A LOW POWER SURVEY OF RADIAL OFFSET AXIAL SPUTTERING AND URANIUM ION PRODUCTION FROM AXIAL SPUTTERING IN SuSI

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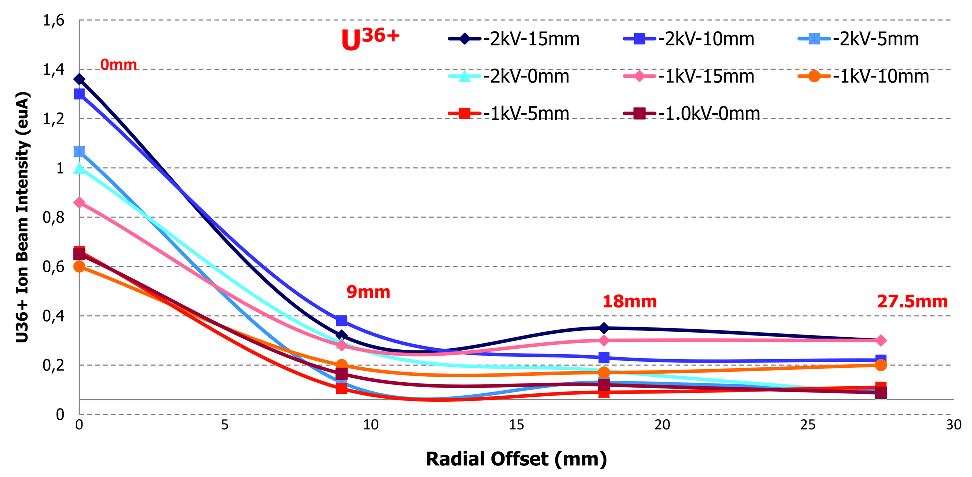
Simple Survey of Radial/Axial Offset Sputter Positions Using A Uranium Sputter Target and Assorted Gases

Small Sample Radial Offset Survey

The SuSI plasma chamber injection baffle is 100mm in diameter and therefore has limited area for installation of RF waveguides, gas port, biased disk, and RF inductive oven or resistive oven assemblies. The need to install a sputter target, for possible uranium beam development, on an already congested surface led to the question of where a sputter target must be located. Intuitively, the sputter surface would seem to be best on the plasma chamber axis, but the possibility of sputtering at positions radially offset from the axis and the relative sputter efficiency at such positions was unknown. In December of 2009 a simple survey of relative sputter efficiency of radially off-axis sputter target positions and at increasing axial insertion toward the plasma was done. The survey was done at very low RF power due to the sample not being cooled and the risk of X-ray damage to the plasma chamber insulation, which had not at that time been upgraded to tantalum shielding and PEEK insulation.

The uranium sputter target geometry , sputtering on the side of a cylindrical surface, was expected to be very inefficient. The sputter target, 5mm in dia. X 19mm long, was mounted normal to the plasma chamber axis and pivoted from an axis within the baffle area not interacting with the plasma loss cone (see photo below). It was swept through an arc into the radial loss line and finally to the on-axis position. Measurements of uranium production were made at radial positions of 0mm, 9mm, 18mm, 27.5mm and completely away from plasma interaction. The injection baffle was generally located on the injection field maximum. At each radial offset position the sample sputter surface was initially 10mm from the injection baffle surface and then inserted toward the plasma with increasing Z position by increments of 5mm. The sputter target was biased over a limited range of 0 to -2kV.



