Metrology of shielded ARC targets using mirror reflection

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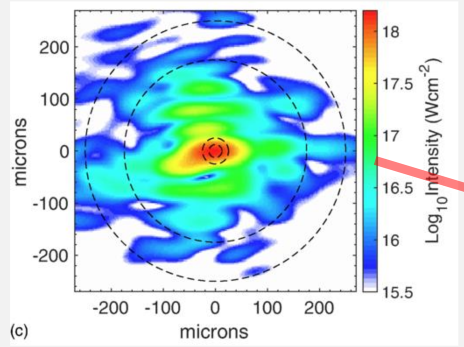
Summary

- The Advanced Radiographic Capability (ARC) laser beams need to point accurately to a micro-scale backlighter in a point-projection radiography experiment
- Low ARC X-ray conversion efficiency measured in several experiments necessitated increasing target metrology accuracy
- A metrology method using mirror reflected light in the Optical Coordinate Measuring Machine(OCMM) was developed to overcome the challenge posed by the backlighter shield

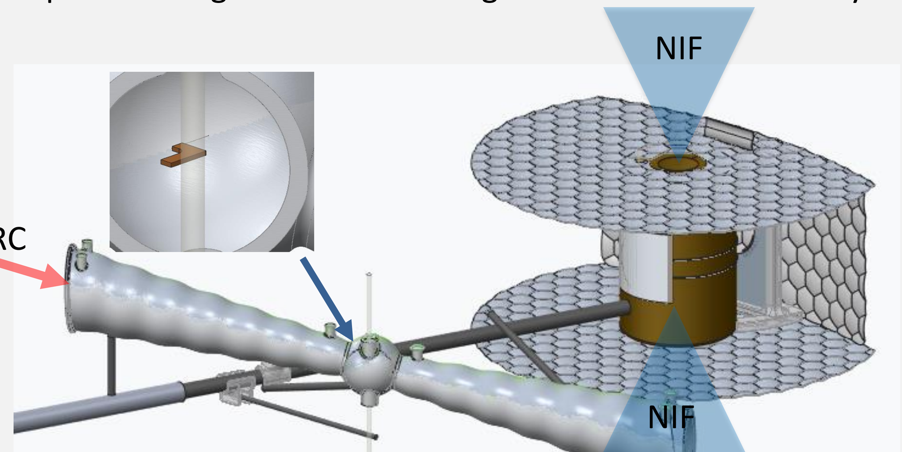
ARC experiments require high accuracy in target metrology

Small size and backlighter shield makes metrology challenging

- ARC backlighter targets are small (e.g., microwires with 12-25 um in diameter)
- Locations of backlighter and fiducial rods need to be measured within 10-um accuracy
- ARC backlighter needs to be hit by center 50 um of beamlets for the best energy coupling
- ARC pointing jitter and ARC alignment sequence using an ARC active target adds extra-uncertainty

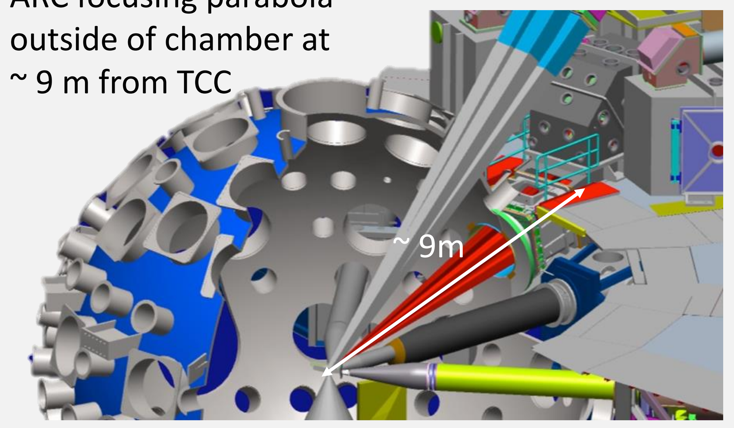


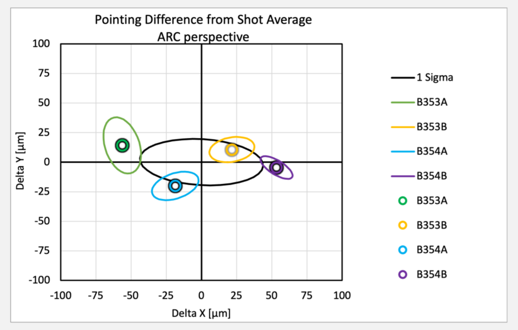
ARC focal spot, 20% energy is within center 50 um (J. Williams, PhysRevE. 103.L031201)



