Manufacturing Process and Characterization Overview of a Cylindrical CH ablator with seamlessly embedded thin aluminum band for use in Omega and NIF Experiments

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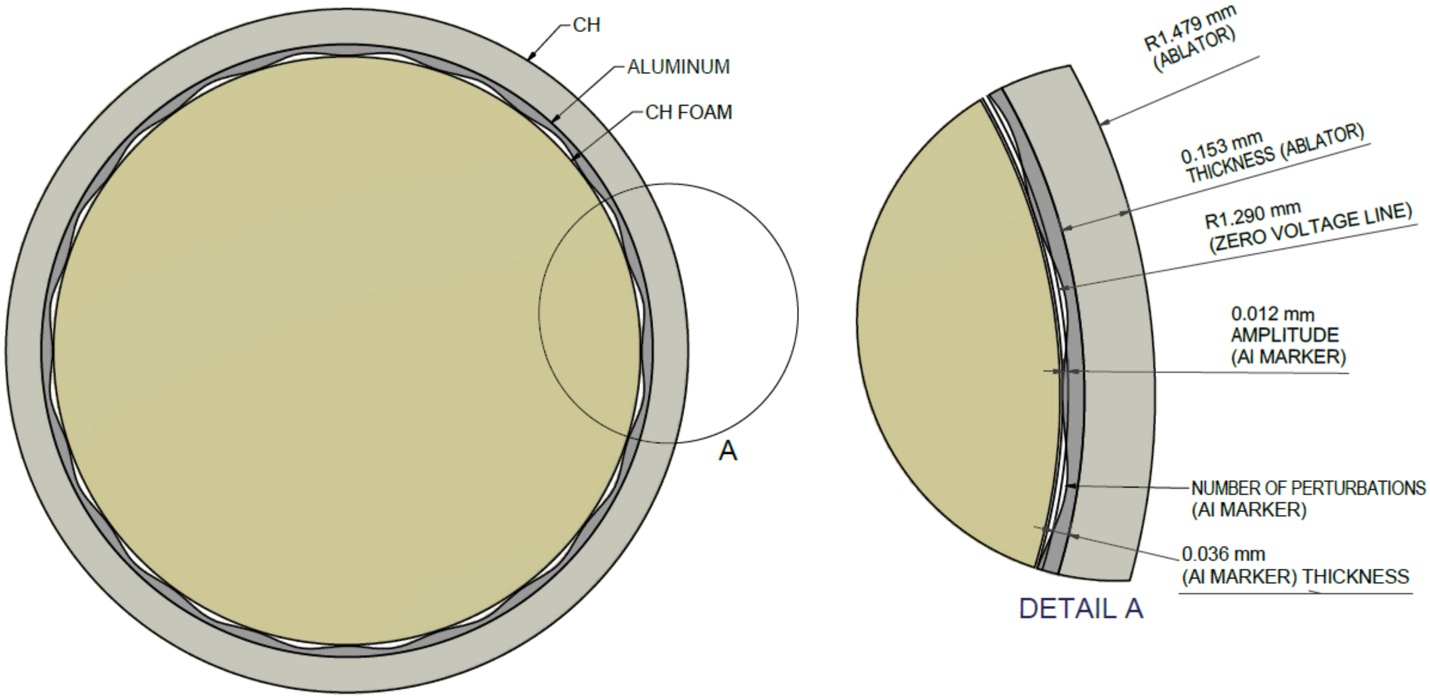
Presentation Overview

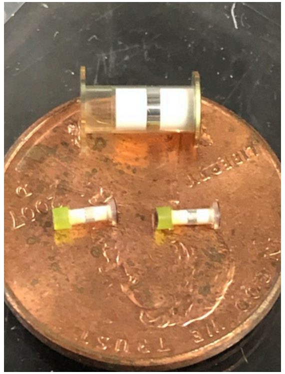
- Nominal Requirements
- Application
- Process Overview
- Inherent Process Vulnerabilities
- Identify critical requirements
- Deeper look at the overall process, key machining, and characterization required to deliver quality components
- Future Improvements
- Results
- Key Points

Nominal Requirements

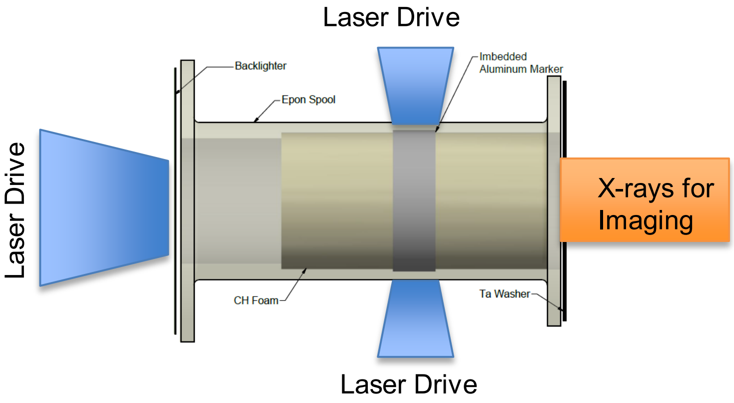


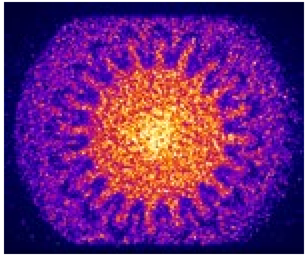
Application

The construction of a cylindrical CH ablator with a seamlessly embedded marker layer was developed for use in CylDRT experiments to study deceleration phase Rayleigh-Taylor instability growth in a cylindrical configuration, as well as fill tube interactions in a cylindrical geometry. Targets using this technique were originally developed for OMEGA, but were fielded on NIF for the first time in January 2019.

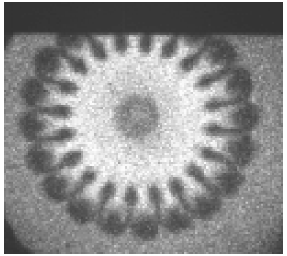


NIF CylDRT next to two OMEGA CylDRT targets



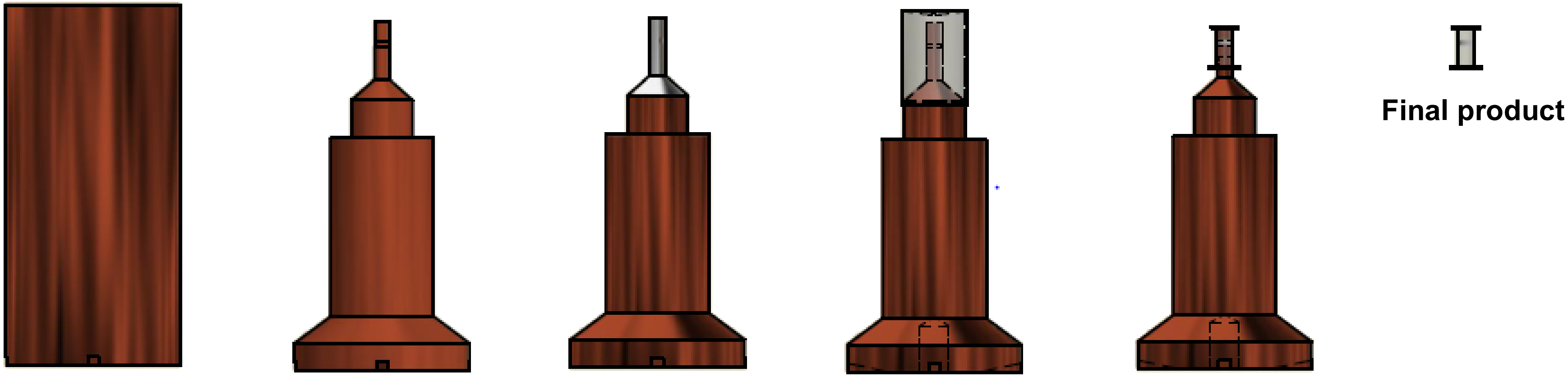


January 2019 NIF CylDRT



March 2019 CylDRT

Process Overview



Step1:
1a: Hand lap mandrel base.