Uranium Sputter Yield Using ^{16}O Support Gas with Radial and Axial offset at -1kV and -2kV bias

It can clearly be seen that the Uranium sputter production yield is highest on the axis of the plasma loss cone, (0 mm radial offset)

Sputter production does occur along the radial loss line, at least to a radius of 27.5 mm

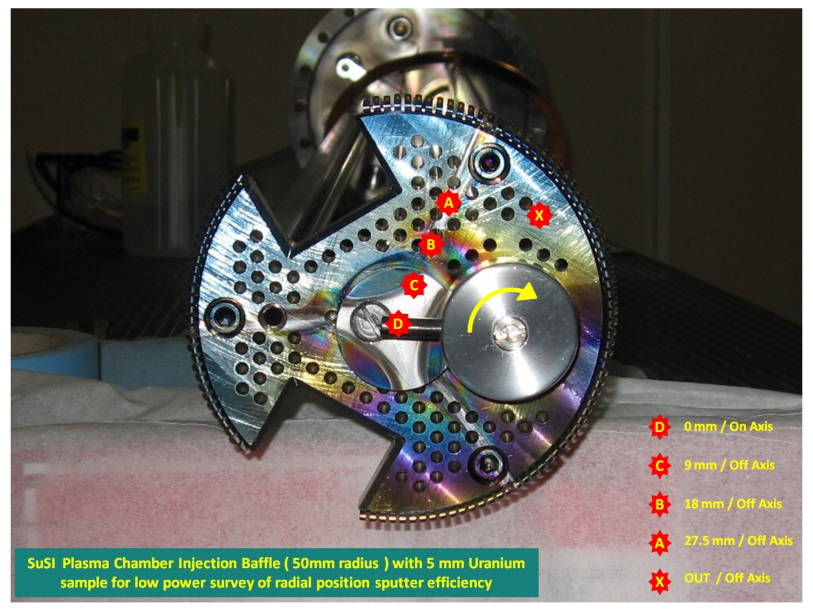
Radial offset sputtering yield may be 10% – 20% of on-axis sputtering yield.

The sputter efficiency is remarkably uniform along the radial loss line from 9mm to 27.5 mm radius

In general the sputter yield increased with axial insertion of the sample from 0 – 15 mm

In general the sputter yield increased with target bias voltage from -1 kV to -2kV

Based on this survey, prototype sputter hardware was built using a 10 mm diameter uranium sample mounted on-axis with the axial position adjustment of 50mm and bias voltage range to -5kV



SuSI Plasma Chamber Injection Baffle (50mm radius) with 5 mm Uranium sample for low power survey of radial position sputter efficiency

Small Sample On-Axis Position Survey

The small uranium sample was mounted on axis and inline with the plasma chamber axis (see photo below). It's sputter surface was 5mm in diameter and at an initial Z position of 25mm above the baffle surface (toward the plasma). The injection baffle was located at the injection field maximum. A low power survey of sputter efficiency was done moving the sample into the plasma chamber in 5mm increments Additionally, an assortment of support gases were tried.

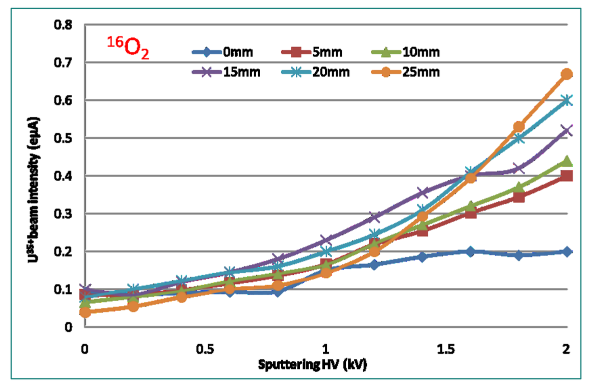
Axial insertion toward the plasma generally increases uranium sputter yield

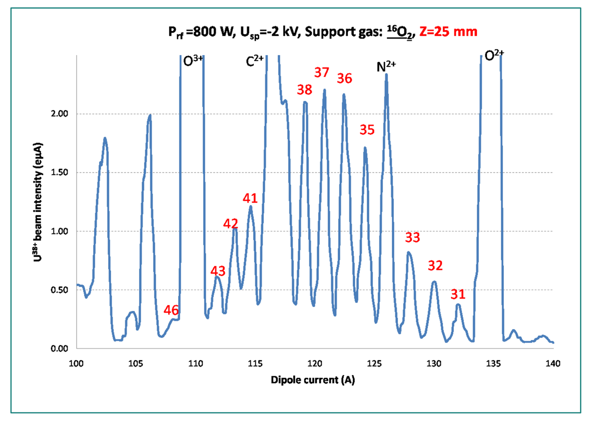
Again, increasing sputter target bias voltage generally increases uranium sputter yield

