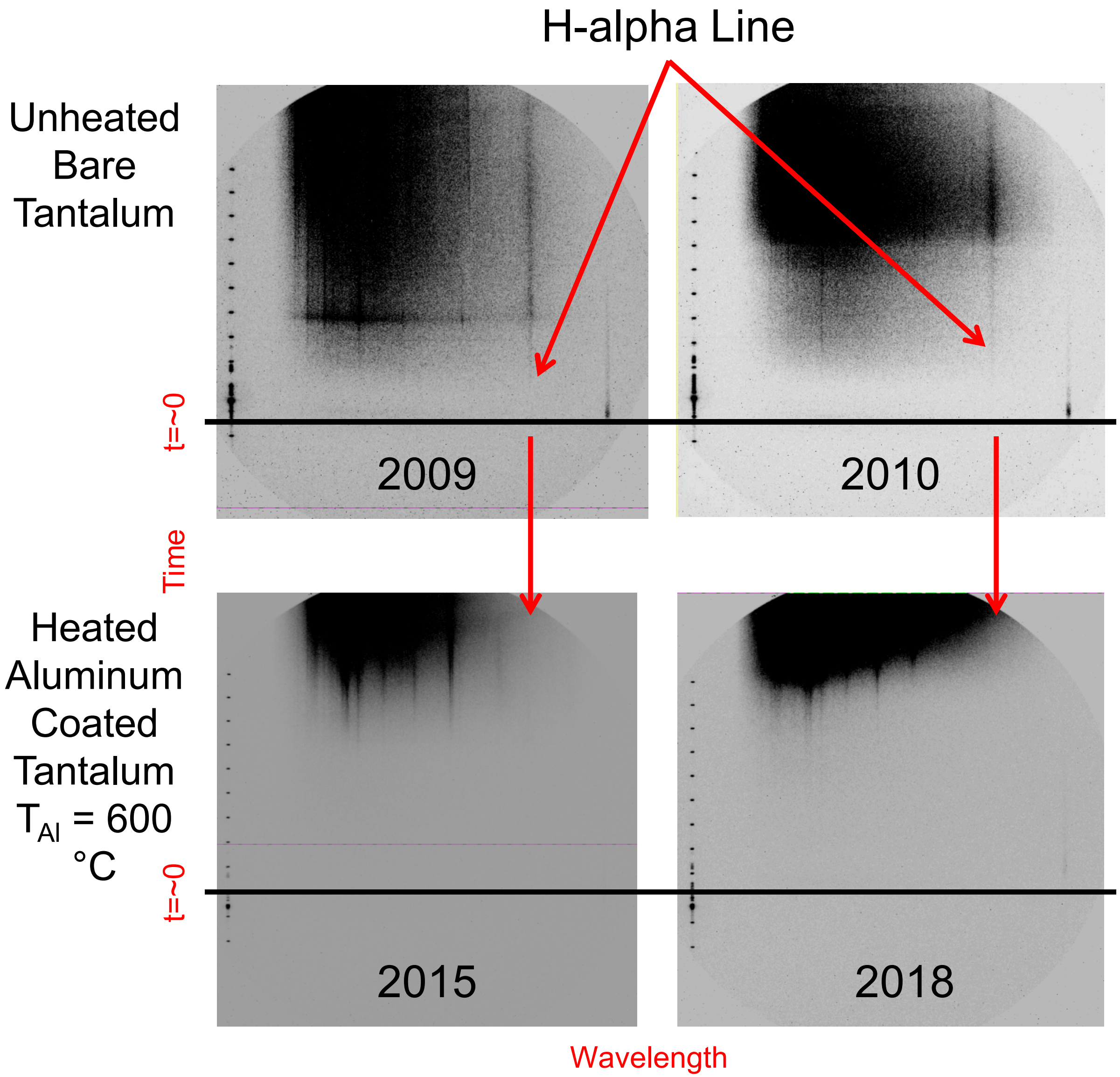
- Redesigned existing hardware to achieve T up to 1200 °C @ BN Heater
- 1200 °C @ BN corresponds to ~850 °C on the surface of Ta converter







Results: Streak Spectroscopy



- In unheated shots, strong H-alpha lines are present early on.
- Both the heated bare Ta and the Al coated Ta show a huge reduction in H-alpha as well as other constituents.