Step2:
2a: Rough to workable dimensions

2b: Machine indicating surfaces.

3c: Cut internal perturbation profile.

Step3:
3a: Send to offsite for aluminum plating.

3b: Re-fixture indicate in and set zeros.

3c: Diamond turn OD of aluminum band.

Step4:
4a: Glue straw to Mandrel.

4b: Fill with Epon.

Step5:
5a: Re-indicate in and set zeros.

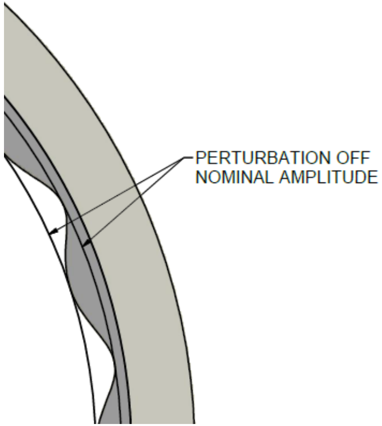
5b: Turn spool external dimensions.

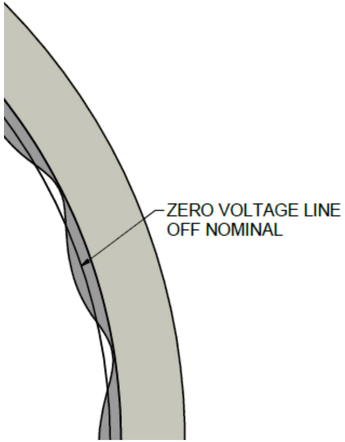
5c: Drill out copper from inside the spool.

5d: Part off spool

5e: Leach out remaining copper.

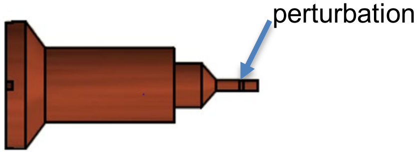
Inherent Process Vulnerabilities

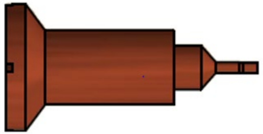




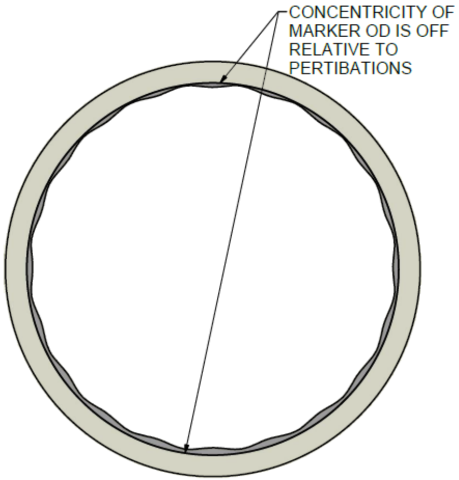
Variation develops
In step 2

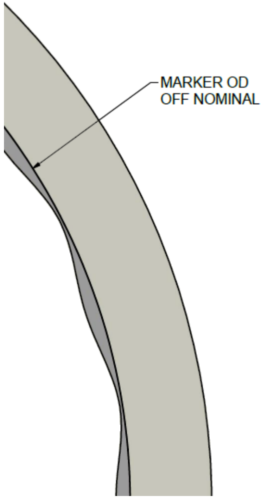
Variation develops
in step 2

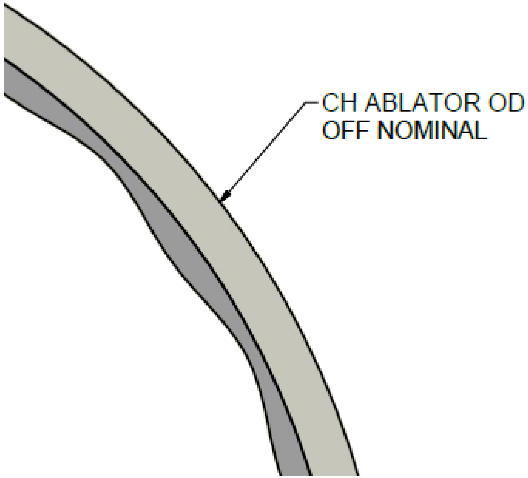




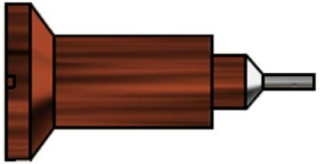
Inherent Process Vulnerabilities



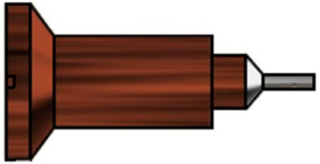




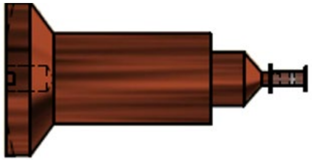
Variation develops
in step 3



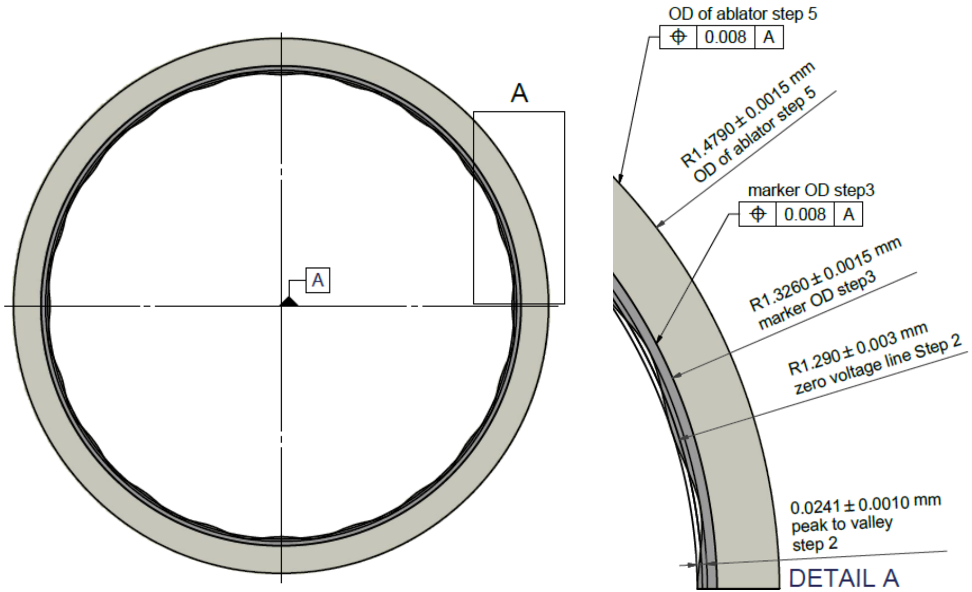
Variation develops
in step 3



Variation develops
in step 5



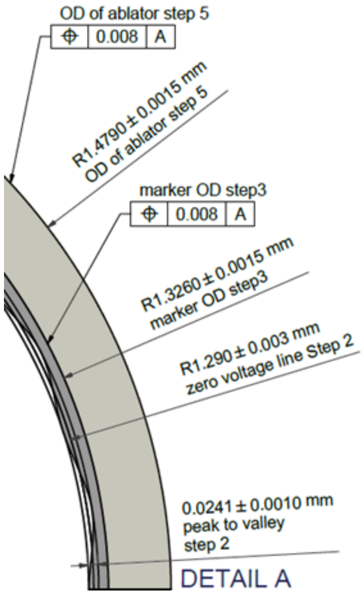
Inherent Process Vulnerabilities

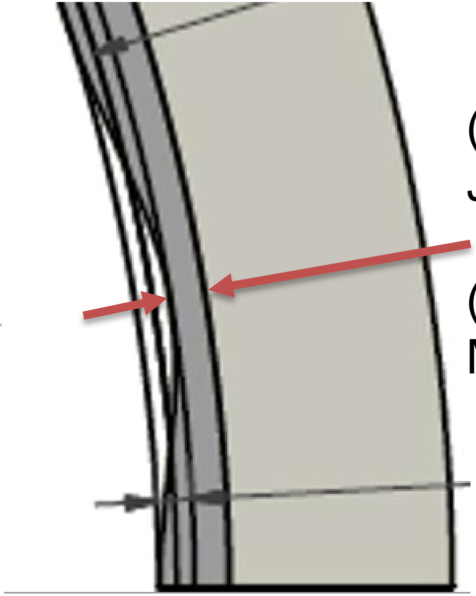


We need a process to:

- Identify critical dimensions.
- Minimize critical feature variation.
- Minimize positional offset.
- Develop an inspection plan that provides high value in process information.
- Develop an inspection plan that provides valuable physics characterization of the final product.

