Production Manufacturing of Depleted Uranium Hohlraums for the National Ignition Facility (NIF)

20th Target Fabrication Meeting

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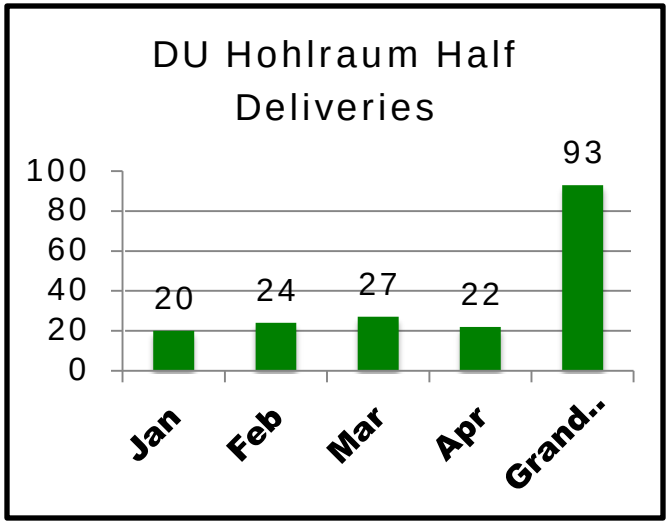
GENERAL ATOMICS

DU hohlraums are regularly fabricated for NIC experiments

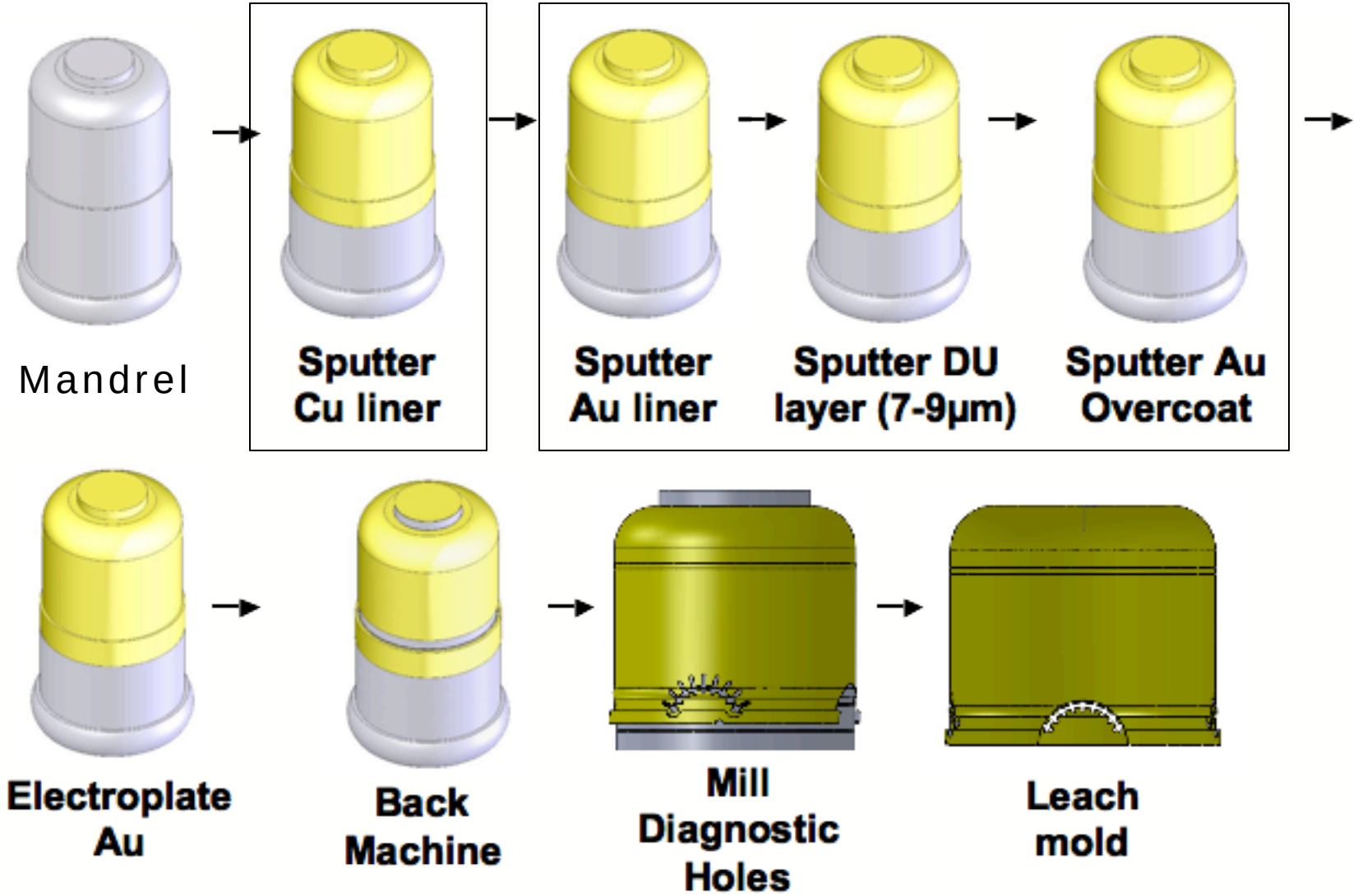
- GA shipped over 90 DU components in 2012
- DU targets are regularly assembled & shot on NIF

