ANGSTROM SCIENCES

Uniformity Control for Rotating Cylindrical Magnetrons

Presented by

ANGSTROM SCIENCES, Inc.

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Magnet Array Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment

Using Spacers to resolve "tilt"

Using Shunts to resolve "local" effects

A Working Example

Magnet Array Throughput Considerations

Maximizing Target Utilization

Maximizing "Throughput Efficiency"

Magnet Array Optimization for Rotating Cylindrical Magnetrons

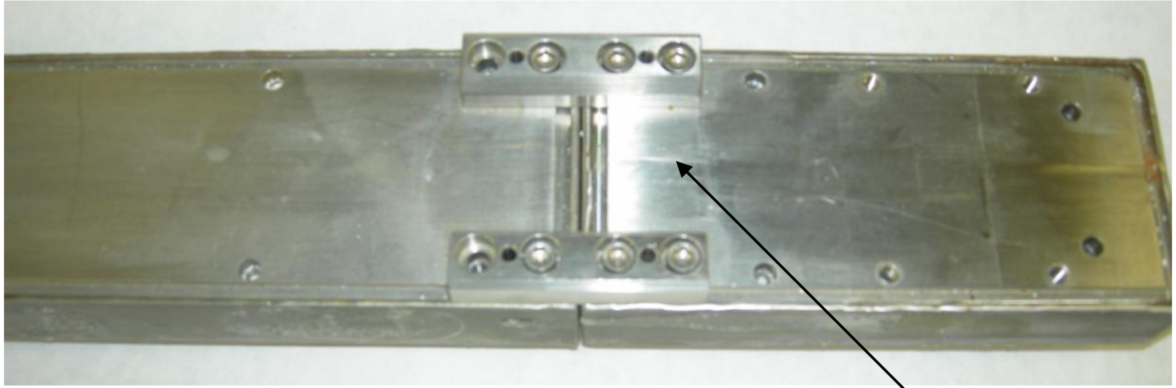
Uniformity Adjustment – Addressing “Tilt”:

“Tilt” – Will be defined as a non-uniformity effect spanning a large distance (~1/2 meter).

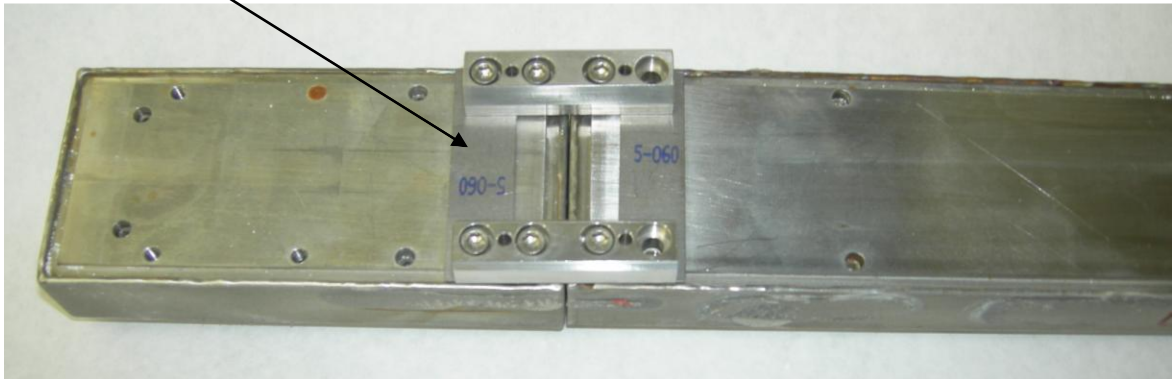
Adjustment means – Adjusting the relative distance between the magnet array and the target surface, at defined intervals, to counter the observed “Tilt”

Magnet Array Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – Addressing “Tilt”:



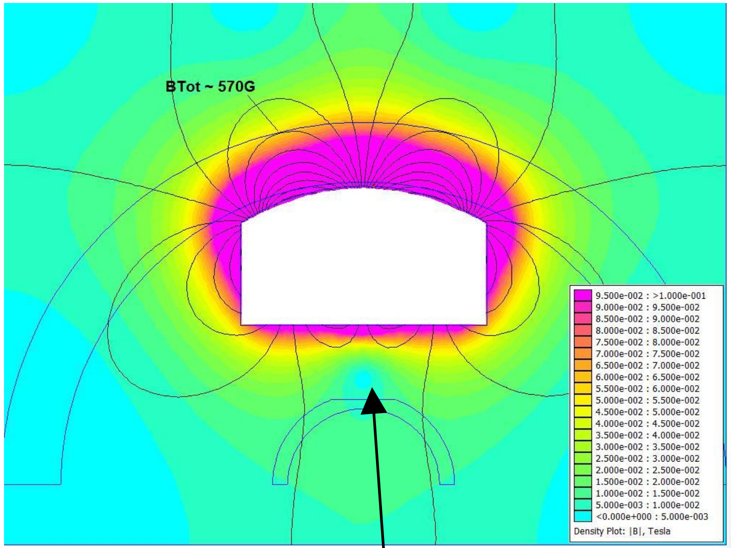
Addition of Spacers to Adjust Magnet Array to Target Surface Distance

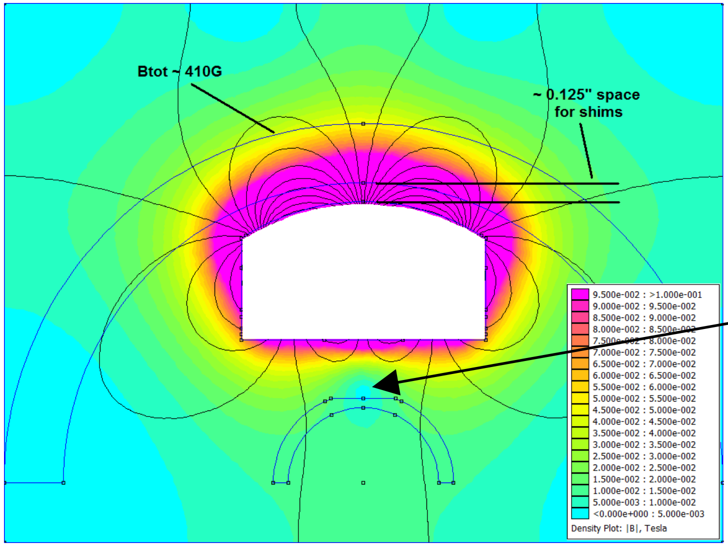


Magnet Array Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – Addressing “Tilt”:

2D Model (FEMM) of magnet array shows the effects on the magnetic field of inserting spacers.