Inherent Process Vulnerabilities

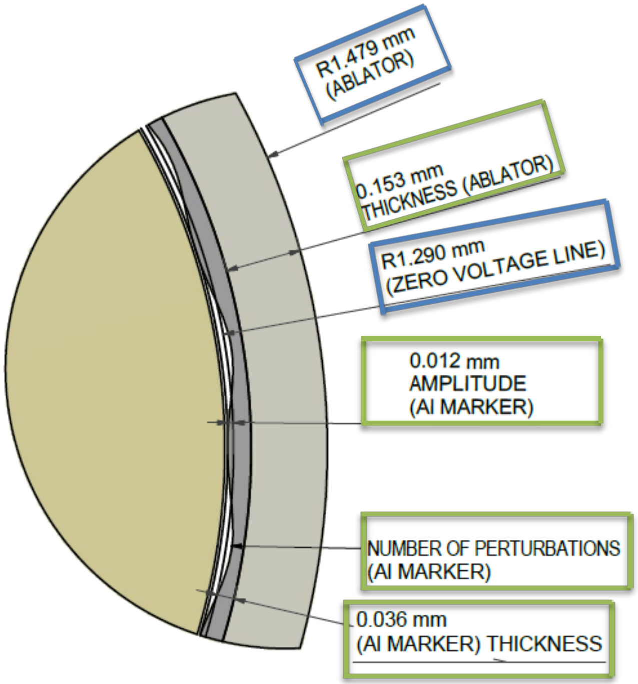




Stack up Minimum aluminum thickness NIF values				
Dimension	NOMINAL	Tolerance	Max	min
Peak to valley	0.024	0.001	0.025	0.023
Zero Voltage Line R	1.29	0.003	1.293	1.287
Marker R	1.326	0.0015	1.3275	1.3245
Marker OD Location	0	0.008	0.008	-0.008
			LMC	0.015
			MMC	0.033

Stack up Minimum aluminum thickness OMEGA values				
Dimension	NOMINAL	Tolerance	Max	min
Peak to valley	0.004	0.001	0.005	0.003
Zero Voltage Line R	0.43	0.003	0.433	0.427
Marker R	0.44	0.0015	0.4415	0.4385
Marker OD Location	0	0.008	0.008	-0.008
			LMC	-0.001
			MMC	0.017