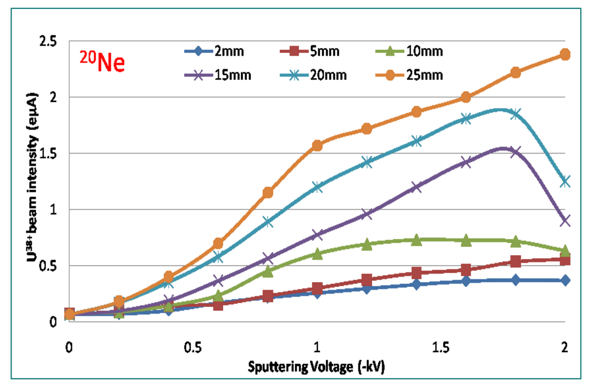
It is clear that sputter yield increases with heavier mass support gasses with oxygen and neon being reasonable choices for middle to high uranium charge states.

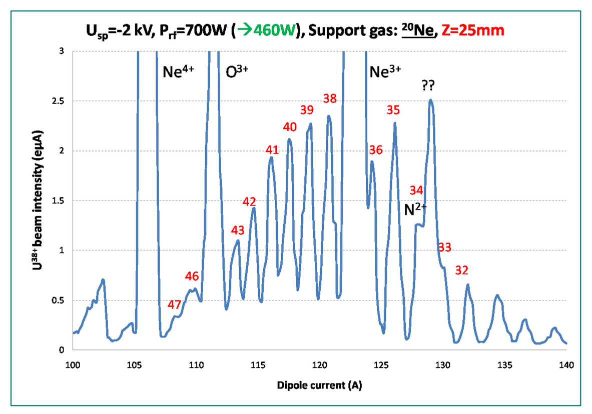
Argon sputters very efficiently, but being a poor mixing gas drives the charge state distribution toward lower charge states with robust sputtering

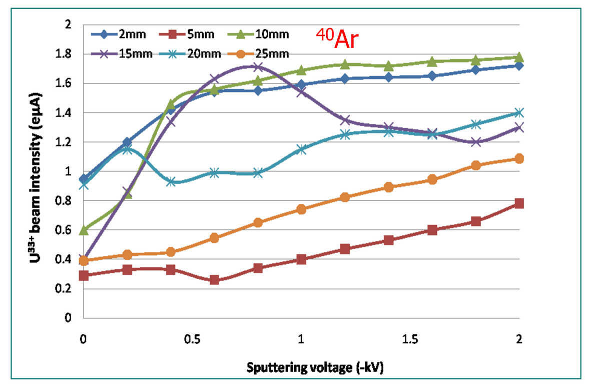
A mixture of support gases should be evaluated

