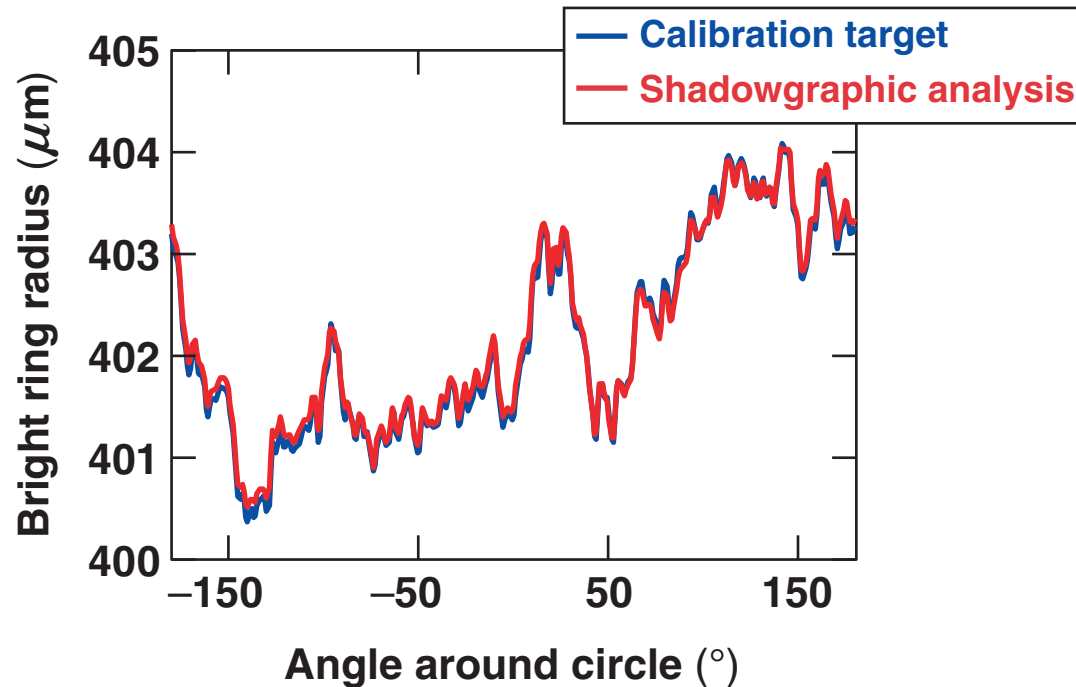


Calibration of the Cryogenic Target Optical Shadowgraphic Characterization System at LLE



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Summary

Optical shadowgraphic characterization of cryogenic targets is typically accurate to $\sim 0.1 \mu\text{m}$



- Need to accurately measure sub- $1\text{-}\mu\text{m}$ rms ice layers in our system with $\sim 1 \mu\text{m}/\text{pixel}$ magnification.
- Backlit shadowgraphic target images show rings from various reflections/refractions at the inner ice surface.
- Major sources of data collection error have been identified, measured, and compensated.
- The errors in outer edge perturbation and bright ring position measurements were $\sim 0.1 \mu\text{m}$.

Collaborators



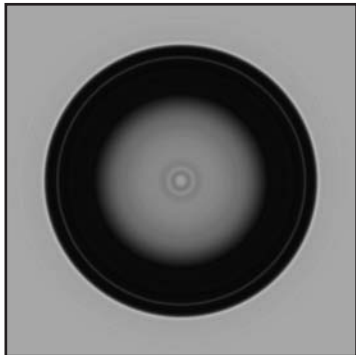
**R. S. Craxton, L. M. Elasky, D. R. Harding,
L. S. Iwan, R. L. Keck, L. D. Lund,
S. J. Verbridge, M. D. Wittman, and W. Seka**