Images courtesy of S. Patel and M. Johnston

Results: Back-streaming Protons

- Measurements via Cu Coupon Activation
- Non-heated Configurations:
  - Average proton current of 2.34 kA
- Heated Configurations:
  - Proton current is undetectable using our existing measurement technique

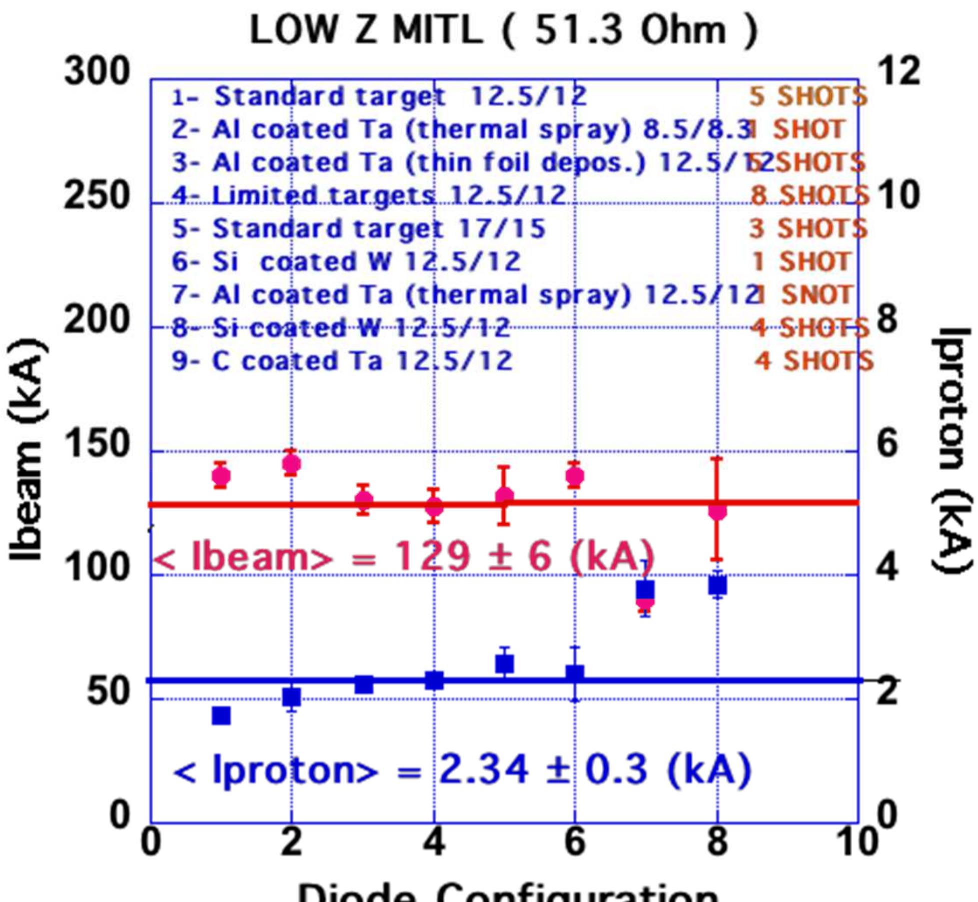
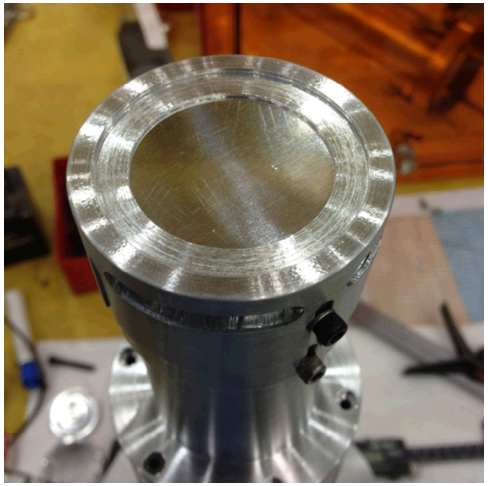
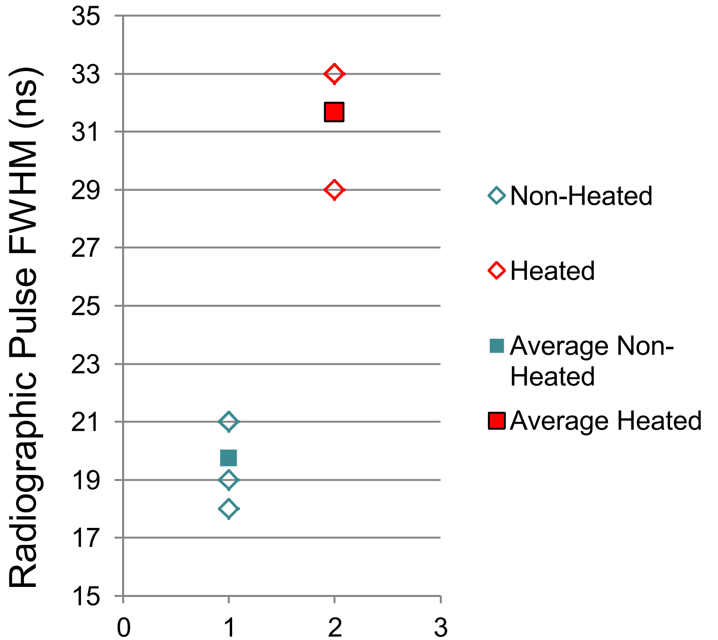