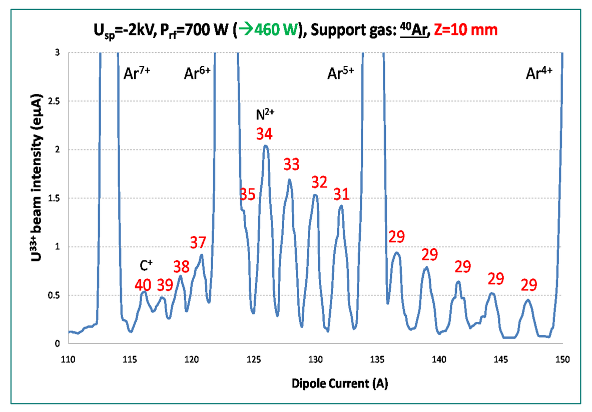


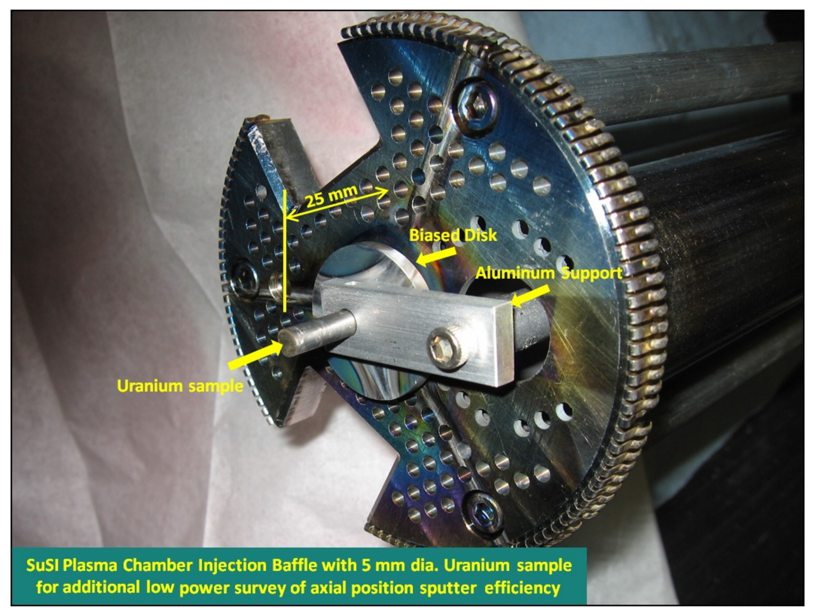












SuSI Plasma Chamber Injection Baffle with 5 mm dia. Uranium sample for additional low power survey of axial position sputter efficiency