Analysis Error

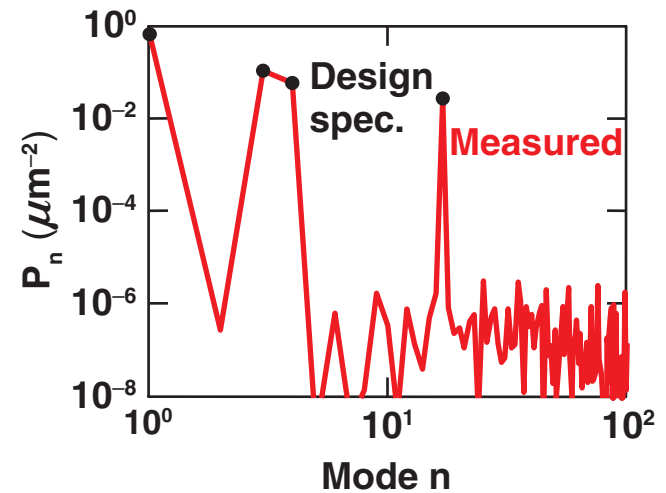
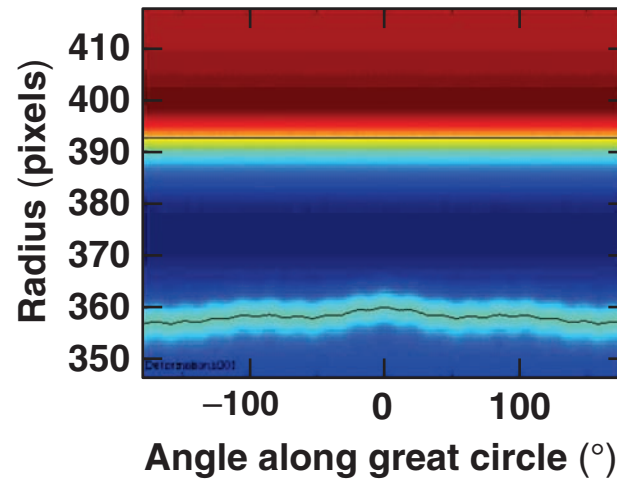
Analysis of simulated shadowgraphs shows that error due to the analysis algorithm is very small



Simulated image from CEA



Unwrapped image



- Analysis precisely determines bright ring mode amplitudes “identical” to image simulation specifications for a typical OMEGA target shadowgraph

P_n spectrum error: $\leq 4.3 \times 10^{-4} \mu\text{m}^2$

Bright ring rms error: $4.5 \times 10^{-4} \mu\text{m}^2$

Measurement Error

The image blurring due to target vibration is negligible

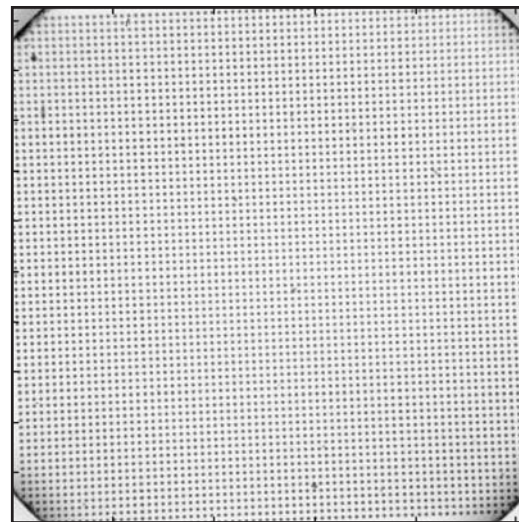


Luxeon III Star
627 nm

- High-intensity LED
- 50- μ s pulse

Radial pincushion distortion due to lens imperfection is characterized, minimized, and compensated using a precision dot-matrix target

Chrome on glass
10- μm -radius dots
20- μm dot pitch
Manufacturing
tolerance 0.1 μm



- Distortion is minimized by aligning the target with the optical axis.
- The absolute magnification also determined.