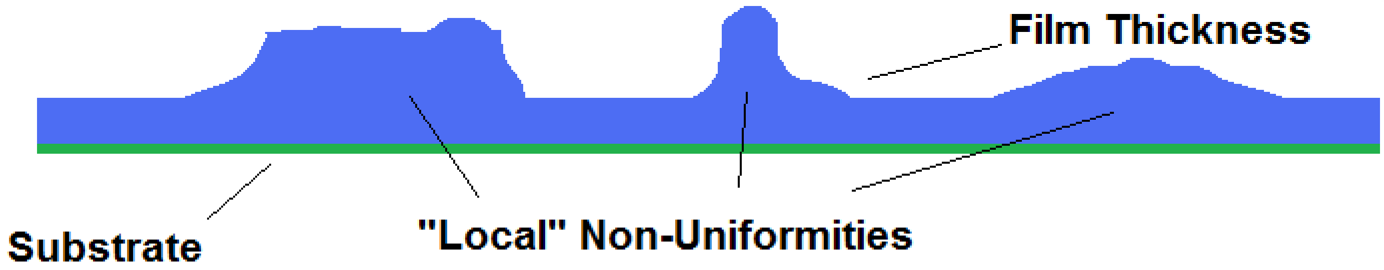
Spacers or mechanical adjustment is used to raise or lower the magnet array at specific locations

Magnet Array Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – Addressing "Local" Effects:

"Local" – Will be defined as a non-uniformity effect spanning a distance from ~ 2-40 cm.

Adjustment means – Change the intensity of the magnetic field in the position directly aligned with the non-uniformity



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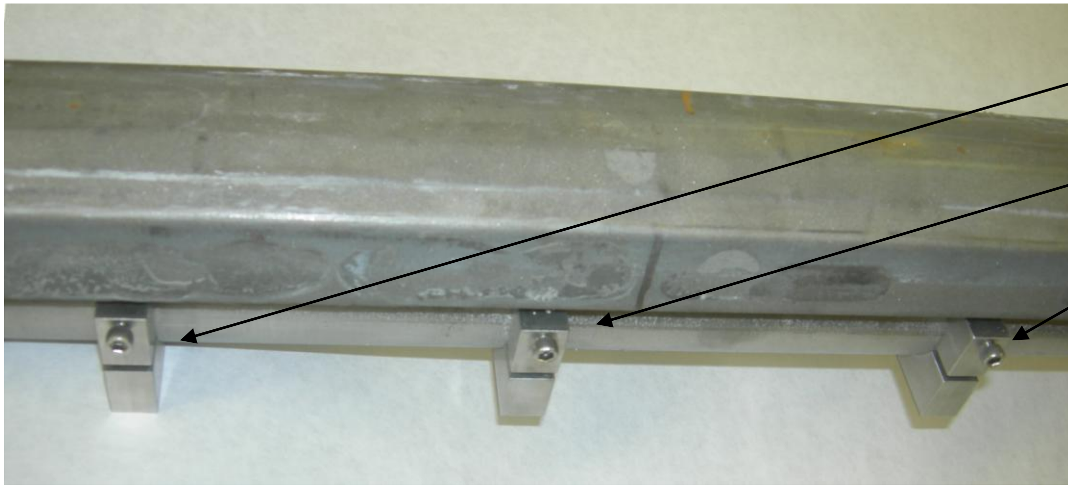
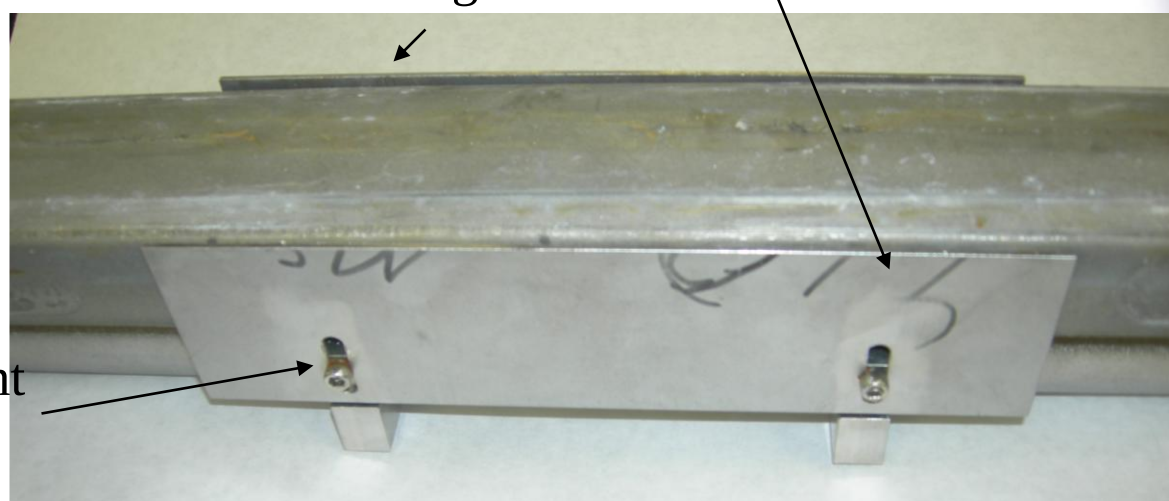
Uniformity Adjustment – Addressing “Local” Effects:



Multiple Shunt Positions Adjustable along Magnet Array Length

Magnetic Stainless Steel Shunts

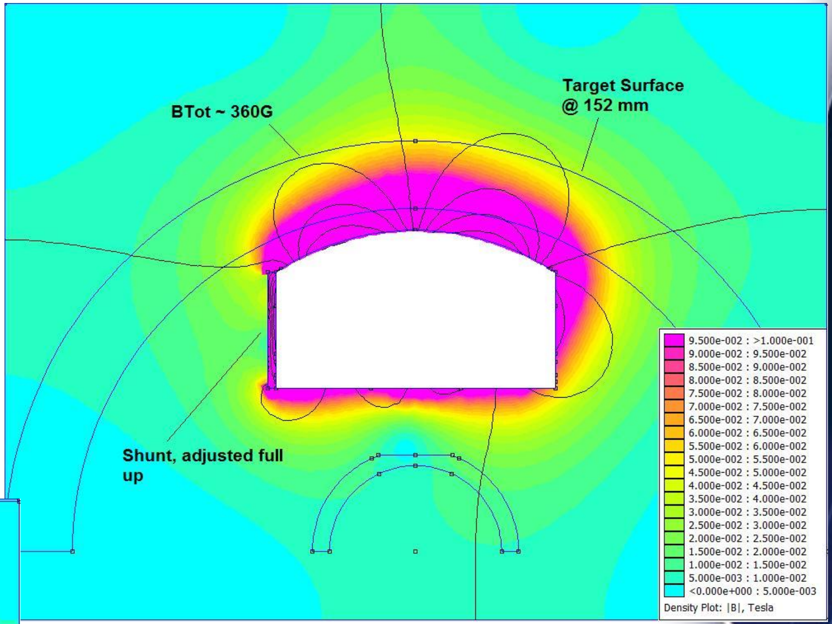


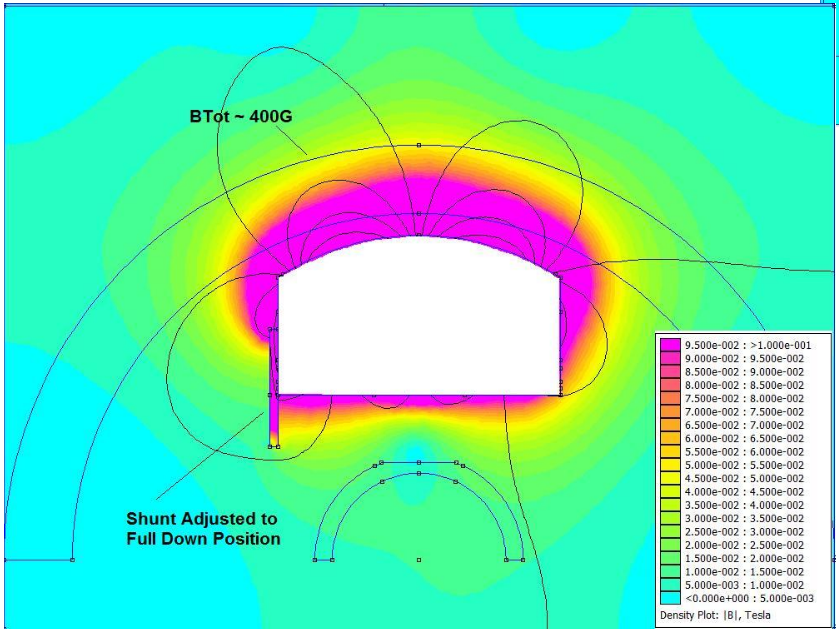
Vertical Shunt Adjustment

Uniformity Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – Addressing “Local” Effects:

To eliminate “local” uniformity effects, 1 or more shunts may be cut to length and used for tuning over the magnet array length





Depending on the size of the uniformity anomaly, shunts may be used on one or both sides of the magnet array.

Uniformity Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – A Working Example:

Exercise: End user must achieve +/-2% film thickness uniformity on their cylindrical magnetrons

System Assumptions:

Anode conditions, gas flow and pumping throughput is constant and stable

Process Conditions :
Al Target – 60” Length
Power Supply 25kW (DC)
10 RPM Target Rotation
Process Gas 3mT Argon

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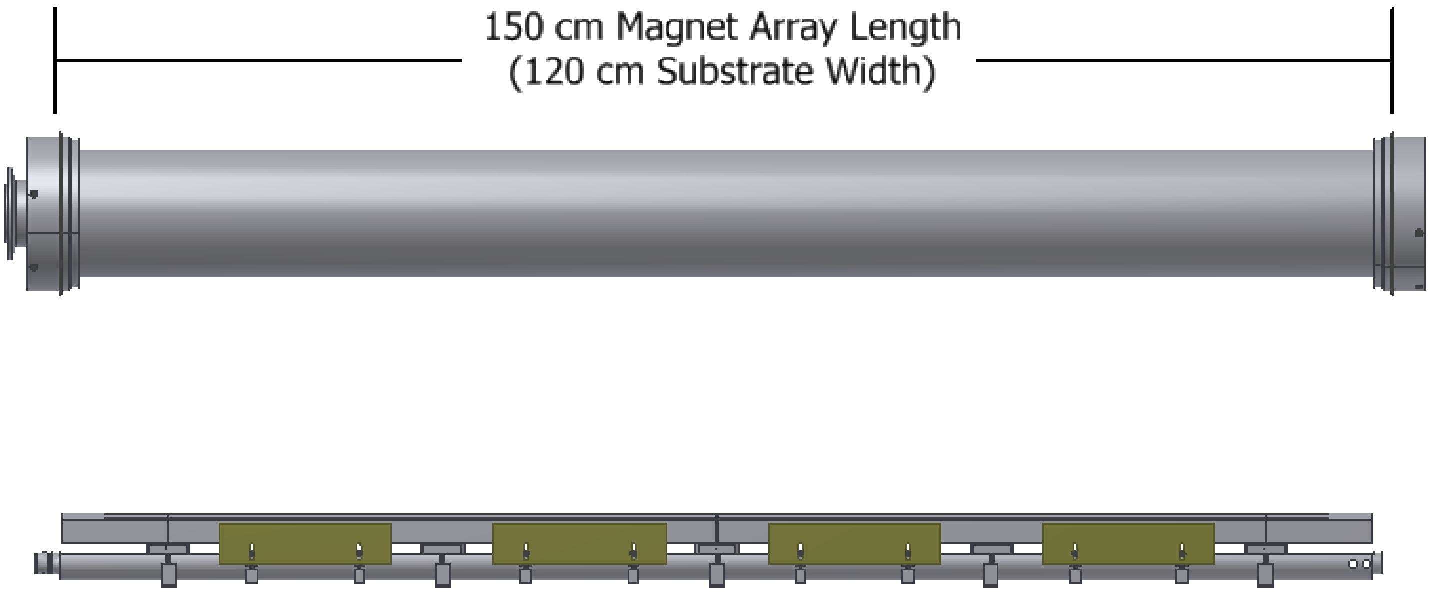
Uniformity Adjustment – A Working Example:



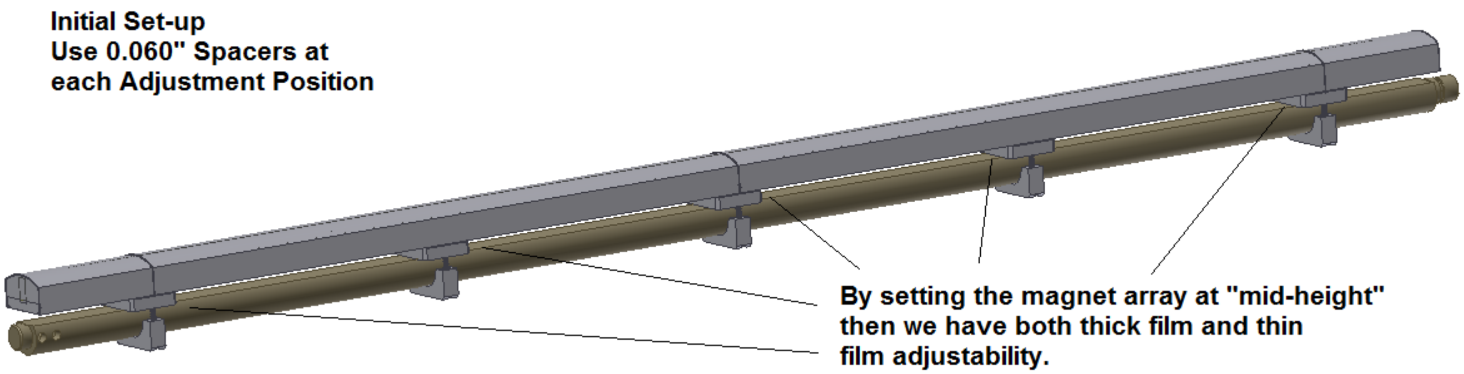
Uniformity Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – A Working Example:

All magnet array adjustments are based on the basic correlation:

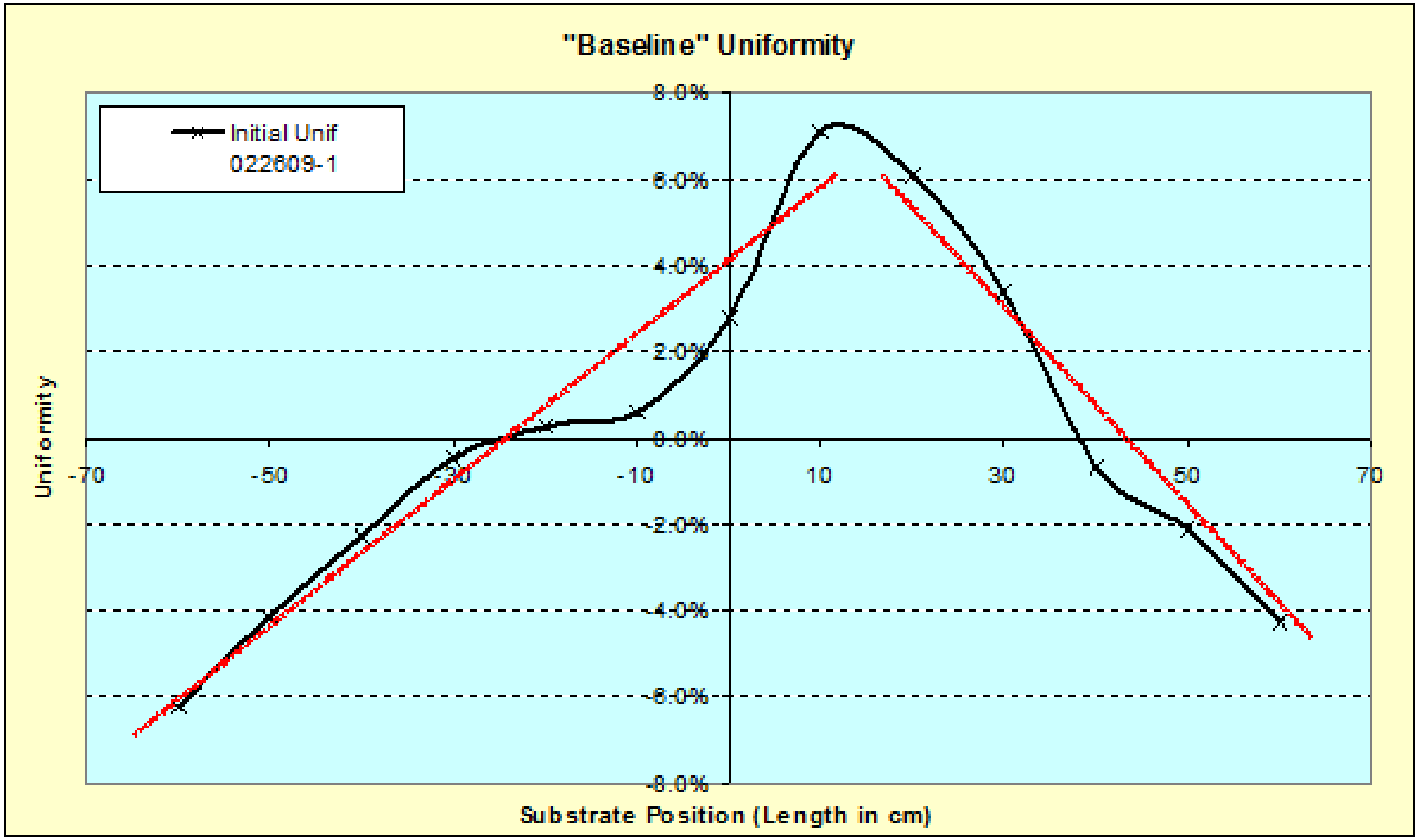
Deposition Rate α Magnetic Field Strength

Step #1: Establish a baseline uniformity from which we will begin to shape the magnet array in order to achieve film thickness uniformity.



Uniformity Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – A Working Example: (+/- 7 %)

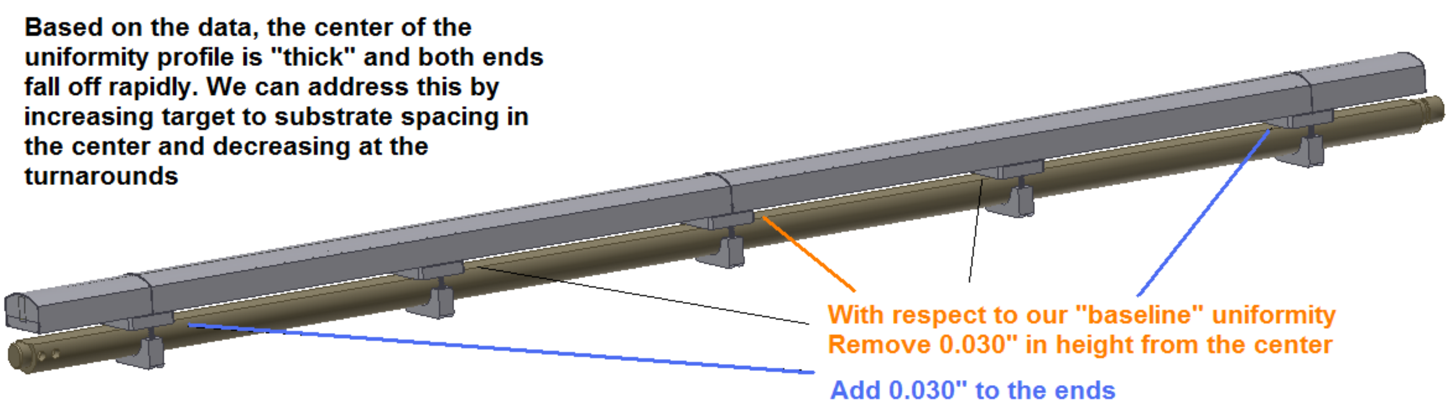


The dashed red lines show we have 2 slopes over the entire length. Both towards the center of the magnet array. We will add spacers and retest!