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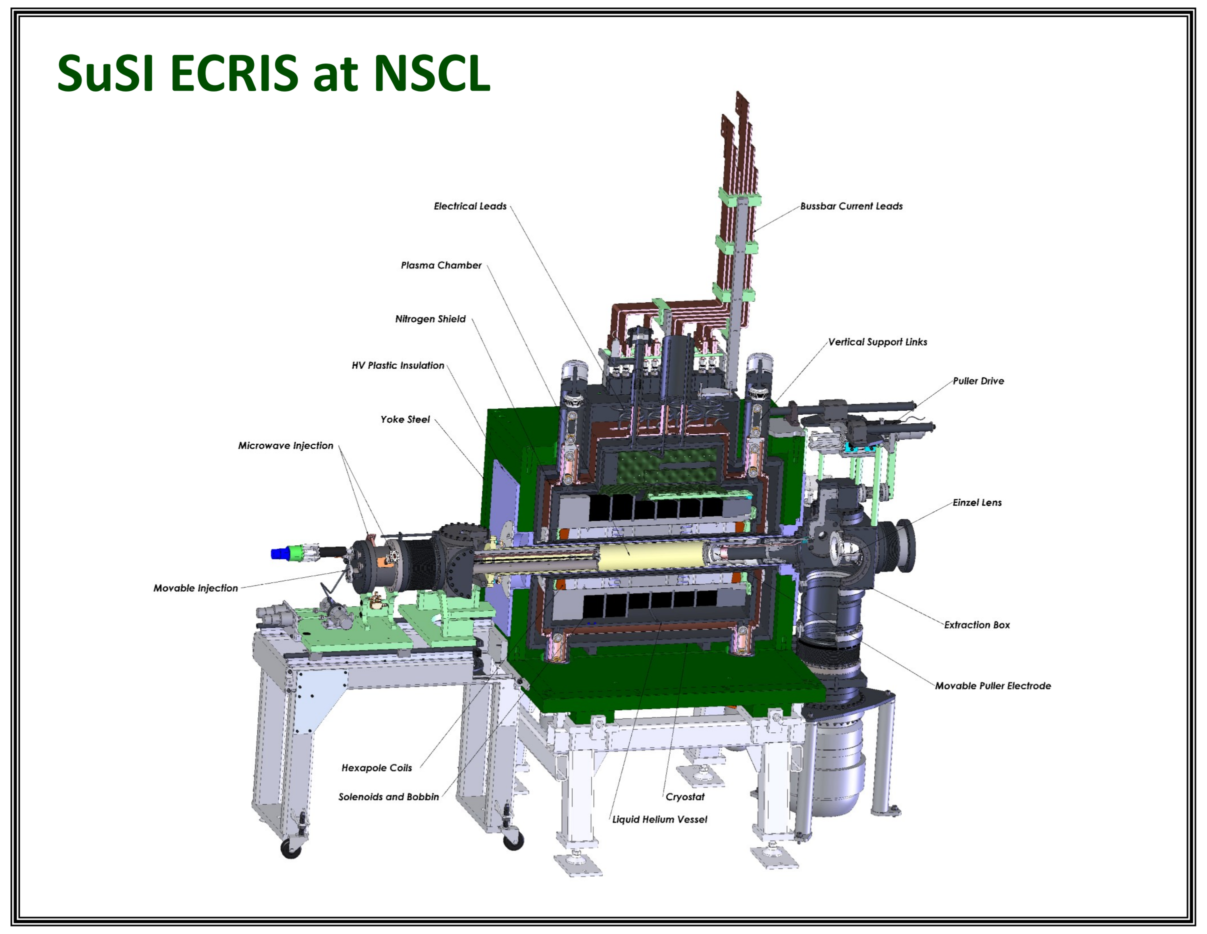
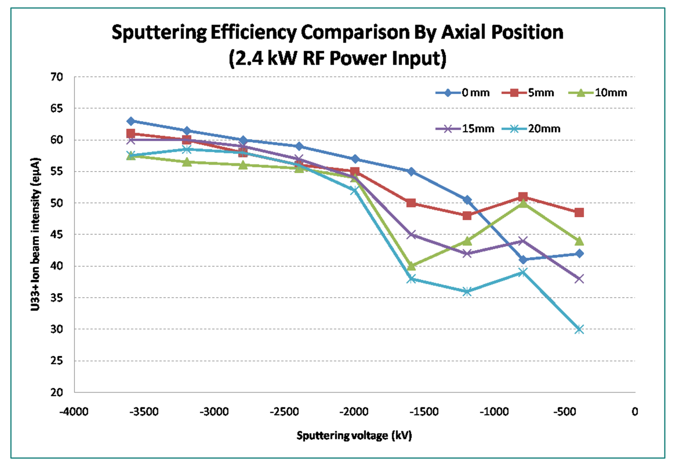
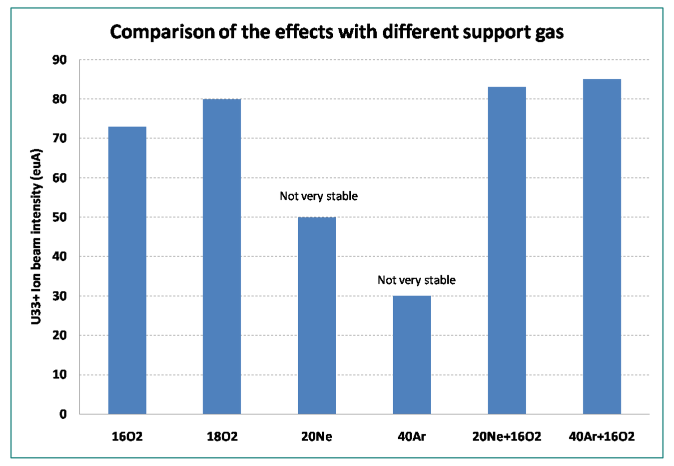
SuSI Uranium Beam Production Results From Prototype On-axis Sputtering Hardware At Higher Power