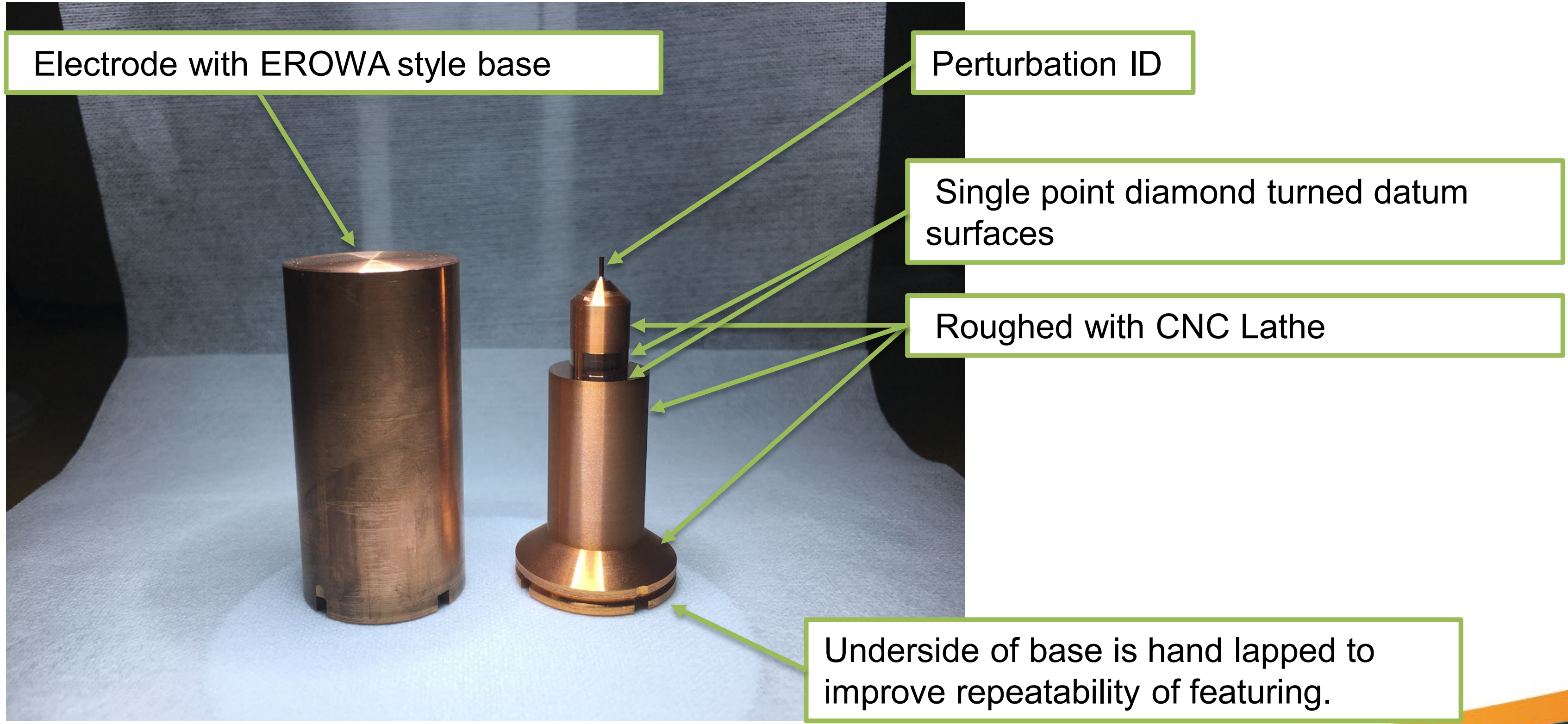
Critical Requirements



- Primary physics requirements

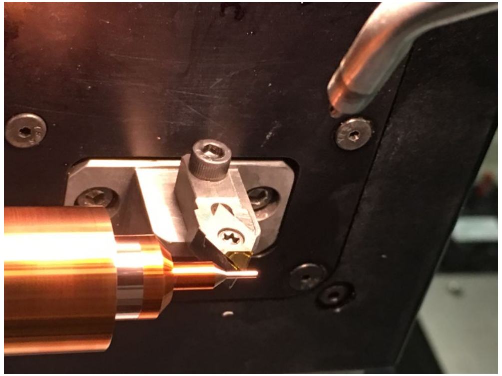
- Secondary physics requirements

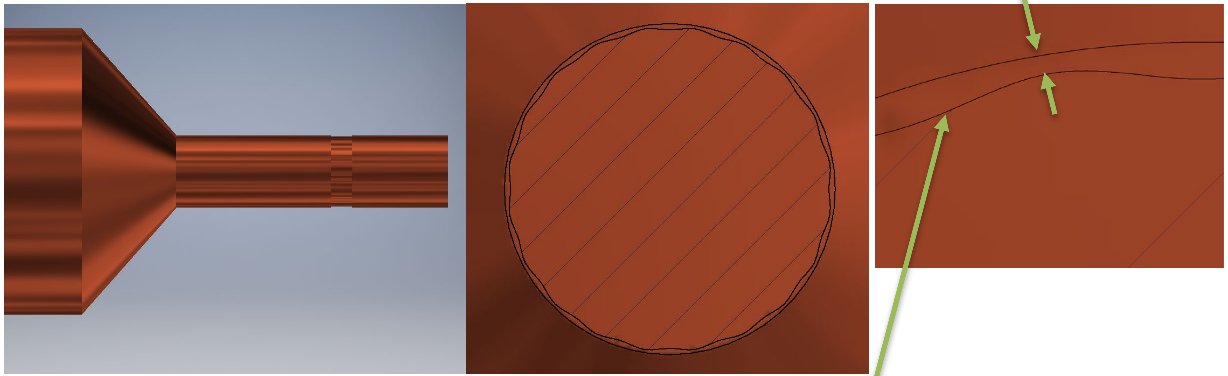
Machining Steps 1 and 2



Internal Marker Profile

Extra material for cleanup after aluminum plating

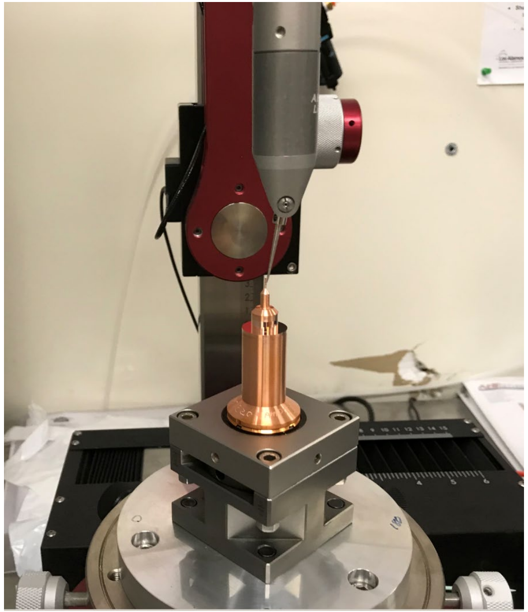




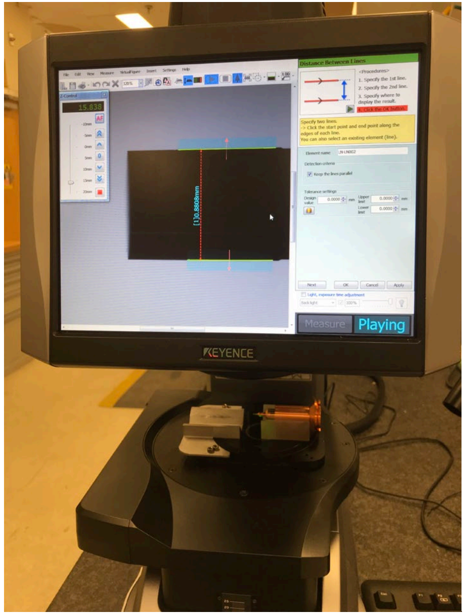
- Mandrel is mounted on Moore Nanotech 350 UPL
- Internal marker profile diamond turned using Moore Nanotech Fast Tool Servo-6000

This profile will form the inside of the Al marker profile. The zero voltage line, and amplitude need to be checked at this point.

Internal Marker Profile



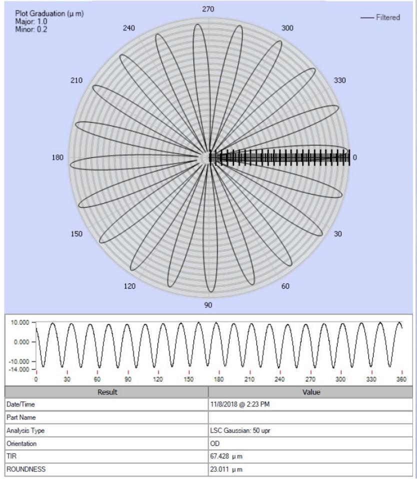
AB Tech uFG-150:
- Direct measurement of perturbations
- Contributes to measuring zero voltage line

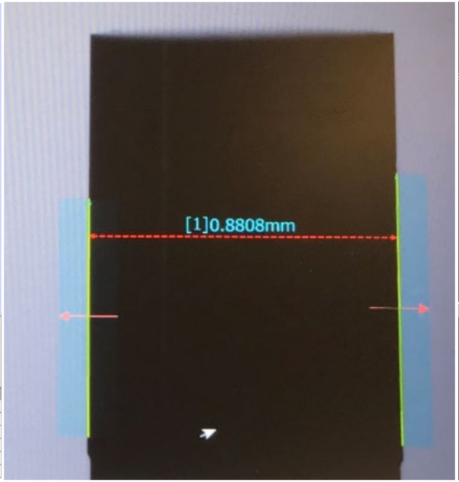


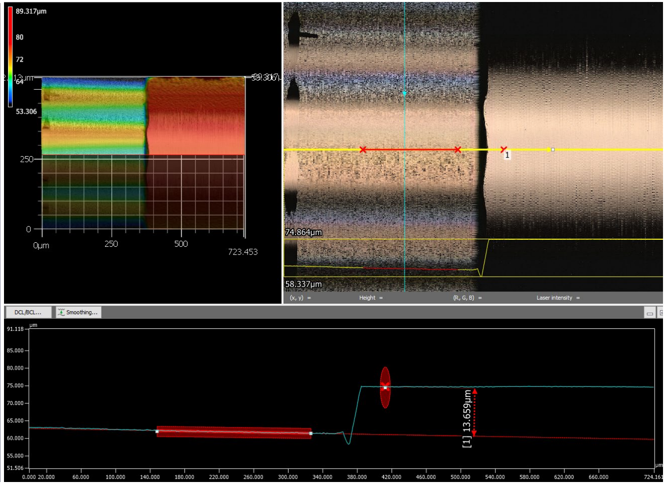
Keyence IM-6145:
- Contributes to measuring zero voltage line

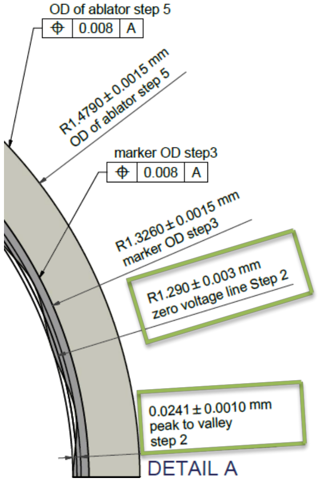
Keyence VK-X1000:
- Indirect measurement of surface finish
- Contributes to measuring zero voltage line

Marker Zero Voltage Line









AB Tech uFG-150:

- Direct measurement of perturbations
- Contributes to measuring zero voltage line

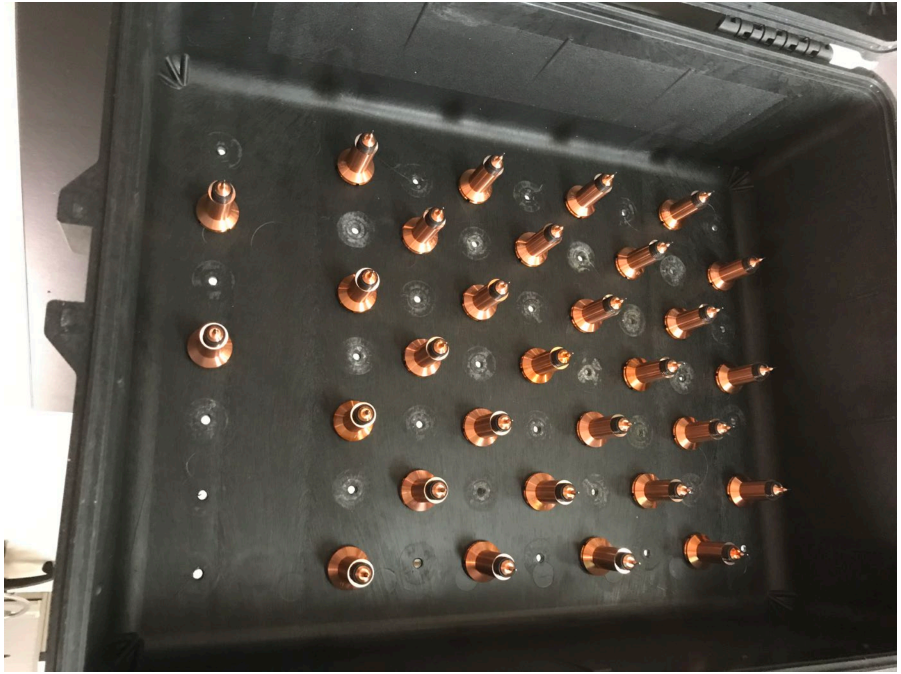
Keyence IM-6145:

- Contributes to measuring zero voltage line

Keyence VK-X1000:

- Indirect measurement of surface finish
- Contributes to measuring zero voltage line

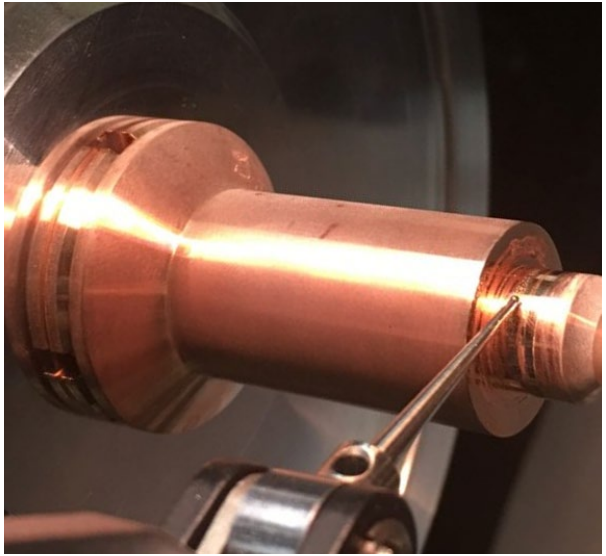
Aluminum plating



- O-rings placed on mandrel datum surfaces
- Shipped out for aluminum plating to Alumiplate
- Lead time 2-4 weeks

Step 3. Machining the marker OD

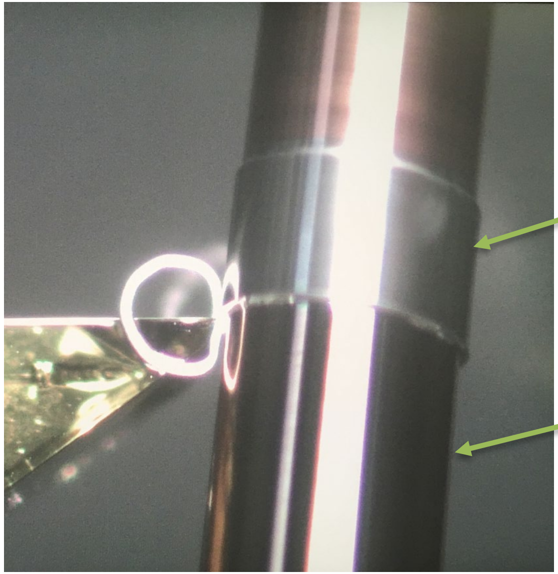
- As recived from Alumiplate
- O-rings are removed



Indicating in XY

Set Z-Zero

Step 3. Machining the marker OD

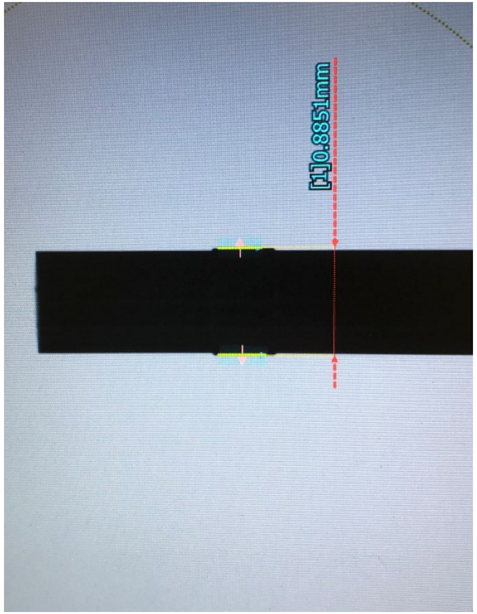


Marker OD

Spool ID where foam will be inserted

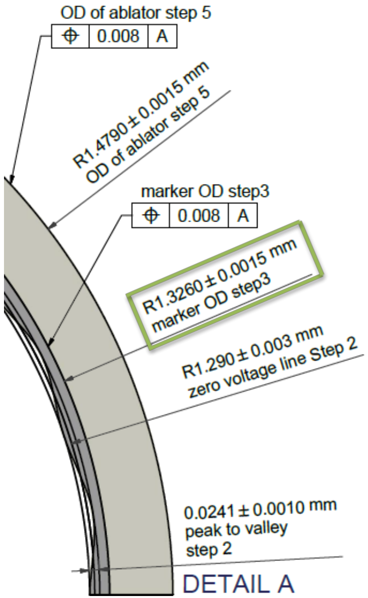
Moore Nanotech 350 UPL:

- Mandrels are serialized and each Al marker OD is machined to the measured zero voltage line + nominal marker thickness.



Keyence IM-6145:

- Direct measurement of aluminum band OD



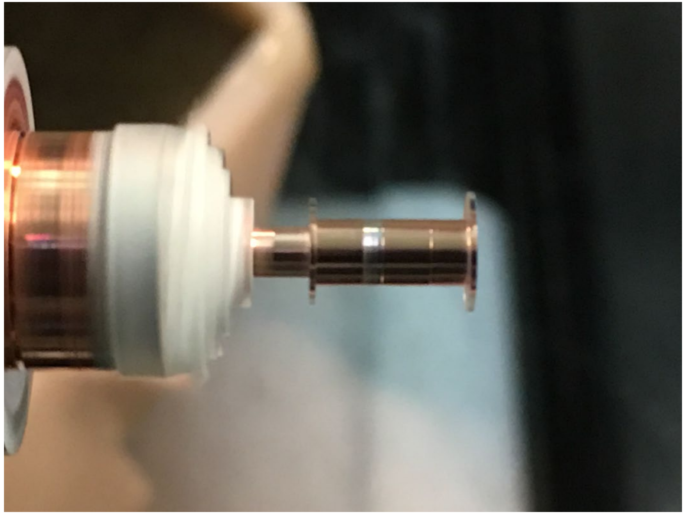
Step 4. Pouring the Epon

Add CH tubes & mix Epon

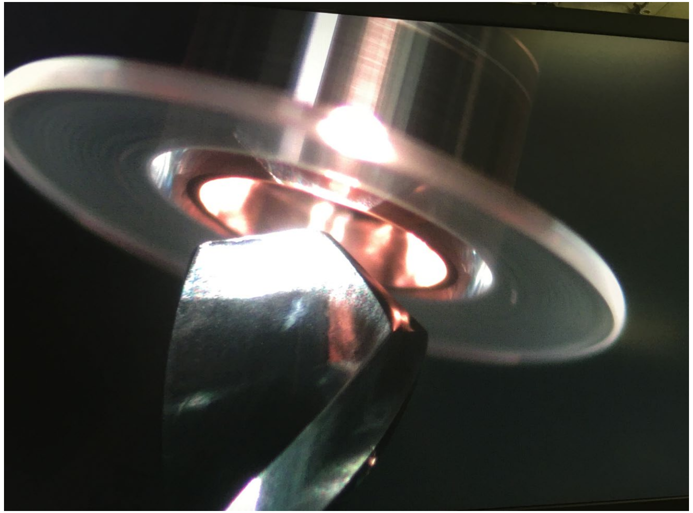
Centrifuge

Pour and cure Epon

Step 5. Machining the Ablator OD

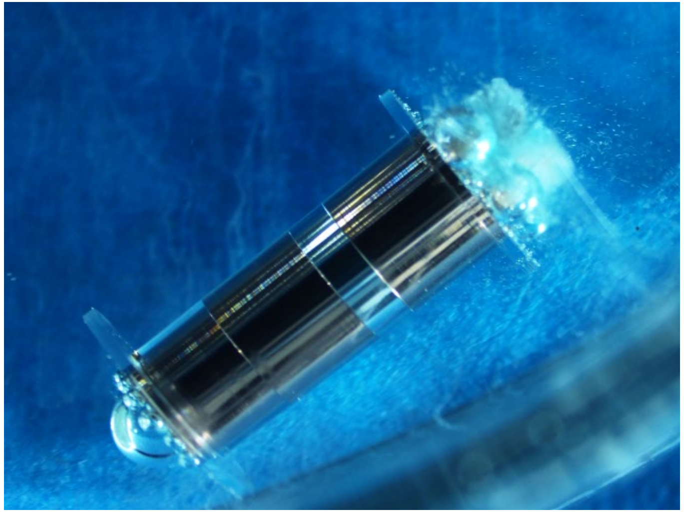


- Mandrels are indicated in on XY.
- Z-Zero is Set
- Each spool is serialized and the final ablator OD is cut to the measured Al marker OD + nominal ablator thickness.