Uniformity Optimization for Rotating Cylindrical Magnetrons

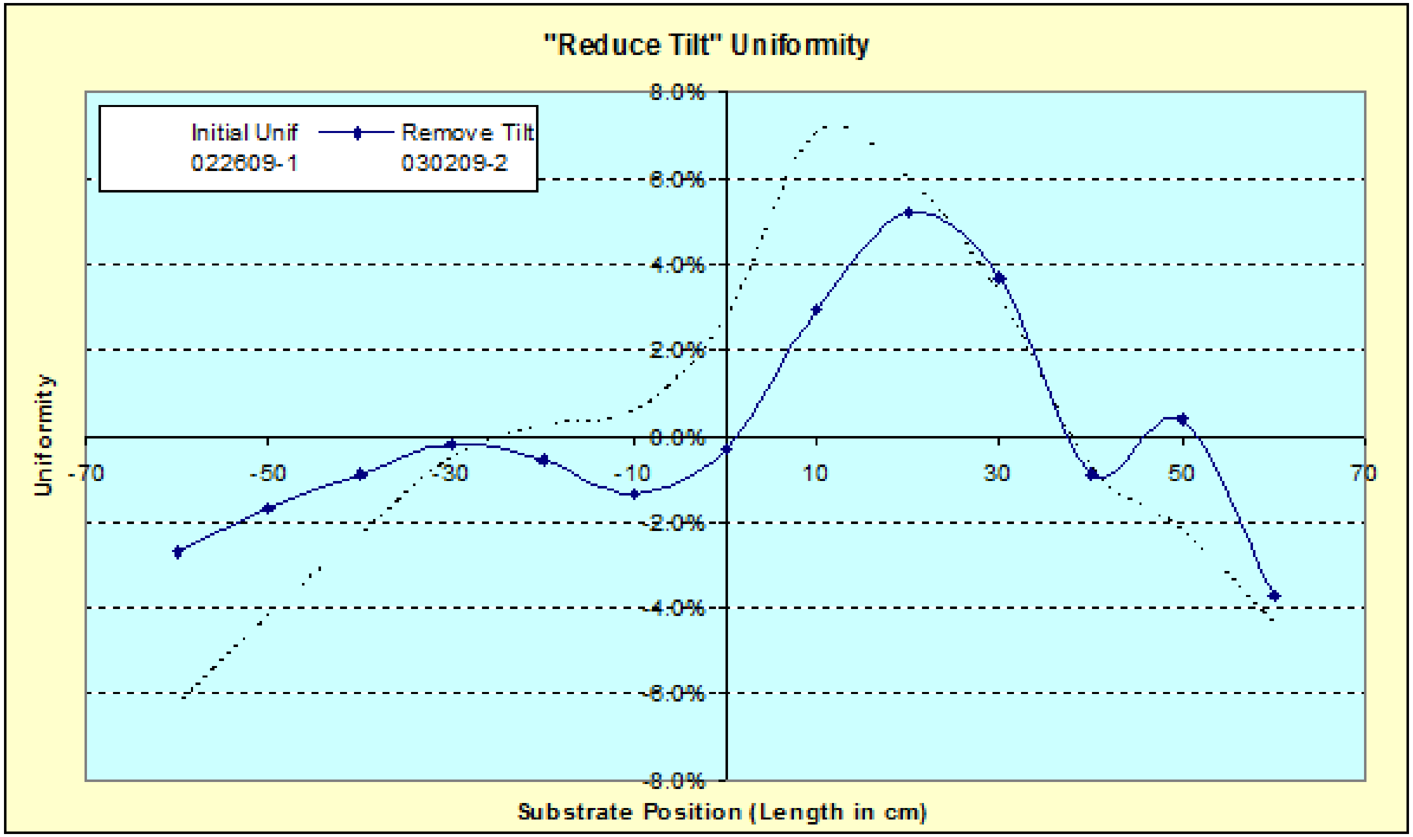
Uniformity Adjustment – A Working Example: (+/- 7 %)

Step #2: Remove "tilt" over a long length by adding/removing spacers along the length of the array.



Uniformity Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – A Working Example: (+/- 4.5 %)

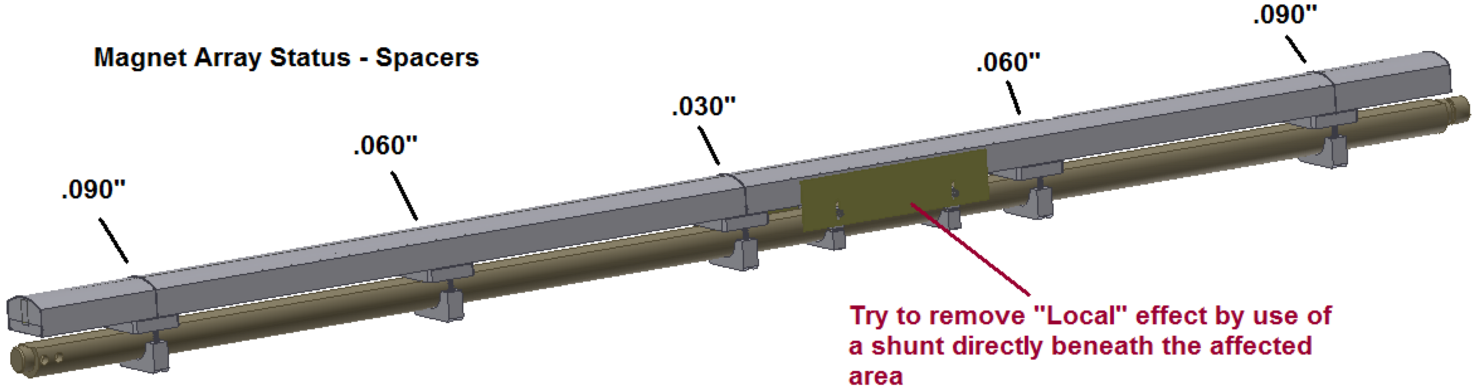


At this point we can either try further adjustment to the tilt, or, try to remove the "local" non-uniformity

Uniformity Optimization for Rotating Cylindrical Magnetrons

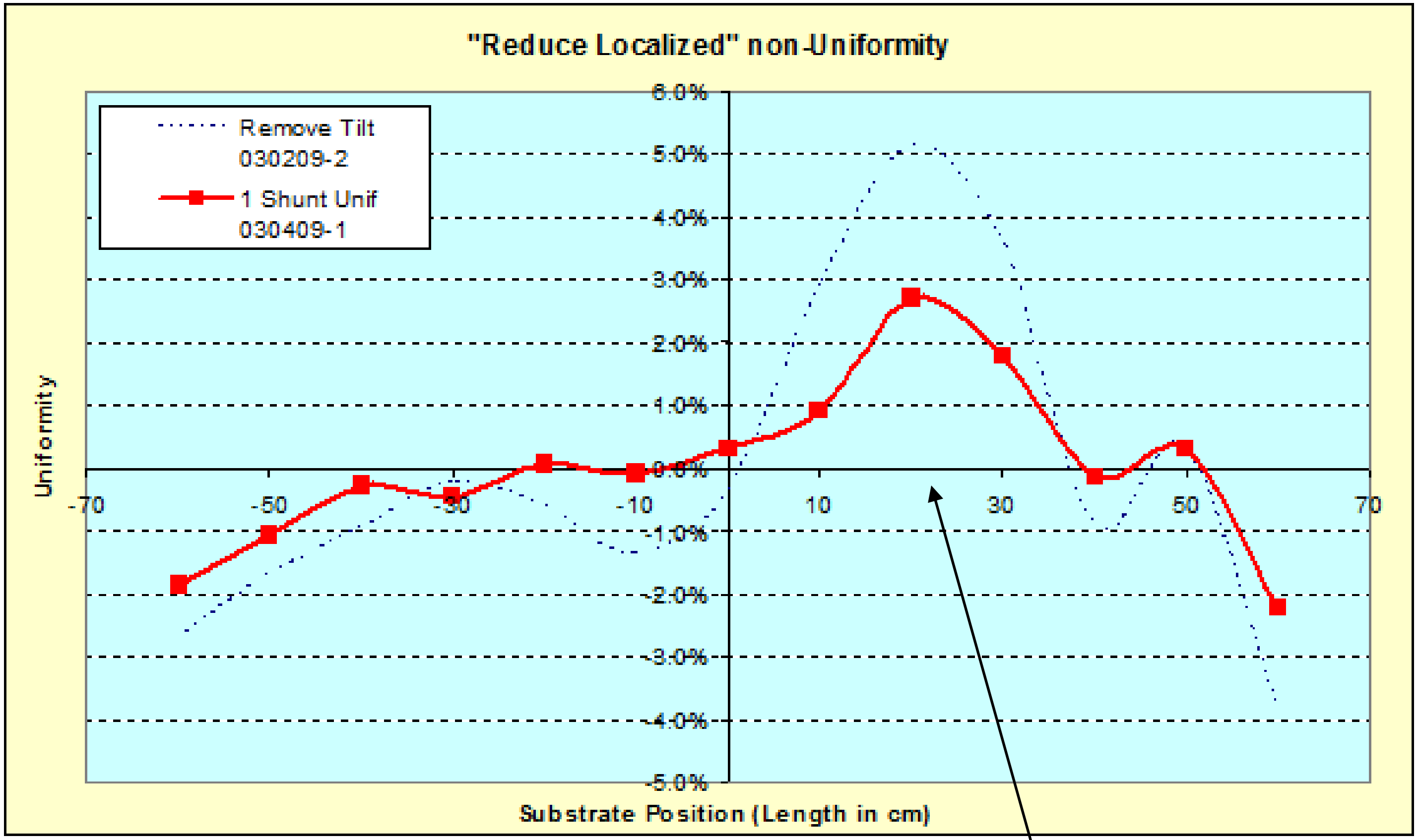
Uniformity Adjustment – A Working Example: (+/- 4.5 %)