SuSI - Present Configuration Summer 2010

Primary RF frequency	18 GHz, 3kW output using 2 Klystrons (24 Ghz procurement in progress)
Magnetic system	Superconducting/Nb-Ti (6 Solenoids + 1 Hexapole)
Plasma chamber	Aluminum, 101 mm dia., 3.1 to 3.9 L
ECR extraction voltage	Up to 30 kV
Residual vacuum	Low 10^{-8} Torr





In June 2010 the first attempt to sputter uranium at production levels in the SuSI ECRIS was made in support of the Coupled Cyclotron Facility primary beam list requirements at NSCL. The prototype sputter hardware consisted of a water cooled 10 mm diameter X 15 mm long depleted uranium target mounted inline with the plasma chamber axis. The injection baffle is adjustable through a range of +/- 50mm around the injection field maximum; generally the baffle was left very near the injection field maximum. The sputter target surface was located 2 mm above the injection baffle surface toward the plasma. The sputter target could be inserted up to 50mm further toward the plasma relative to the baffle position. Because the on-axis location of the sputter target displaced the biased disk, the bias disk was replaced with a biased ring with internal diameter of 19 mm allowing the sputter target to travel through the ring. The sputter target could be biased from 0 to -5kV and the biased ring could be biased from 0 to -2kV. The sputter production was evaluated changing target axial position, bias voltage, and support gases while tuning the source field and RF power to optimize performance and stability. It should be noted that the biased ring worked well, however the bias voltage required for the ring to perform as well as the original disk was about a factor of ten higher or -700 to -1000 V. Additionally, the biased ring ceased having an effect on beam intensity when the sputter target bias reached about -4kV. Performance was measured by intensity at the end of the SuSI collimation channel. During the uranium development the transport efficiency of beam produced by SuSI through the collimation channel using 10mm -12mm slits was about 50% due to efforts to obtain best resolution of charge states.

Low intensity uranium production began immediately without the target being biased. We feel there is enough target interaction with the normal flow of ions leaving the plasma on axis through the loss cone to explain this initial sputtering. Beam intensity increased greatly with increasing target bias voltage.

Beams were developed using various support gases alone and in combination. Gas mixing advantage was gained using oxygen but best sputter efficiency required gases with higher mass. It appears that the best performance for higher charge state uranium production used a combination of ^{16}O and ^{20}Ne, while best performance for lower charge states , < 34+, was achieved with a combination of ^{16}O and ^{40} Ar.

Beam production increased with RF power and was still showing such a trend when limited by maximum power available at the time of 2.5 kW with a maximum drain current of about 5mA

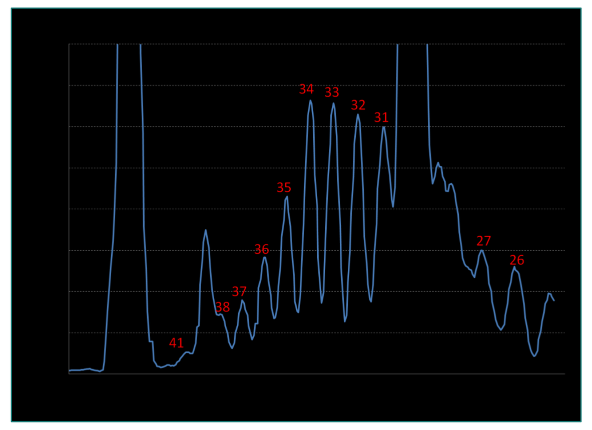
While generally, sputter yield increases with insertion of the target toward the plasma, the sputtering was so robust at higher power and voltage that the best axial position was the starting position of 2mm above the injection baffle and toward the plasma.