ARC backlighter target, LaNina; A tungsten wire generates X-rays for a radiograph of NIF driven capsule when coupled with ARC energy (wire dimension : 12.5 um dia x 800 um L)

ARC focusing parabola outside of chamber at ~ 9 m from TCC





ARC pointing has statistical offset, ~David Martinez

Micrometer size ARC targets need to be measured within 10 um accuracy in TCC coordinates

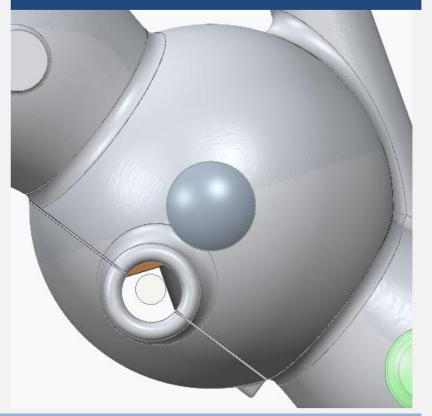
Target stability needs to be confirmed after shield install

- Backlighter wire and fiducial rod are measured before shield caps are installed
- Z-distance sensing laser cannot directly measure the wire after viewing window is closed
- Target stability needs to be confirmed after shield assembly

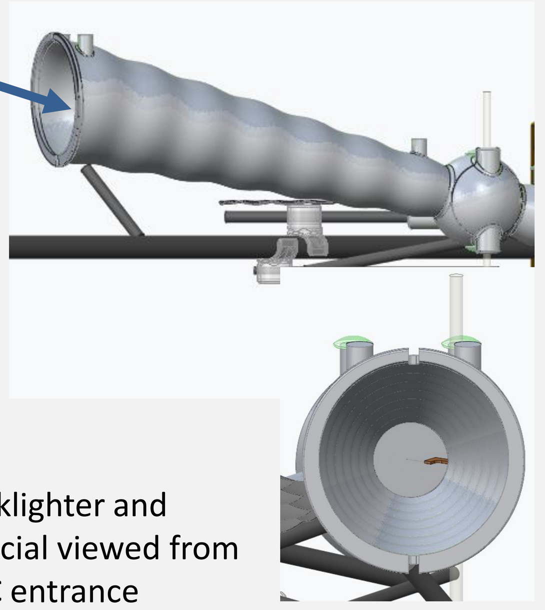
Assembly breakpoint for metrology

Wire is measured through metrology viewing window

Shield caps installed after final metrology



Wire is not measurable after shield caps are installed



Backlighter and fiducial viewed from ARC entrance

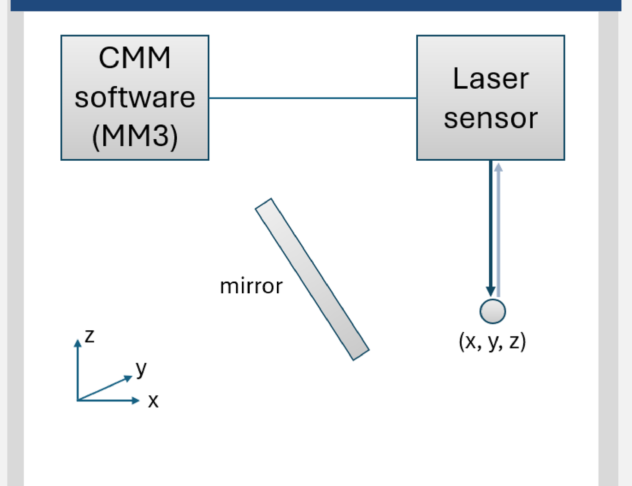
Measuring shielded backlighter through ARC beam entrance is needed to check target stability