- DU provides higher hohlraum drive
- DU = Au for "neutron yield" with 25 TW less laser power

- <u>Less laser optics damage!</u>

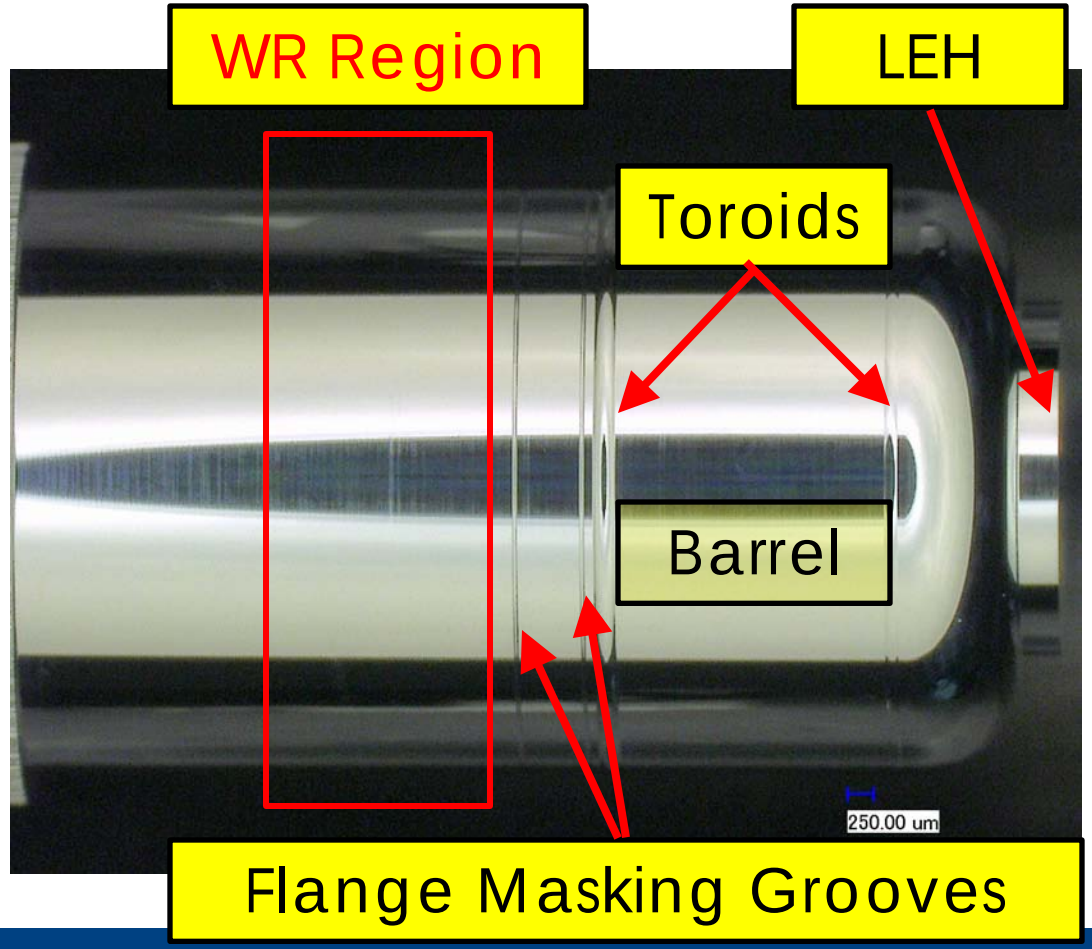


DU Hohlraum production process is composed of 9 steps utilizing two coating systems