- The majority of the copper in inside of spool is drilled out to reduce leaching time.
- Spool Is parted off
- Ablator OD is measured on a measuring microscope

Leaching out copper mandrel

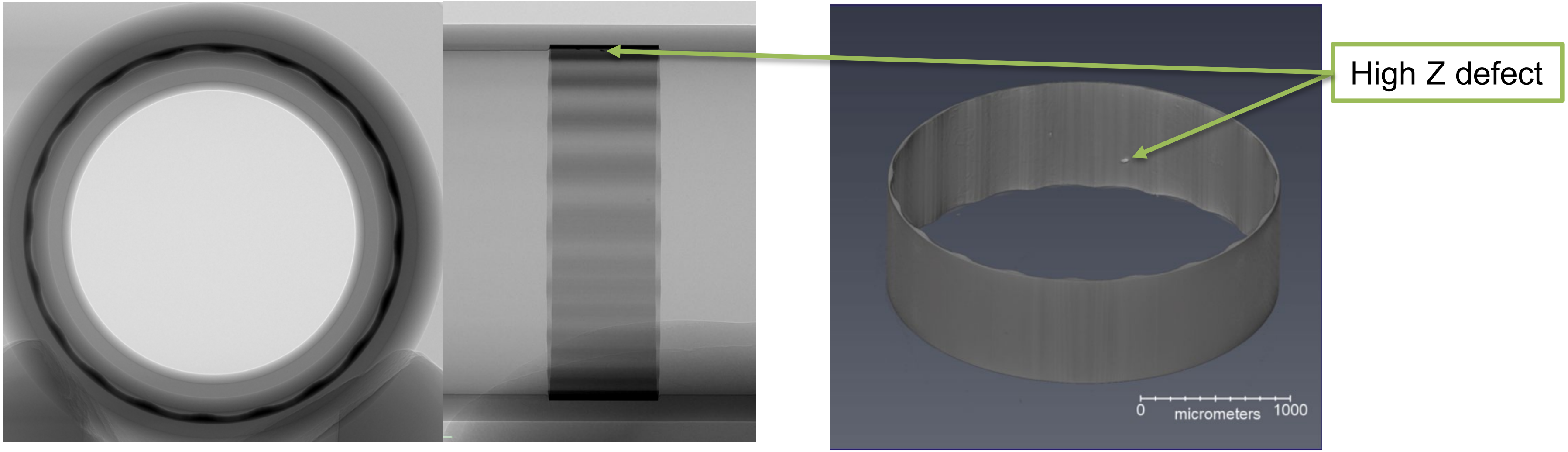


- Copper is leached out of spools with 35% nitric acid

Spool ID often shrinks during leaching and requires measuring with an OCMM or measuring microscope to ensure assembly.

NIF CylDRT final spool

Additional characterization



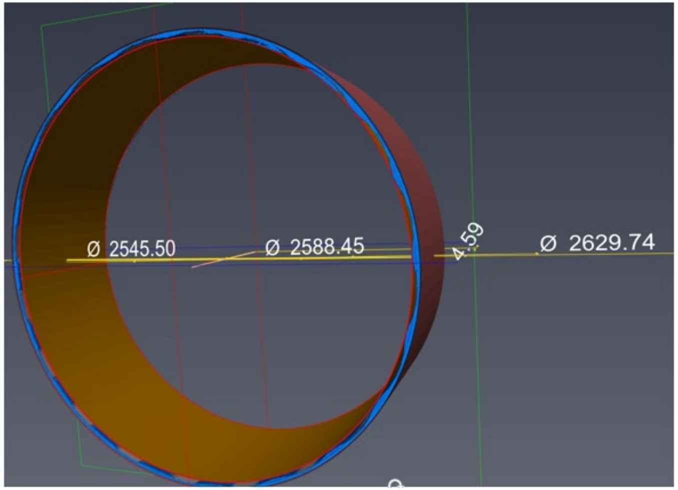
NIF CylDRT M20_02:

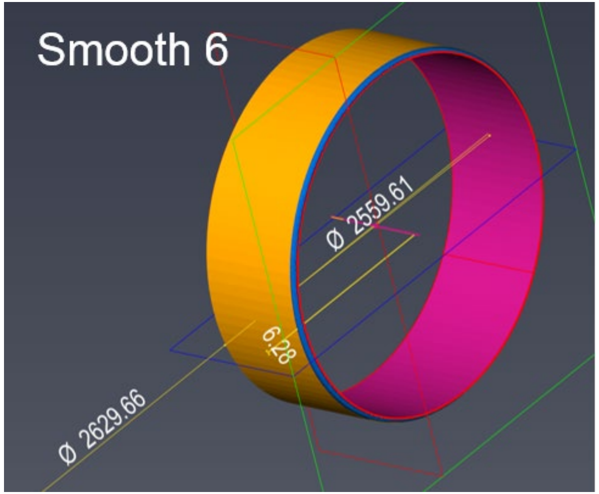
- NIF and OMEGA spools are radiographed to check for non-uniformities.

NIF CylDRT M20_02:

- For NIF targets 3D images are collected with x-ray tomography to look for defects in the Al marker.

Additional Characterization





Touch Probe scans	
Spool #	Amp
1	23.011
2	23.12
3	23.316
4	23.056
5	22.881
6	23.046
std	0.131
min	22.881
max	23.316
max-min	0.435

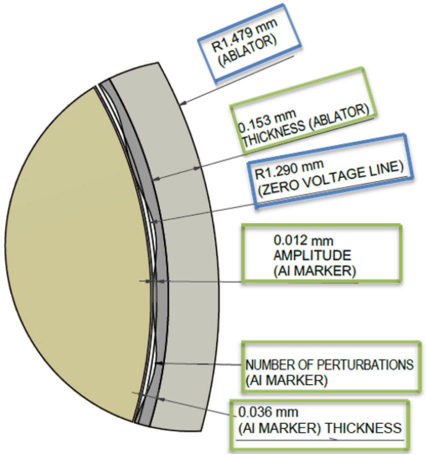
NIF CylDRT Mode 20 #2:
OD of Al band: 2629.74 μm
OD of perturbations: 2588.5 μm
ID of perturbations: 2545.5 μm
Offset between OD-band and ID pert.: 4.6 μm

NIF CylDRT Smooth #6:
OD: 2629.7 μm
ID: 2559.6 μm
Thickness of Band: 35.1μm
Offset of Centers: 6.28 μm

Results OMEGA CylDRT March 2019

M20 12um Thick, 4um Amp, 8um P-P (Off of Nominal)						
Mandrel#	P/V	Diameter of Swave	Diameter of Al Band	Band Thickness	OD CH Tube	Ablator Thickness
M20-1	-0.000055	0.002485	0.0028	-0.0002	-0.006	-0.0001
M20-2	-0.000227	0.001737	0.004	-0.0011	-0.005	0.0010
M20-3	-0.000096	-0.001176	-0.0013	0.0001	0.002	0.0019
M20-4	0.000051	-0.003011	-0.0029	-0.0001	-0.022	-0.0110
M20-5	0.000050	-0.003294	-0.0034	0.0001		
M20-6	0.000112	-0.000264	-0.0008	0.0003	-0.005	-0.0014
M20-7	0.000007	-0.000473	0.001	-0.0007	-0.001	0.0015
M20-8	0.000067	0.000781	0.002	-0.0006	-0.006	-0.0005
M20-9	0.000094	0.000806	0.0014	-0.0003	-0.007	-0.0013
M20-10	0.000068	0.000614	0.0019	-0.0006	-0.006	-0.0006
M20-11	-0.000039	-0.000223	-0.001	0.0004	-0.003	-0.0005
Standard deviation	0.000096	0.0017	0.0023	0.0004	0.0060	0.0035
max	0.000112	0.0025	0.0040	0.0004	0.0020	0.0019
min	-0.000227	-0.0033	-0.0034	-0.0011	-0.0220	-0.0110
Max-Min	0.000339	0.005779	0.007400	0.001520	0.024000	0.012800