Mirror reflected beam allows measurement along shield axis

OCMM compatible mirror reflected measurement was developed

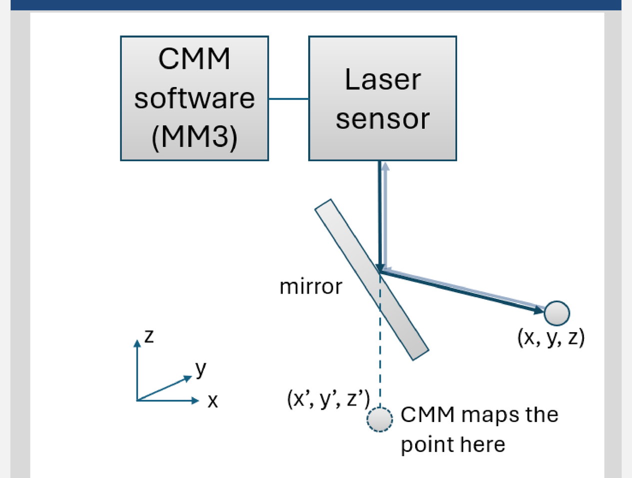
- All targets are measured using CMM and target base is used to align Cartesian coordinate axes
- Laser interferometer moves along the CMM bridge to measure z-distance (Digital readout of X, Y, Z)
- All measured points are transformed with respect to a specified datum origin within MeasureMind3 (MM3) software: a typical target origin is Target Chamber Center (TCC)

A. Direct beam measurement



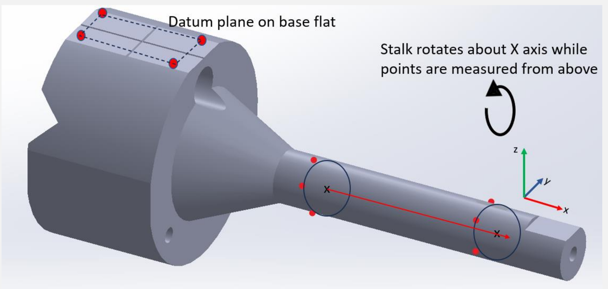
Laser sensor measures distance of travel

B. Mirror reflected beam measurement



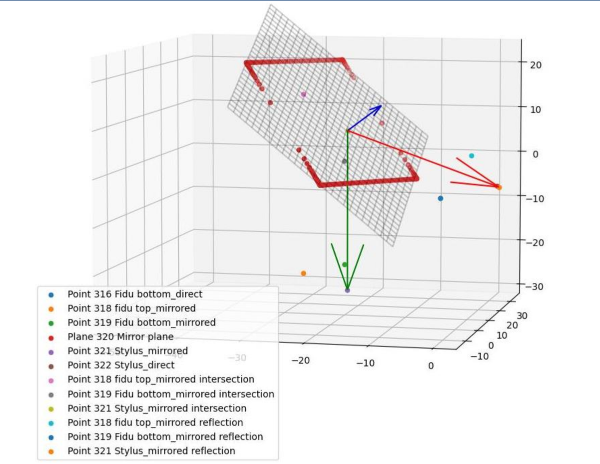
Mirror reflected light measures features under shield. Parts appear to be under the mirror