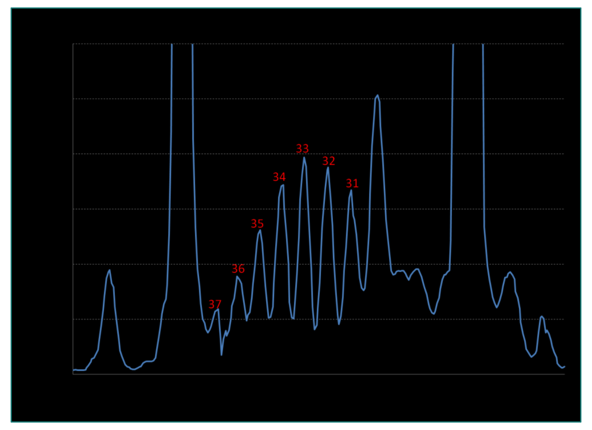
Biased ring and biased target voltages were adjusted together producing increasing intensity until the target bias reached -4kV and the ring bias , no longer helping was reduced to less than -100V.

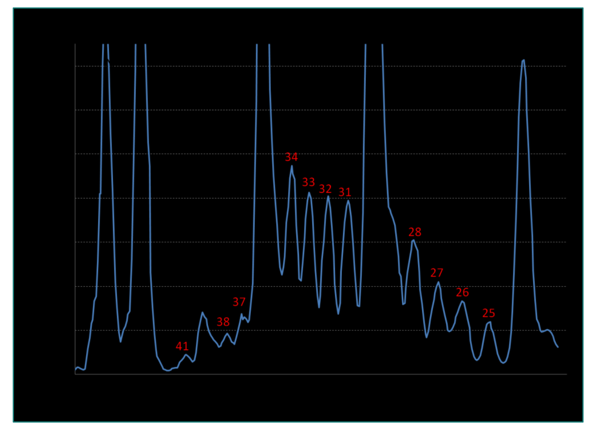
The sputter pattern on the surface of the sputter target shows that the effective interaction area is greater than the 10 mm diameter of the target. Also, the sample was misaligned 1 mm radially resulting in significant loss of sputtered material available to the plasma.

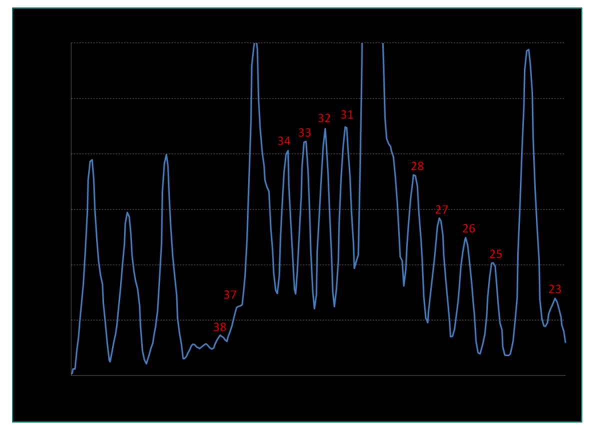
Uranium production averaging about 30 euA over 105 hours of running consumed 211 mg of the target or 2mg / hr

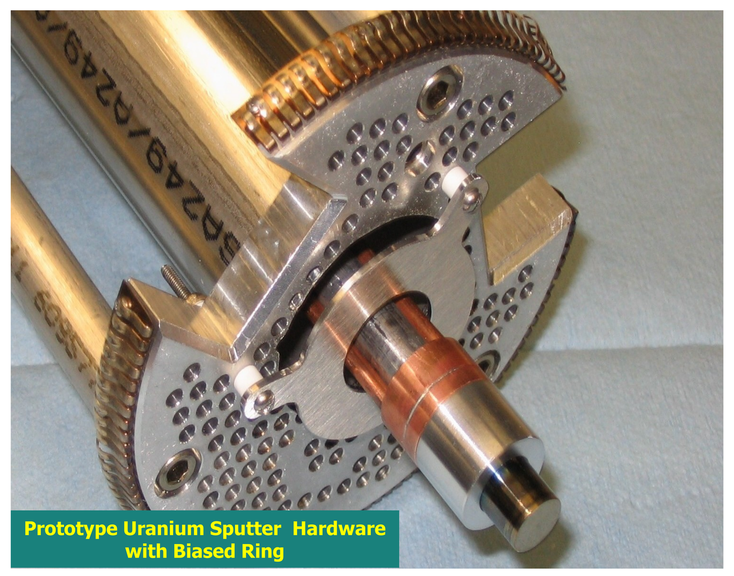
Further development, scheduled Fall 2010, will include a redesign of the sputter equipment to allow the target to be withdrawn at least 25mm behind the injection baffle, an increase in target size to 25mm diameter, and increased RF power capability > 3kW