Al mandrels are single point diamond turned to an RMS roughness < 60 nm

- **This level of precision is required to meet the 200 nm spec**

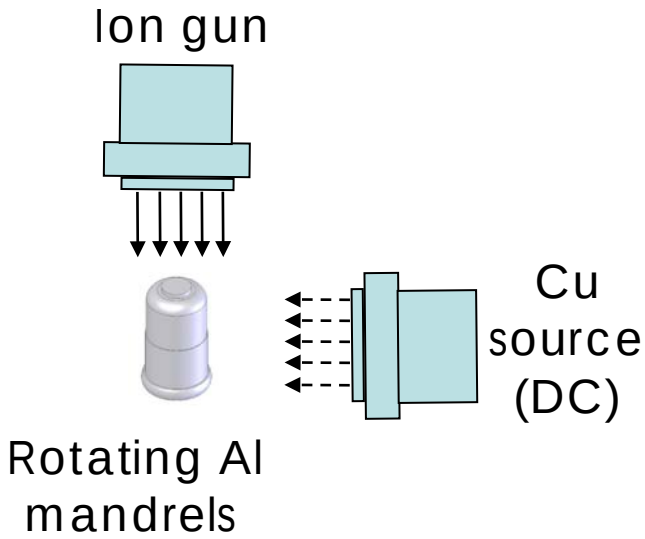


Cu is deposited as barrier layer to protect DU from leach chemicals

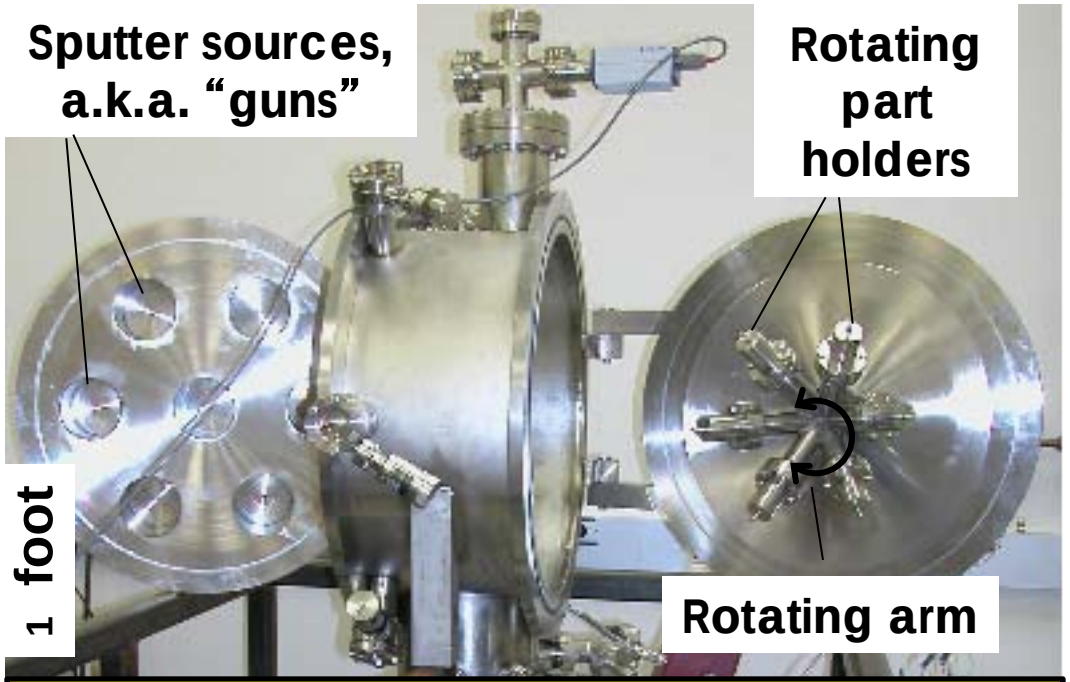
- Ion etch removes Al oxide preparing the surface prior to Cu deposition
- Hohlraum ID is determined by OD of sputter Cu layer. This layer thickness is monitored by QCM.

Cu coater setup

Cu coater configuration

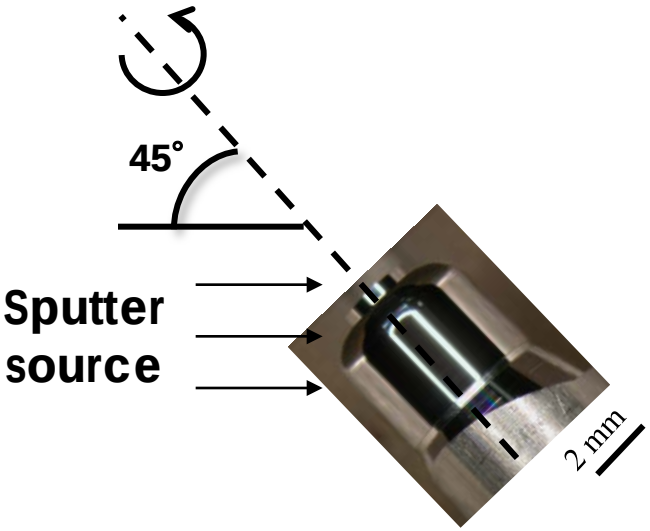


Au liner and DU layer are deposited at 45º angle to cover of all surfaces



DU Coater

Orientation to gun



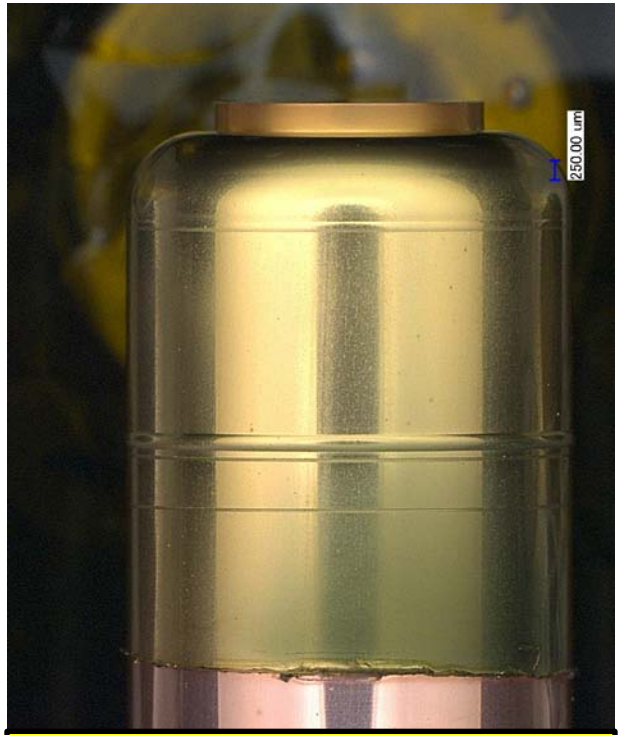
Rotating Al mandrel onto which material is sputtered