Nonparallelism between the image plane and target plane is measured and compensated using a precision dot-surrogate target

Dot-surrogate target

Chrome on glass

“Perfect” circular edge

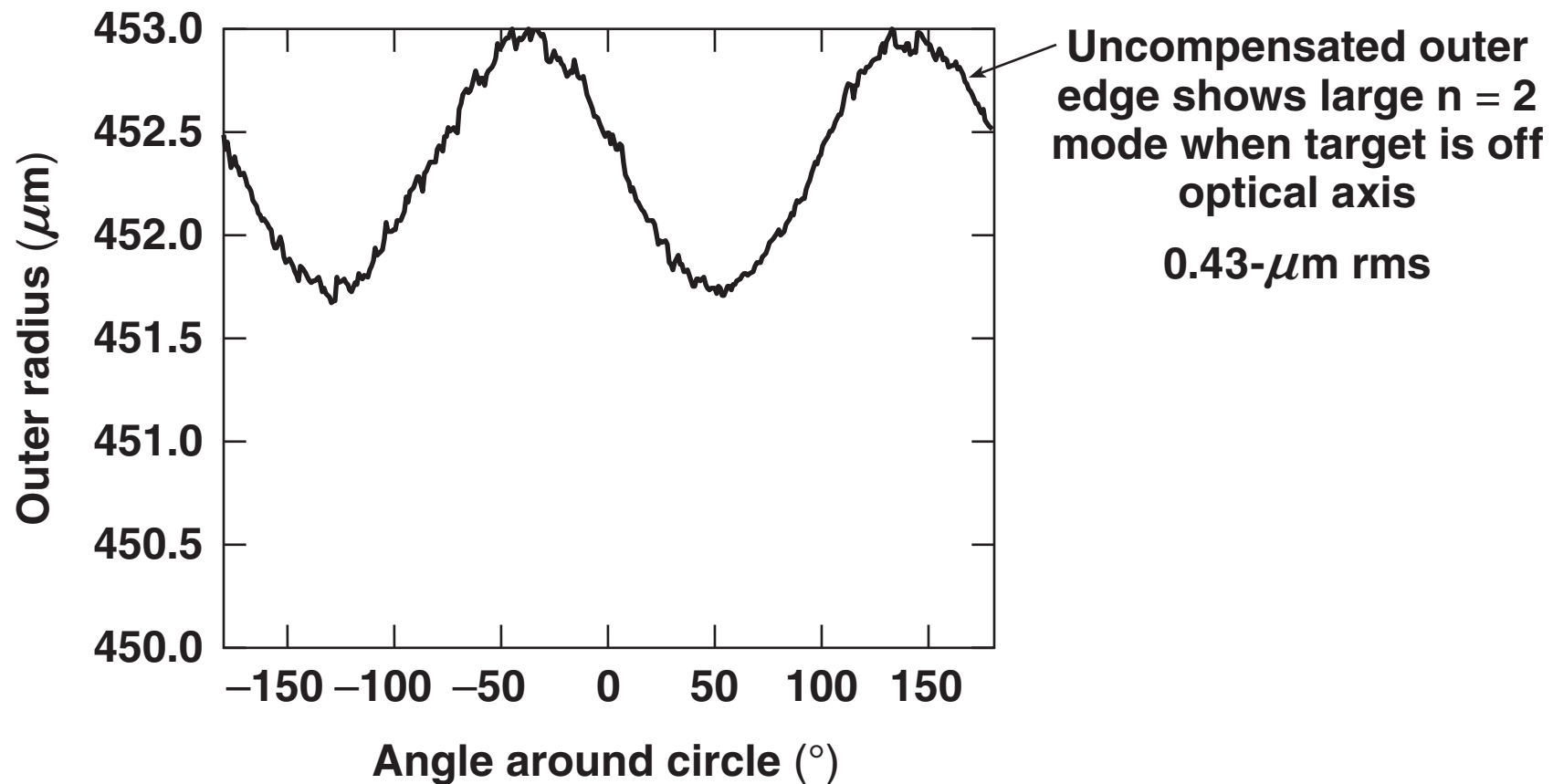
Rings calculated for a given ice surface with $1\text{-}\mu\text{m}$ rms