D. Compare data from step A and C



Data is compared in a common coordinate system set on target base

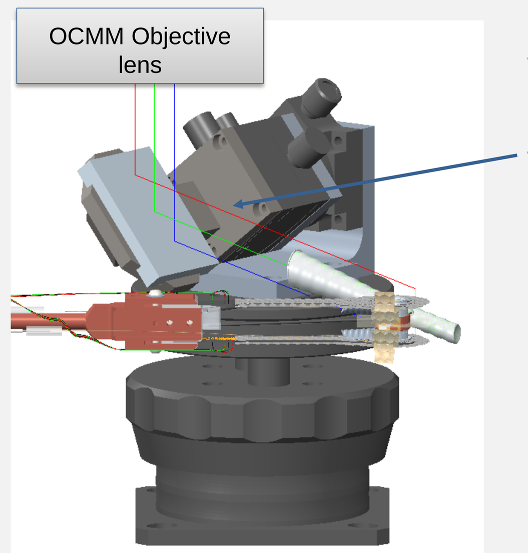
C. Reflection of points over the mirror



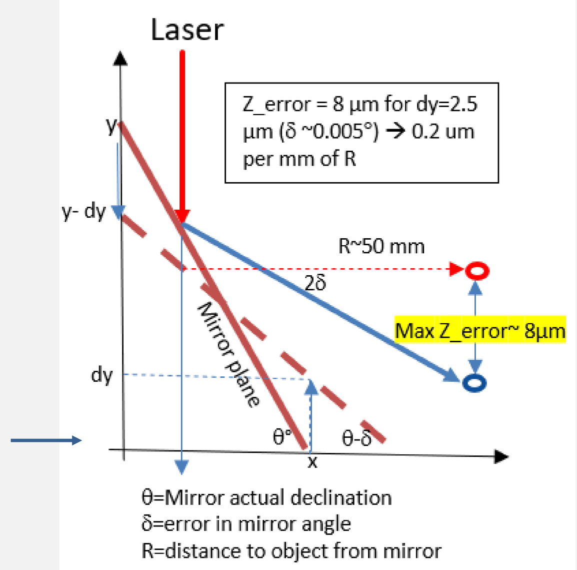
Mathematical reflection of measured points

Key acceptance criteria and requirements

Requirements	Engineering tool	Adopted parameters
Measure targets within 10 um accuracy	• Laser probe accuracy • Mirror flatness • Mirror measurement accuracy	• Probe accuracy = 2.5um in x, y, z • Mirror flatness =1/4λ or higher • Mirror perimeter was laser abated to allow laser measurement
Measure in ARC line of sight	• Mirror mount adjustable in z, θ and ϕ direction	• Dual axis goniometer mounted on height adjustable stage
Measure wire, foil, cone and U-flag	• OCMM programming	• MM3 routine optimization
Measure fiducial rods in the same FOV	• Mirror size	• 25 x 35 x 5 mm BK7, minimum size to measure 20 mm long fidu rod
Avoid collision during measurement	• Laser probe working distance	• 130 mm WD with 0.5x objective lens for 70 mm needed clearance



- Mirror tilt angle and height are adjustable
- Minimum clearance to target stalk and shield > 10 mm
- Max error in mirror angle by laser accuracy limit (2.5μm) = 0.005°
- Error in z increases with distance from mirror. Max error at 50 mm point = 8 μm.

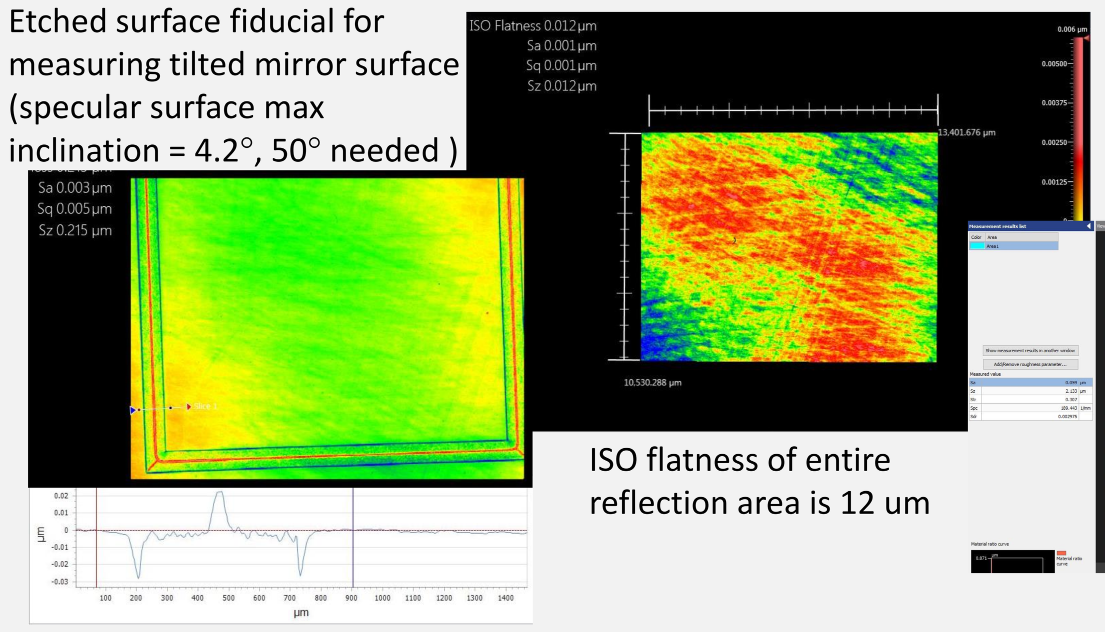


Mirror reflected CMM laser sensor can be used to measure location of shielded objects