Important to minimize DU oxidation

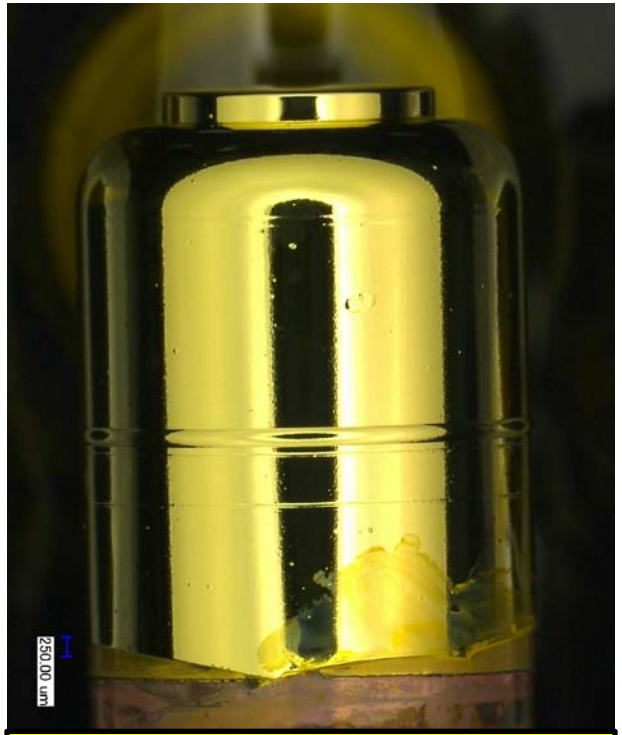
- Base pressure - high 10^{-8} Torr
- Monitor process with residual gas analyzer (RGA)

Hohlraums are electroplated immediately after coating to minimize air exposure

- GA plates up to 10 components in one batch
- ~ 3.5 hours, additional 18 hrs for thick flange