Step #3: Begin to focus on localized non-uniformities by use of shunts.



Uniformity Optimization for Rotating Cylindrical Magnetrons

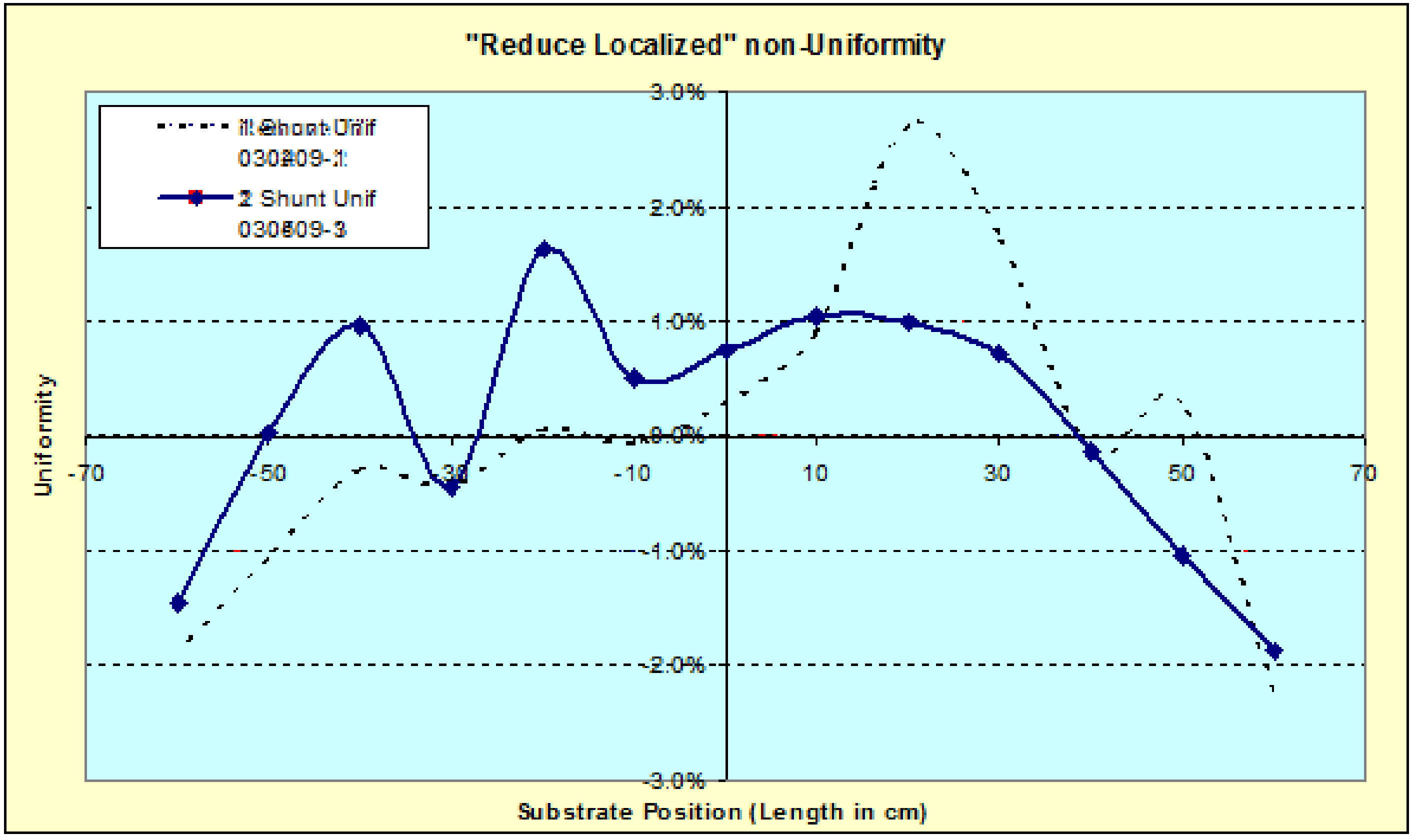
Uniformity Adjustment – A Working Example: (+/- 2.5 %)



The addition of a single shunt brought the total uniformity in the correct direction but was not strong enough. Add 2nd shunt to other side of magnet array!