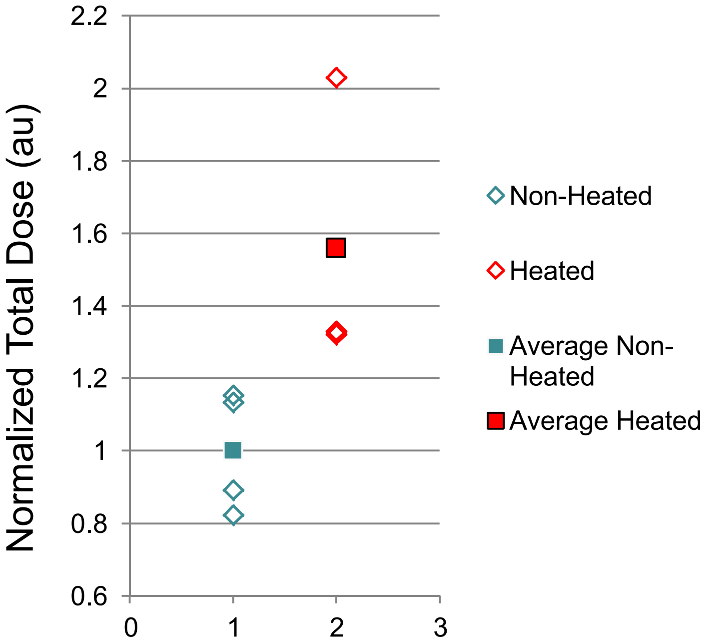
Image courtesy of M. Mazarakis

Results: Radiographic Performance

- 8.5mm Cathode with 8.3mm A-K Gap with Al Foil and Ta Converter:
  - Comparing Non-Heated Shots 1772, 1773, 1774, 1825 and Heated Shots 2031, 2033, 2034
  - Average non-heated duration = 20 ns; average heated duration = 32 ns
  - Average heated dose is 55% higher than non-heated geometry







Summary:

- Fielded first ever in-situ heating geometry on RITS-6
  - Demonstrated ability to deplete inventories of H_2 and H_20 from Ta converter and Al foils and coatings
    - Reduced other molecular constituents as well
  - Spectroscopy measurements indicate drastic reduction of H_2 present in the A-K gap
  - Back-streaming proton current reduced to undetectable levels
  - Demonstrated extended pulse durations and increased x-ray dose for 8.5/8.3 Foil Geometry
- Next Step:
  - Design a system capable of T > 2200 ^oC
  - Plasma Glow Discharge Cleaning + High Temp Cleaning
  - Explore smaller A-K configurations

Questions?

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