As coated

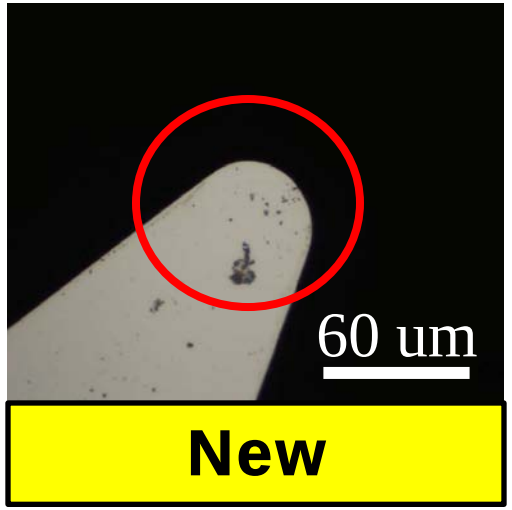


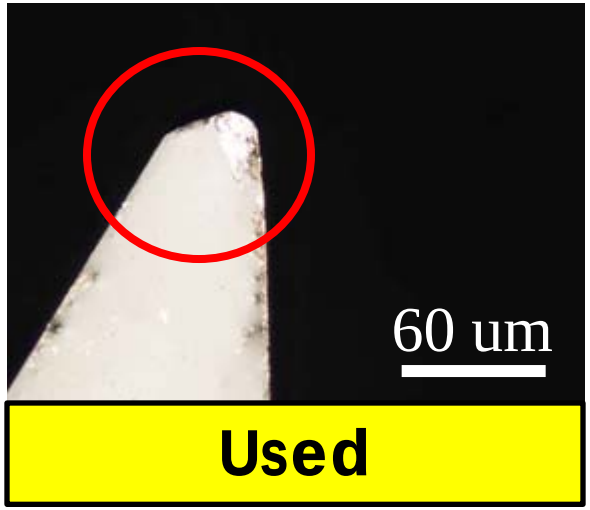
After E-plating

After Flange

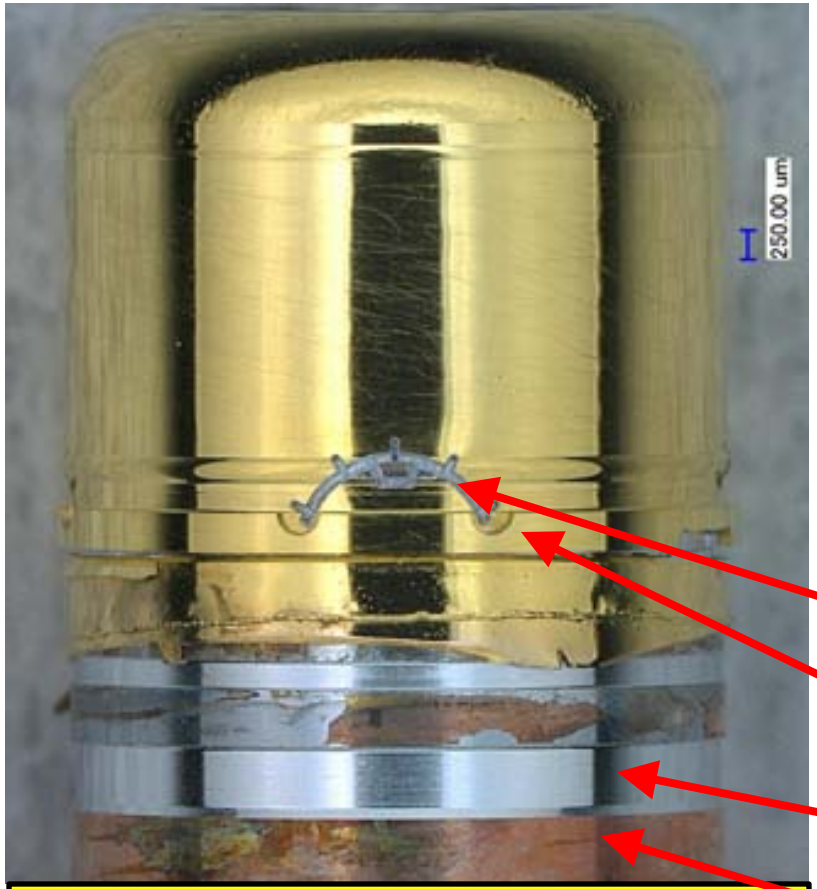
Careful tool management required during final back-machine to achieve specifications

- **Tool wear is significant when machining DU**
  - Tools are changed and refurbished on a regular interval to avoid poor surfaces and to hold proper dimensions and tolerances
  - Two images of diamond tools,
  - Used has 4 hours of DU cutting time.





Milling of various diagnostic features is required to 'see' the experiment*



After Milling

Milled diagnostic feature

- Diagnostic feature
- Thick Au flange
- Back machined to Al
- Cu coating

*Poster Session: Giraldez, Sohn, Price

Gentle leaching minimizes delamination induced by 'dynamic' chemical reactions

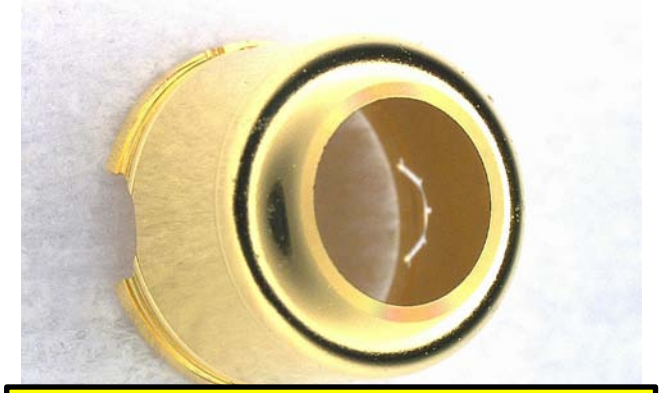
Al Mandrel

- Leached in NaOH
- ~ 48 hr leach time
- Researching decreased leach time
  - Bulk Al removal
  - Increased surface area for NaOH to act on

Cu Barrier Layer

- Leached in NH_4OH – gentle leaching agent
  - HNO_3 causes mechanical failure via hydrogen gas production at DU/Au interface
  - Bubble agitation can induce delamination
- Short dilute acid exposure of 15% HNO_3 removes Al_2O_3 residue after NaOH leach