Mirror reflected measurement meets required accuracy

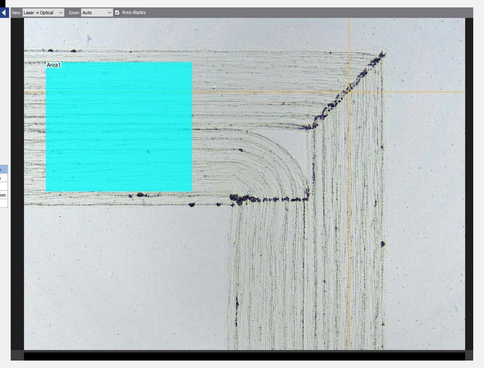
Mirror surface was roughened for mirror angle measurement by interferometer

Etched surface fiducial for measuring tilted mirror surface (specular surface max inclination = 4.2°, 50° needed)

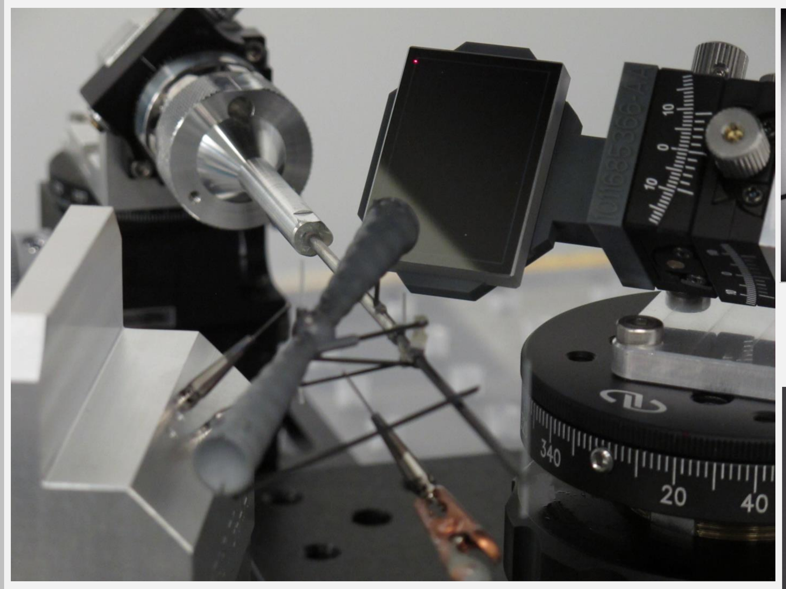


ISO flatness of entire reflection area is 12 um

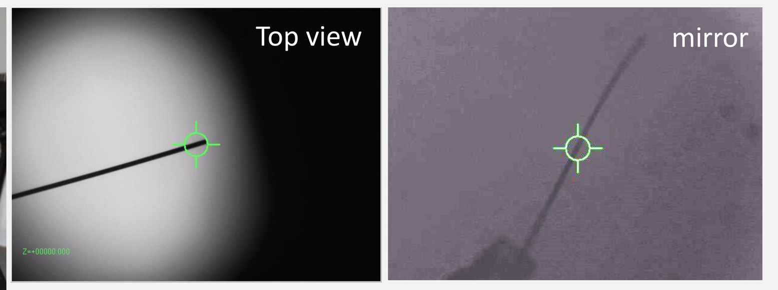
Roughness of etched trace was measured by confocal microscope (Sa =18 nm)



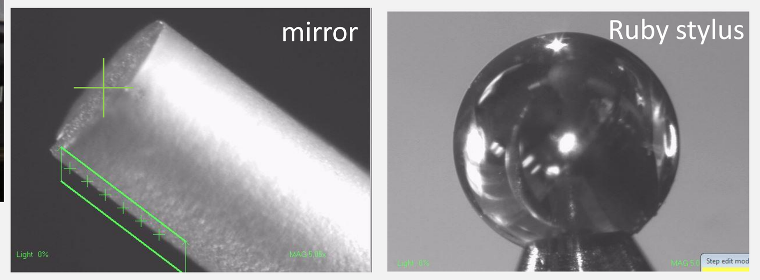
Mirror reflection measurement shows good agreement with direct measurement



Mirror reflection metrology set up : three Renishaw styli spheres were measured as reference for every target measurement