M20 12um Thick, 4um Amp, 8um P-P (Off of Nominal)						
Mandrel#	P/V	Diameter of Swave	Diameter of Al Band	Band Thickness	OD CH Tube	Ablator Thickness
M20-1	-0.000055	0.002485	0.0028	-0.0002	-0.006	-0.0001
M20-2	-0.000227	0.001737	0.004	-0.0011	-0.005	0.0010
M20-3	-0.000096	-0.001176	-0.0013	0.0001	0.002	0.0019
M20-4	0.000051	-0.003011	-0.0029	-0.0001	-0.022	
M20-5	0.000050	-0.003294	-0.0034	0.0001		
M20-6	0.000112	-0.000264	-0.0008	0.0003	-0.005	-0.0014
M20-7	0.000007	-0.000473	0.001	-0.0007	-0.001	0.0015
M20-8	0.000067	0.000781	0.002	-0.0006	-0.006	-0.0005
M20-9	0.000094	0.000806	0.0014	-0.0003	-0.007	-0.0013
M20-10	0.000068	0.000614	0.0019	-0.0006	-0.006	-0.0006
M20-11	-0.000039	-0.000223	-0.001	0.0004	-0.003	-0.0005
Standard deviation	0.000096	0.0017	0.0023	0.0004	0.0060	0.0011
max	0.000112	0.0025	0.0040	0.0004	0.0020	0.0019
min	-0.000227	-0.0033	-0.0034	-0.0011	-0.0220	-0.0014
Max-Min	0.000339	0.005779	0.007400	0.001520	0.024000	0.003250



- Primary physics requirements
- Secondary physics requirements

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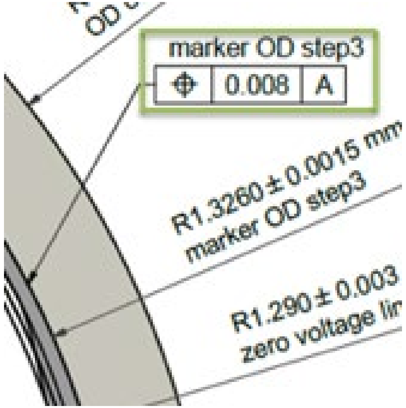
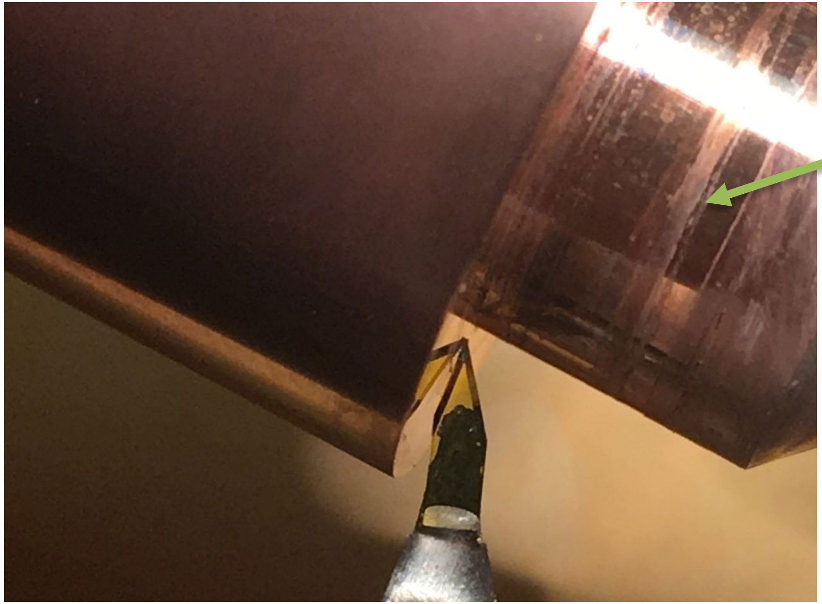
Future Improvements





Improve masking or clean mandrel indicating surface after it returns from Alumiplate

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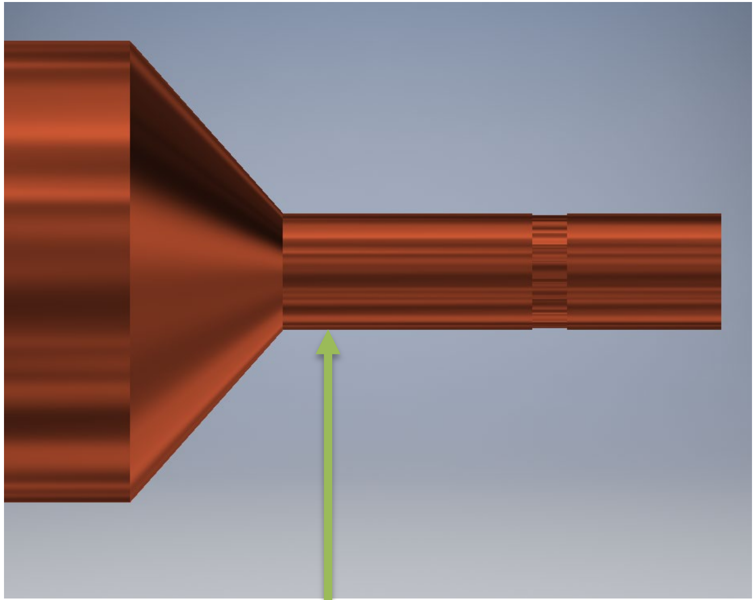
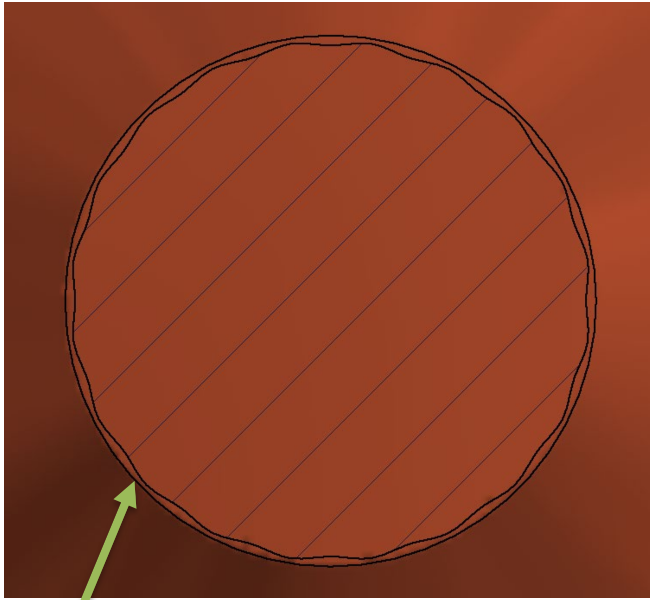
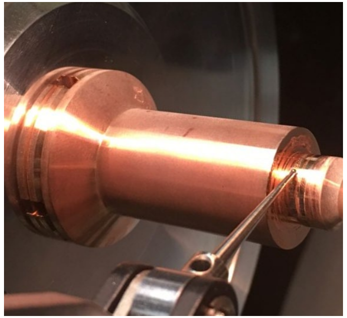
Future Improvements