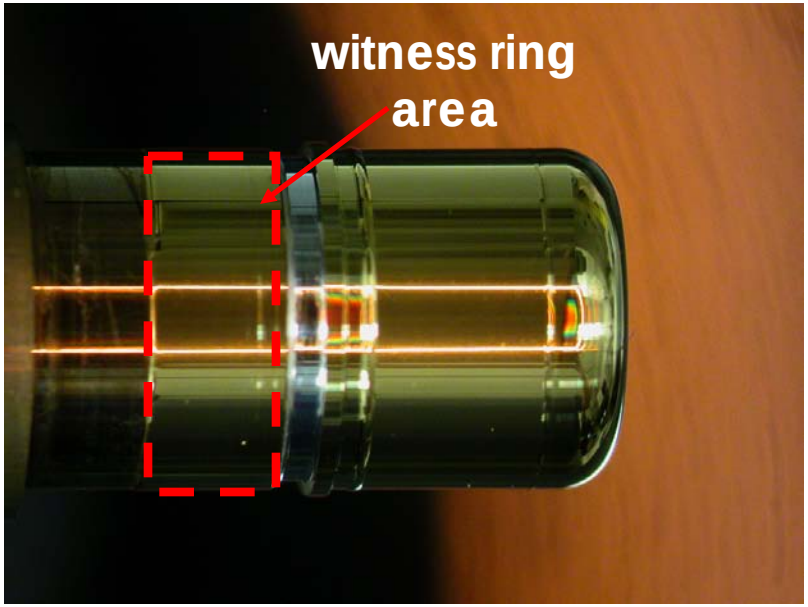
Al_2O_3 residue



Finished Hohlraum

Metrology performed on witness ring avoids destruction of a deliverable part

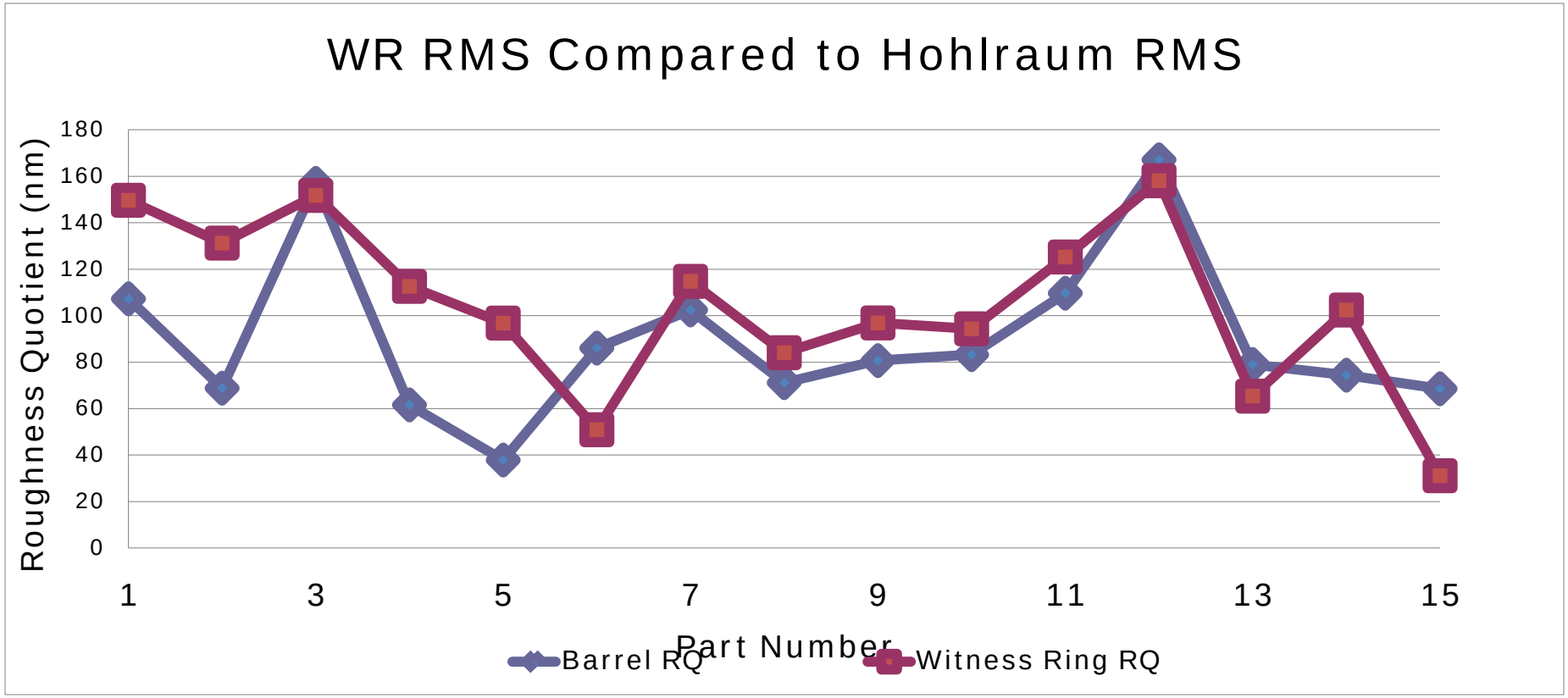
- **Witness Ring goes through all the same processes**
- **Is a good surrogate for 3 critical measurements**
- **100% inspection is possible**