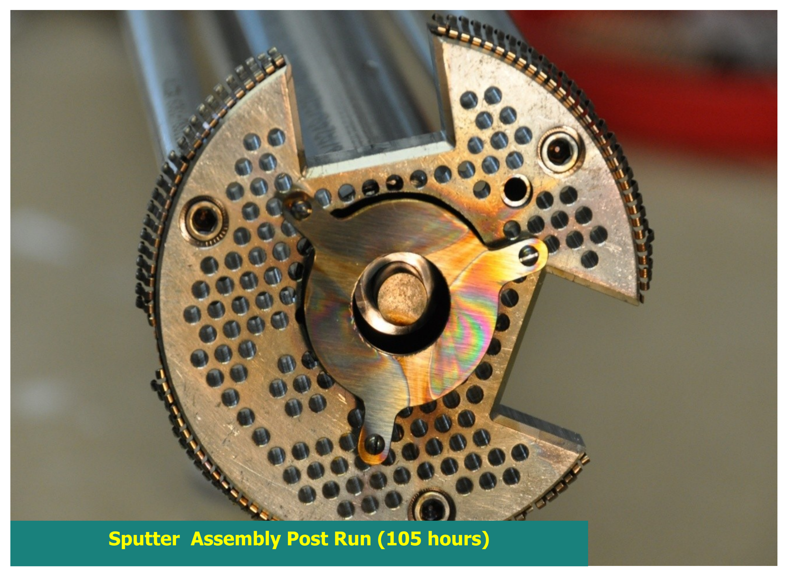




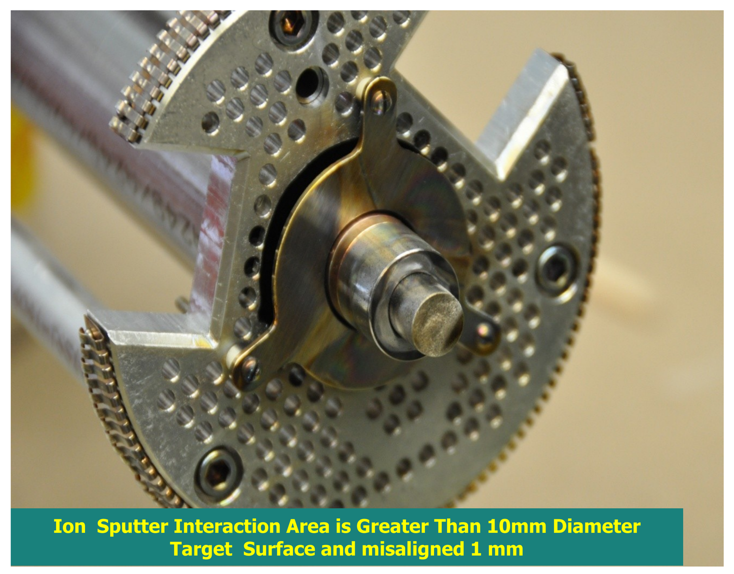




Prototype Uranium Sputter Hardware with Biased Ring



Sputter Assembly Post Run (105 hours)



Ion Sputter Interaction Area is Greater Than 10mm Diameter Target Surface and misaligned 1 mm