Uniformity Optimization for Rotating Cylindrical Magnetrons

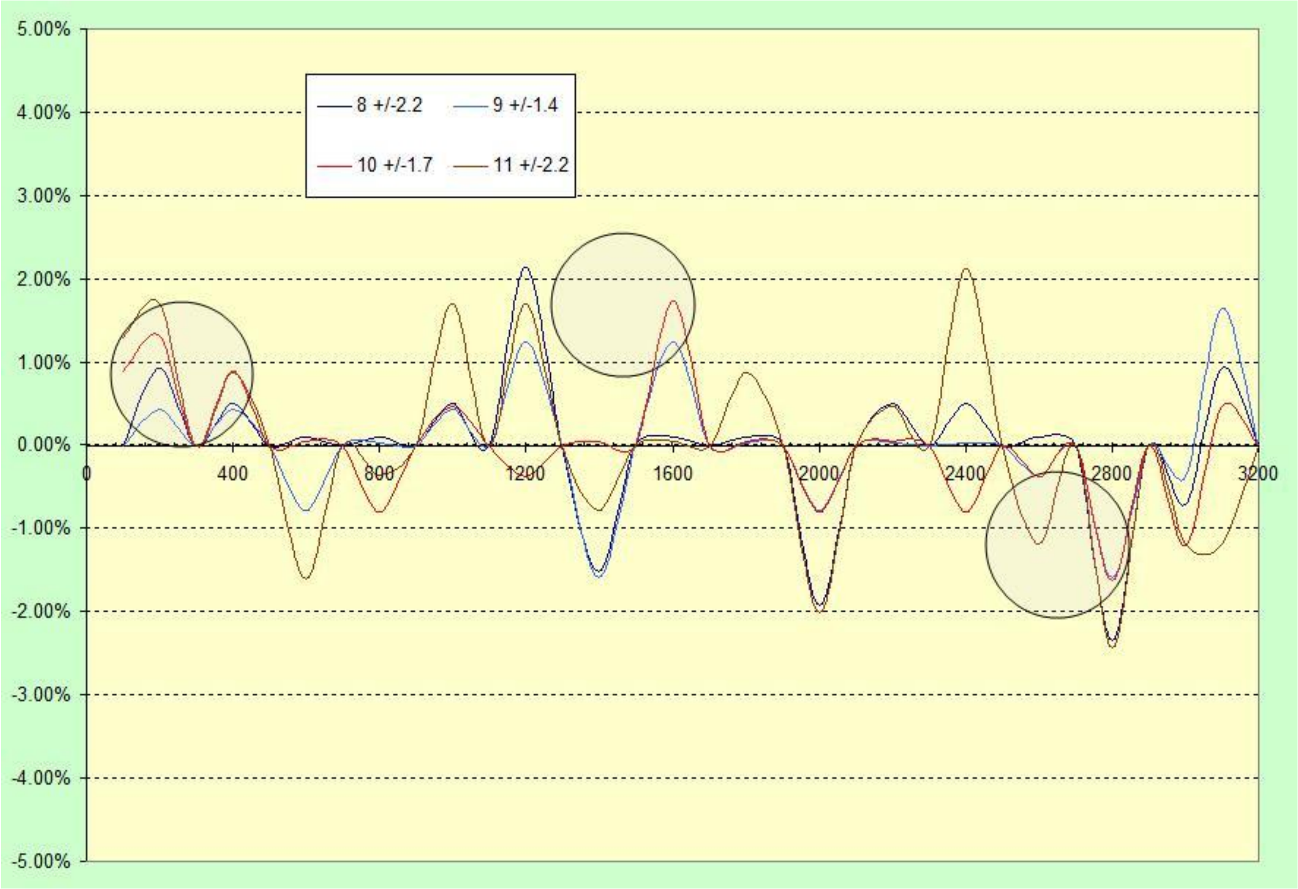
Uniformity Adjustment – A Working Example: (< +/- 2.0 %)



Uniformity Criteria is met!

Uniformity Optimization for Rotating Cylindrical Magnetrons

Uniformity Adjustment – A Working Example: (< +/- 2.0 %)



Applying the same procedures for a single 3.5m magnet array on a 3.2m Substrate

Throughput Considerations – Target Utilization

Maximize Your System Uptime and the Stability of the Sputtered Thin Film Uniformity

Many magnet array designs induce End-Grooving

- Reduces target utilization
- Changes distance of magnet array to target surface, thus changing uniformity distribution

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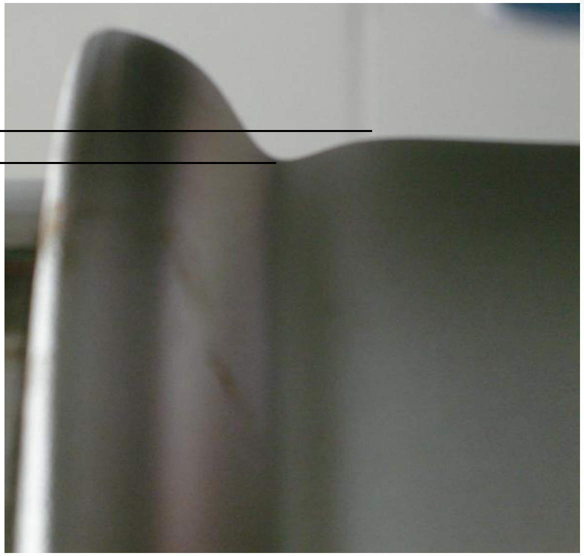
Throughput Considerations – Target Utilization

End Grooving refers to the target erosion at the racetrack turnarounds

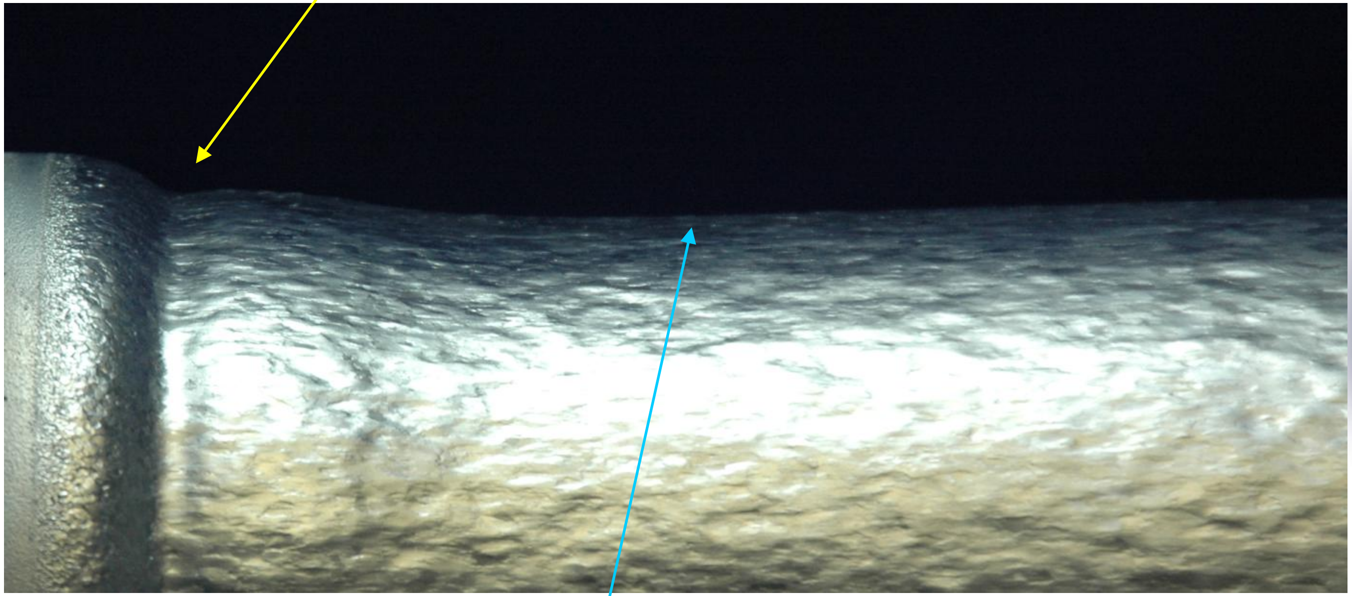
This effect causes a loss in target utilization and changing uniformity effects



Magnet Array Optimization for Rotating Cylindrical Magnetrons

Throughput Considerations – Target Utilization

No End-Grooving!