- RMS Interior Roughness
- Au Liner Thickness
- Oxygen At% through bulk

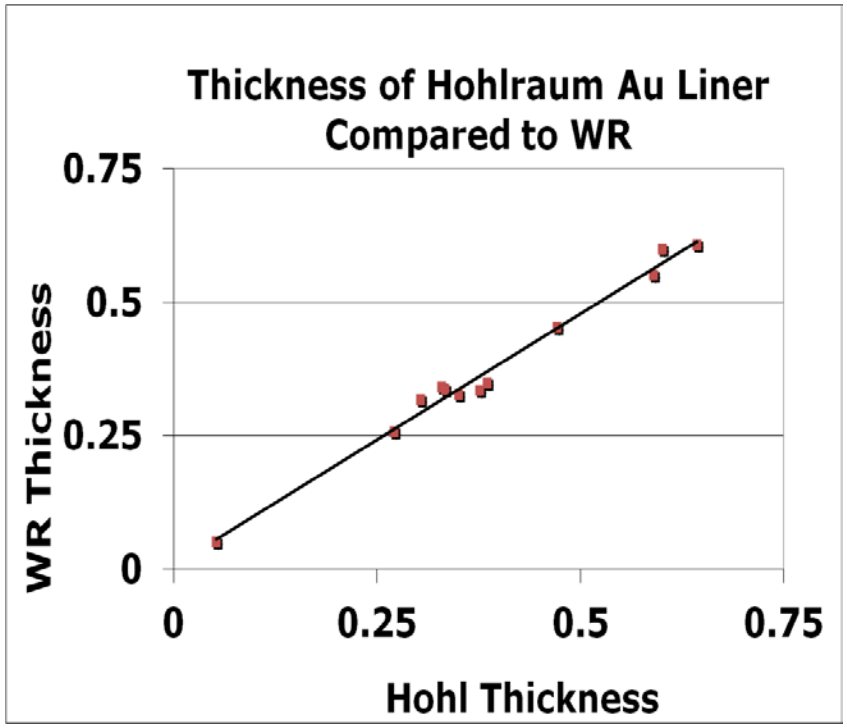
Measured WR interior RMS is within 60 nm of measured interior of the hohlraum

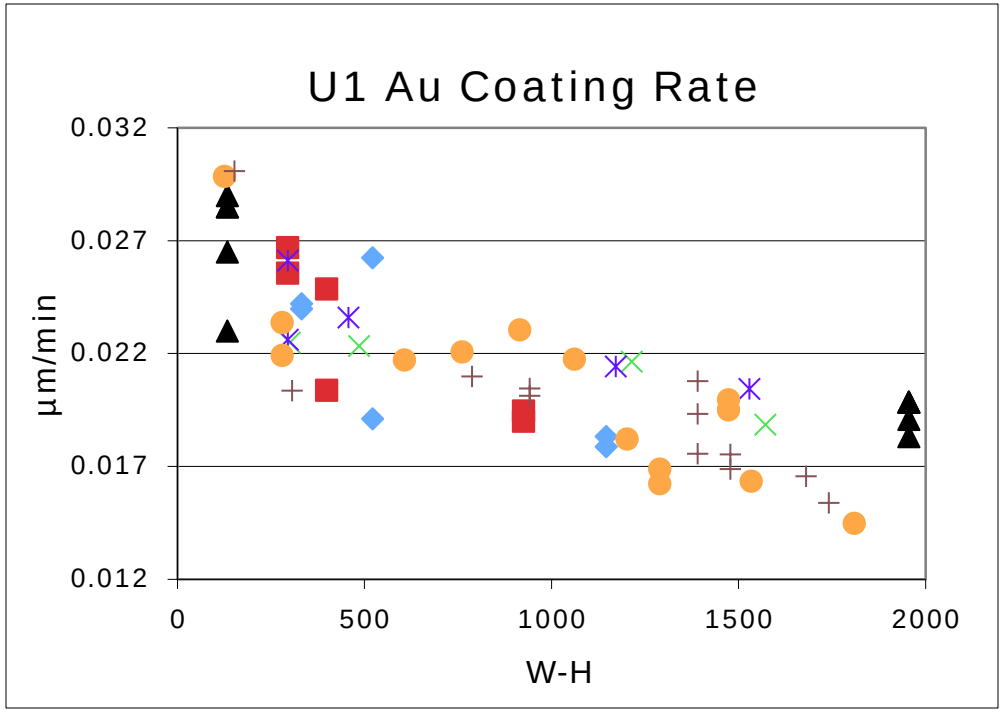
- **RMS can not be measured directly on mandrel due to ion etch in Cu liner step**



Au liner thickness is controlled using a coating rate model based on Au target usage