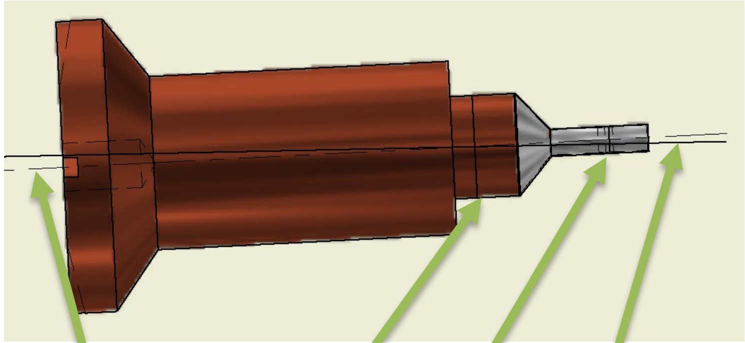


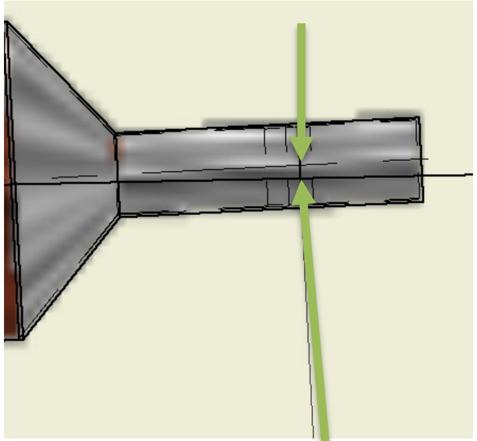


This OD is measured in step 2, we should be taking note of how many microns of aluminum are removed in step 3c before the od is clean to get an early on estimate of concentricity.

Step 2 and 3 axis could be shifted







Spindle axis in Step 2

Spindle axis in Step 3

Step3: Indicating in XY

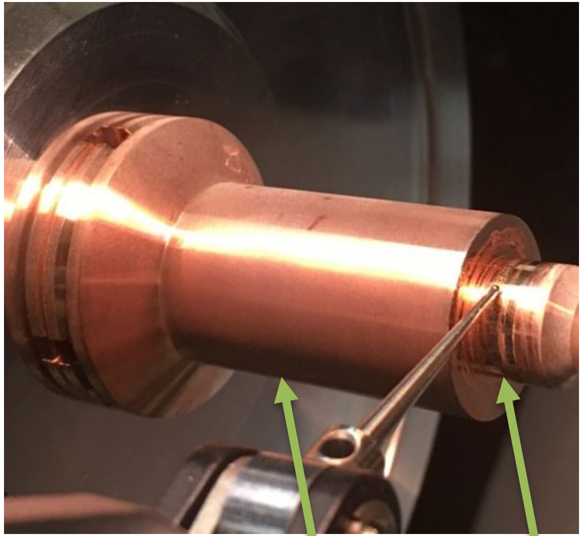
Indicating surface

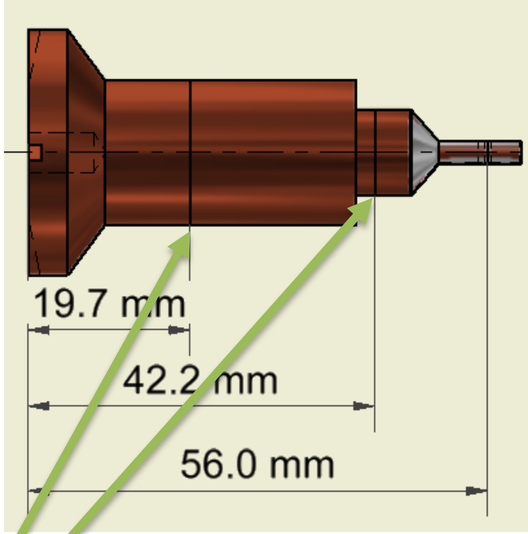
Center of AL band

Concentricity offset between perturbations and Al marker OD

- The angle that the mandrel is mounted on the spindle has changed (a concentricity change of 0.008 microns equates to a shift of 0.025 degrees)

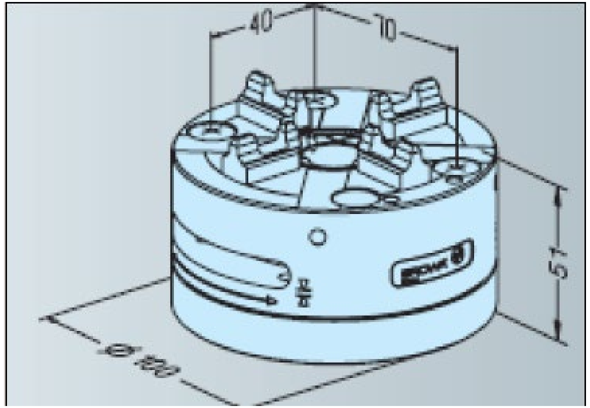
Add a second indicating surface



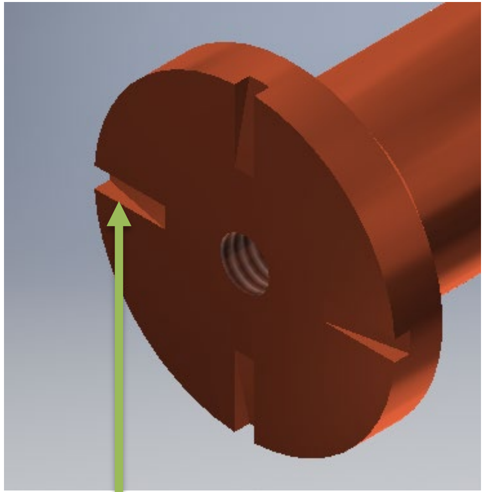


Indicating surface

Change to standard EROWA holder



EROWA style base

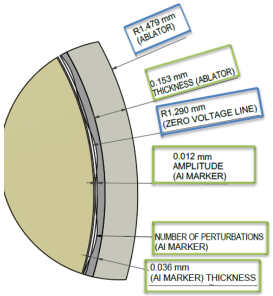


Copper mandrel (mushrooming of edges has been observed)

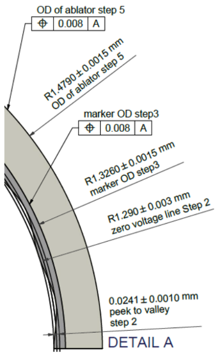
Standard EROWA style holder

Key Points

-



- Physics primary requirements
- Physics Secondary requirements

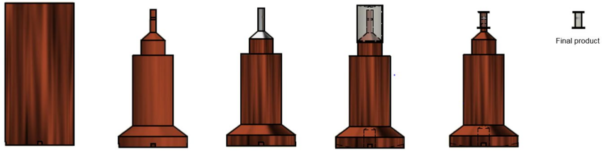


- Identify process vulnerabilities

- Identify critical requirements, (these may not be directly measurable)

M20 12um Thick, 4um Amp, 8um P-P (Off of Nominal)

Mandrel#	P/V	Diameter of Swave	Diameter of Al Band	Band Thickness	OD CH Tube	Ablator Thickness
M20-1	-0.000055	0.002485	0.0028	-0.0002	-0.006	-0.0001
M20-2	-0.000227	0.001737	0.004	-0.0011	-0.005	0.0010
M20-3	-0.000096	-0.001176	-0.0013	0.0001	0.002	0.0019
M20-4	0.000051	-0.003011	-0.0029	-0.0001	-0.022	-0.0110
M20-5	0.000050	-0.003294	-0.0034	0.0001		
M20-6	0.000112	-0.000264	-0.0008	0.0003	-0.005	-0.0014
M20-7	0.000007	-0.000473	0.001	-0.0007	-0.001	0.0015
M20-8	0.000067	0.000781	0.002	-0.0006	-0.006	-0.0005
M20-9	0.000094	0.000806	0.0014	-0.0003	-0.007	-0.0013
M20-10	0.000068	0.000614	0.0019	-0.0006	-0.006	-0.0006
M20-11	-0.000039	-0.000223	-0.001	0.0004	-0.003	-0.0005
Standard deviation	0.000096	0.0017	0.0023	0.0004	0.0060	0.0035
max	0.000112	0.0025	0.0040	0.0004	0.0020	0.0019
min	-0.000227	-0.0033	-0.0034	-0.0011	-0.0220	-0.0110
Max-Min	0.000339	0.005779	0.007400	0.001520	0.024000	0.012800



- Know the nominal process

- Improve if possible, and restructure the process to meet critical requirements first