Deepest Erosion is along the length of the target surface

Magnet Array Optimization for Rotating Cylindrical Magnetrons

Throughput Considerations – Flux Distribution

The angular separation, or distance between racetracks can effect throughput

- Excessive amount of sputtered film ends up on shields – reducing rate
- Excessive amount of film on shields leads to onset of debris and particulate contamination

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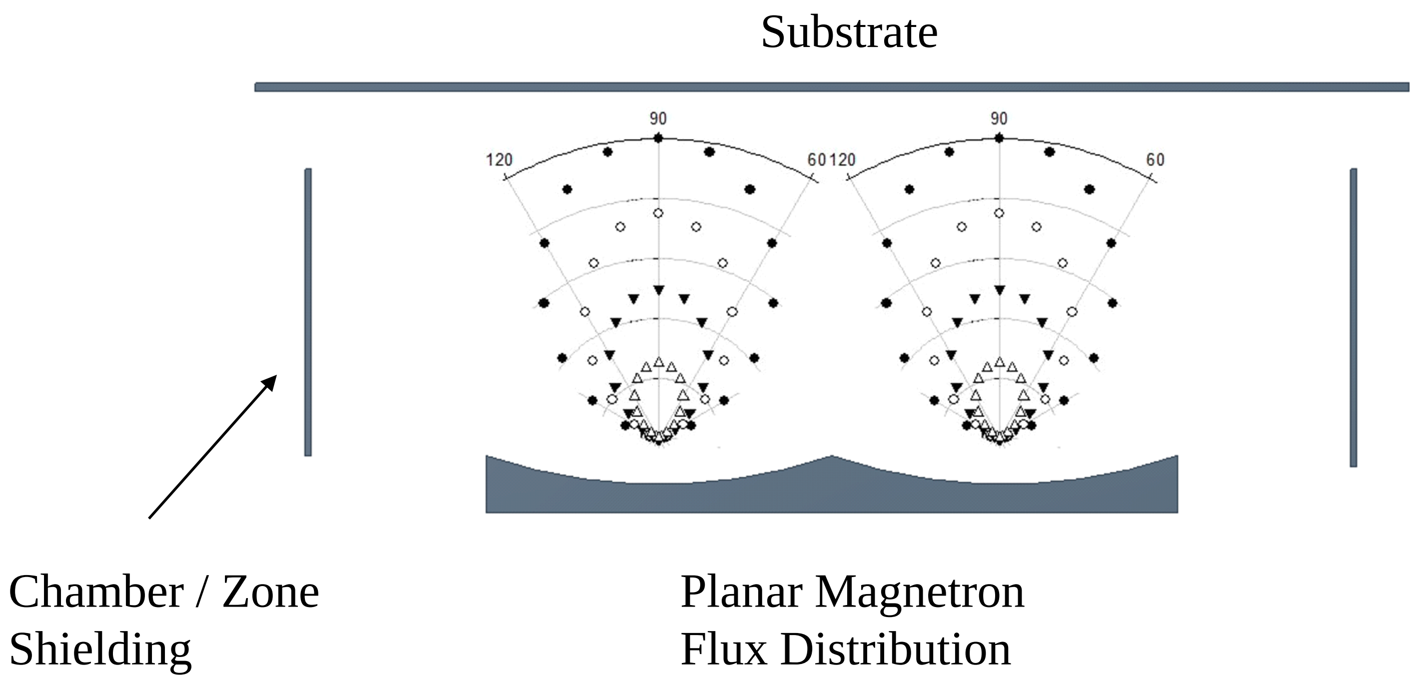
Throughput Considerations – Flux Distribution

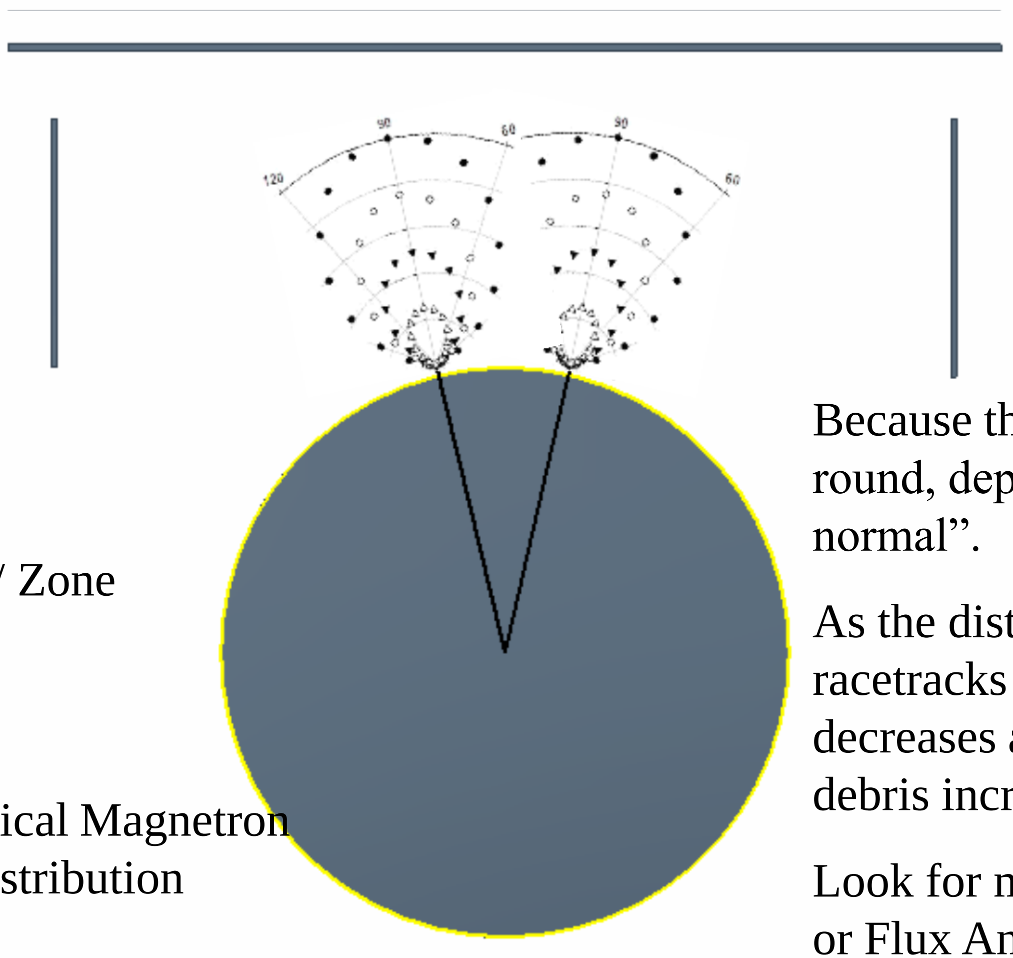


The “normal” orientation of the material flux to the substrate helps to minimize the amount of debris migrating to the sputter shields

Magnet Array Optimization for Rotating Cylindrical Magnetrons

Throughput Considerations – Flux Distribution

Substrate



Chamber / Zone Shielding

Cylindrical Magnetron Flux Distribution

Because the target surface is round, deposition is now “off-normal”.

As the distance between racetracks increases, rate decreases and likelihood for debris increases

Look for minimum separation or Flux Angle

Summary

1. Rotatable Cylindrical Magnet Arrays can be tuned for thin film layers in uniformities of +/-2% or better
   - Look for ability to use spacers
   - Look for ability to use shims

2. Rotatable Cylindrical Magnet Arrays also have a large influence on uniformity stability and Rate or Throughput
   - Look for elimination of "End-Grooving"
   - Minimize the Angular Flux Between Racetracks