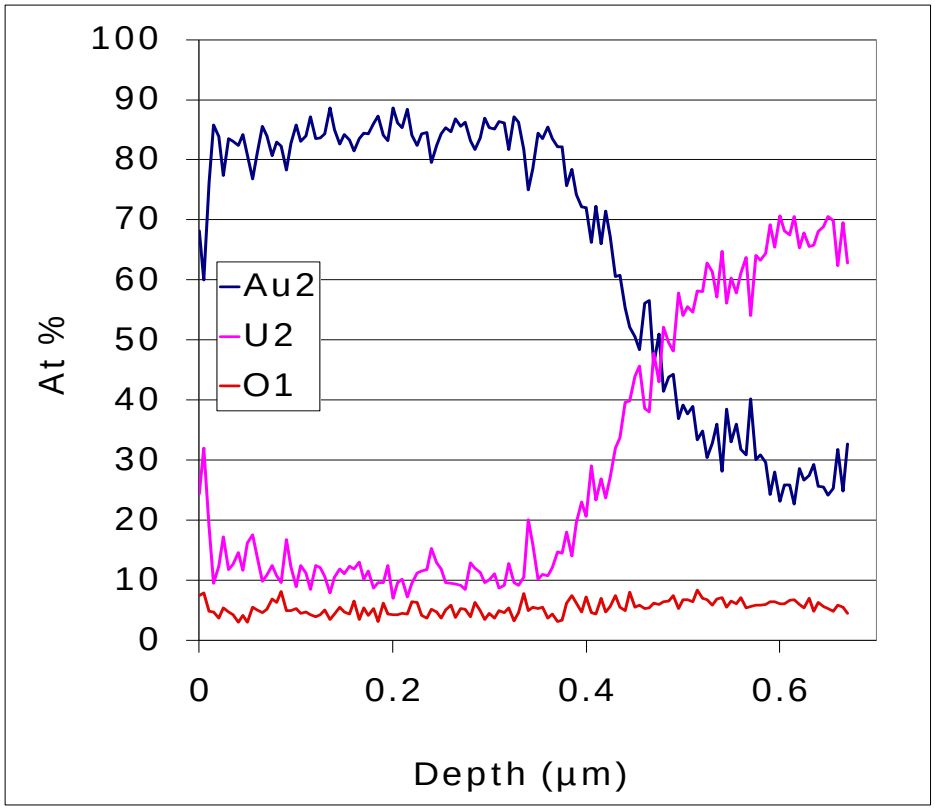
- Au liner measure by XRF and double checked by AES
- 0.5 µm Au foil standard is measured and the WR data is checked against the standard
- Trend model is accurate for 90% of coatings





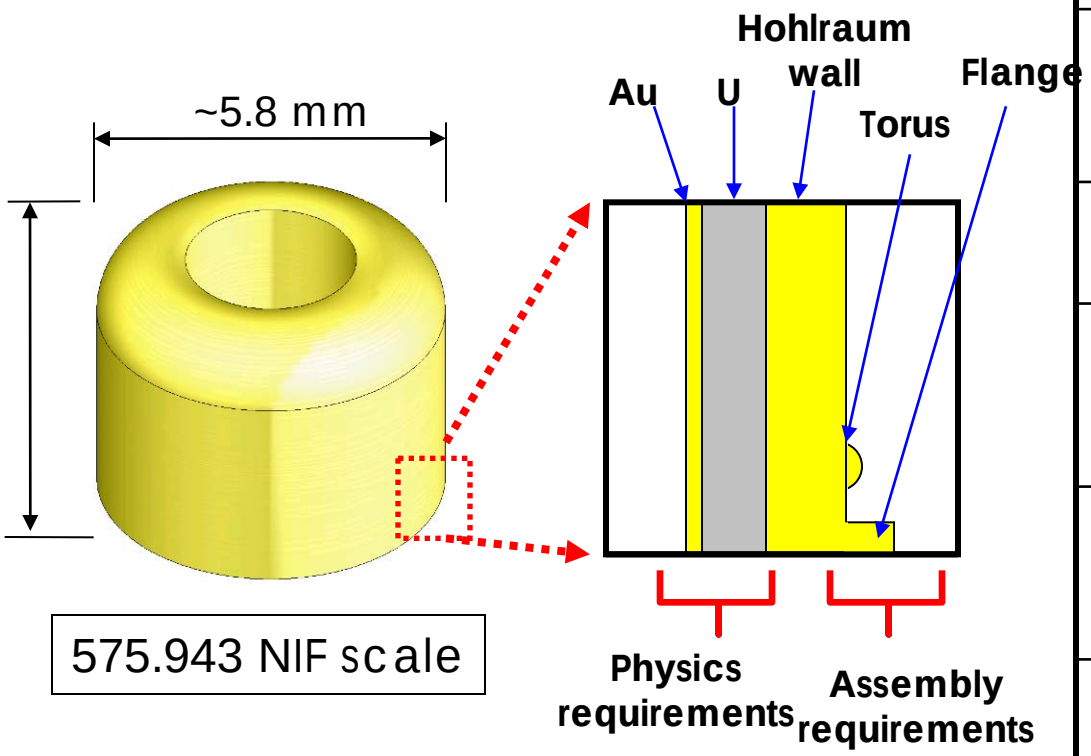
If Oxygen At% is greater than 5% - gains from DU layer are diminished

- **Determined by Auger Analysis on WR**
- **If hohlraum is production quality O At% is < 5% through the bulk**



GA meets DU thickness for 90% of coating runs – preventative maintenance will improve this yield to >95%

- **Missed specification is due to gun arcing which causes sputter gun to shut off during coating**



Parameter	Spec	Tol
Au thickness, µm	0.7	±.1
U thickness, µm	7	+3/-0
Au thickness µm	~ 23	
Torus diameter, µm	TMP ID	+0/-3
O at%	< 5	

2011 Q3 Yield dropped from 40% to 0% due to process drift – brought back to 40% in late 2011-2012

- **Process drift was identified in crucial adhesion steps**
- **Yield for DU hohlraums returned to 40% through corrective actions**
- **Improvements were made to each process step to increase yield**

- **Leach yield improved further in Q1-Q2 2012**
  - Discussion of process drift identification and process improvement will be covered by H. Streckert in the next talk