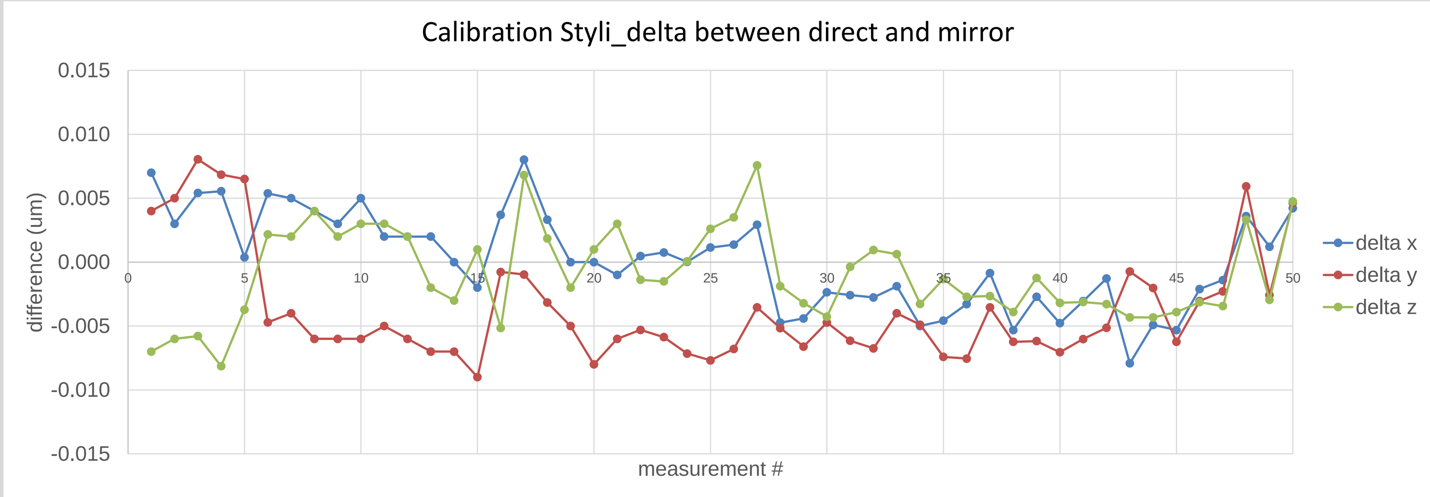


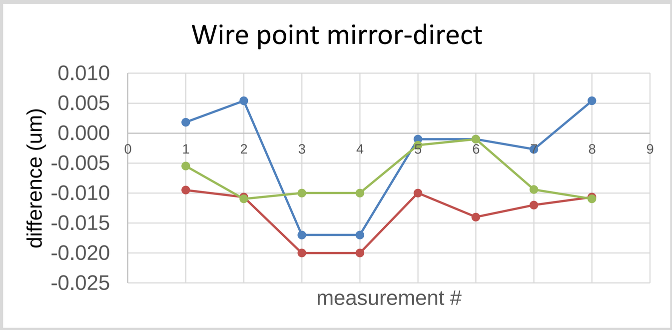
ARC aim point on W wire was measured from top view and mirror reflected view for comparison

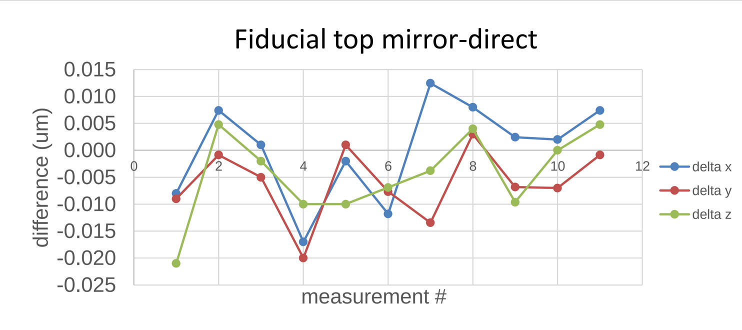


Top and bottom of backlighter rod are fiducial reference location for ARC beam alignment

Stylus spheres measured by mirror vs direct show agreement within 10 um







- Accuracy of sphere center measurement is within 10 um consistently for 50+ measurements
- Measurement of fiducial rod has higher uncertainty because of lack of shape symmetry. (10-15 um)
- Accuracy of ARC aim point on wire is within 10 um in z-direction (more critical than x,y direction for ARC pointing). Errors in x and y directions can be reduced by improving CMM software design

- Concept of measuring target coordinates by mirror reflected light was demonstrated.
- Hardware pallet is being designed and fabricated by precision engineering team for production commissioning.

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