Manufacturing tolerance $0.1\ \mu\text{m}$

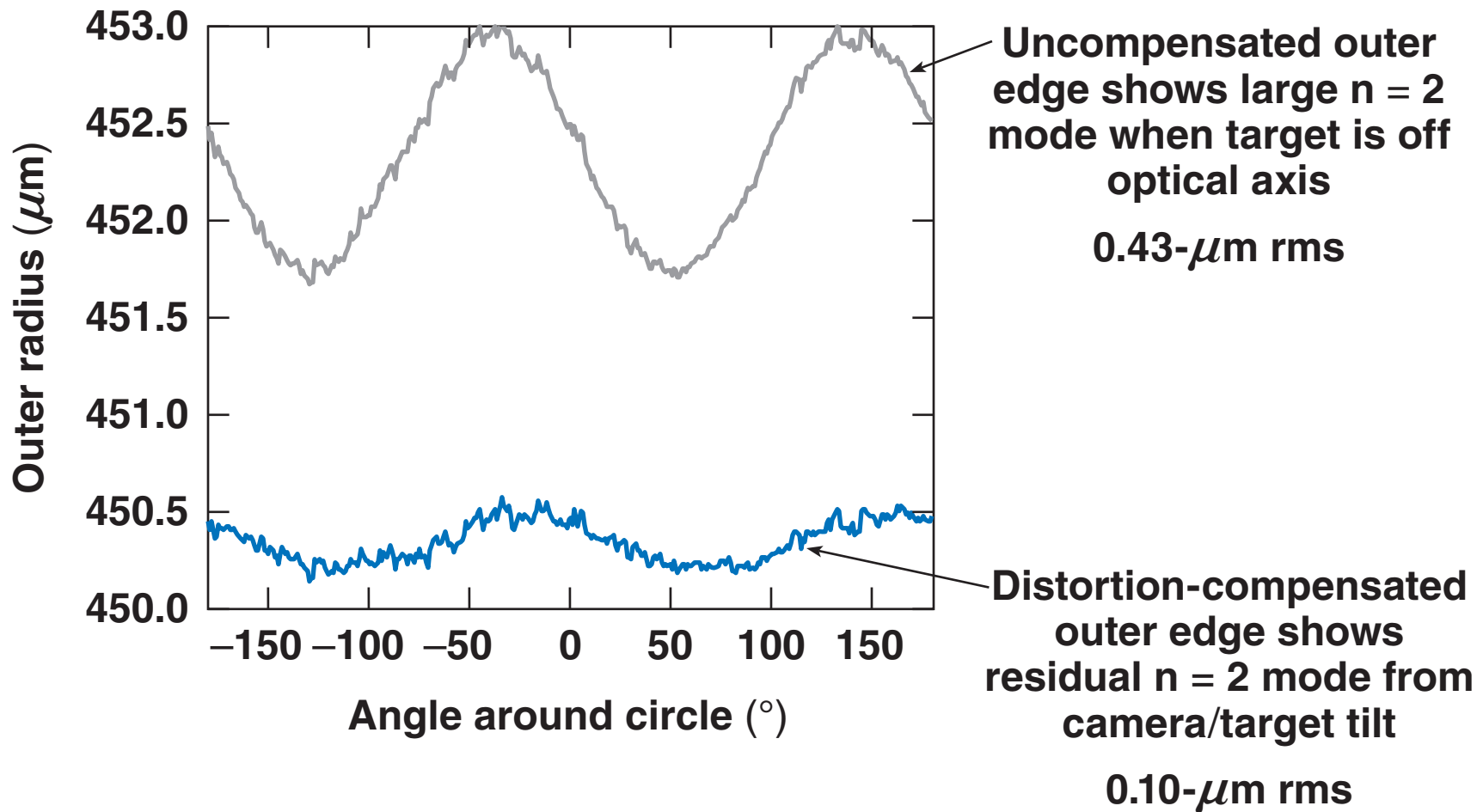


- The $n = 2$ Fourier mode of the outer edge is used to determine the image/target-plane tilt.
- The target is also used to determine the accuracy of the edge/ring measurements.

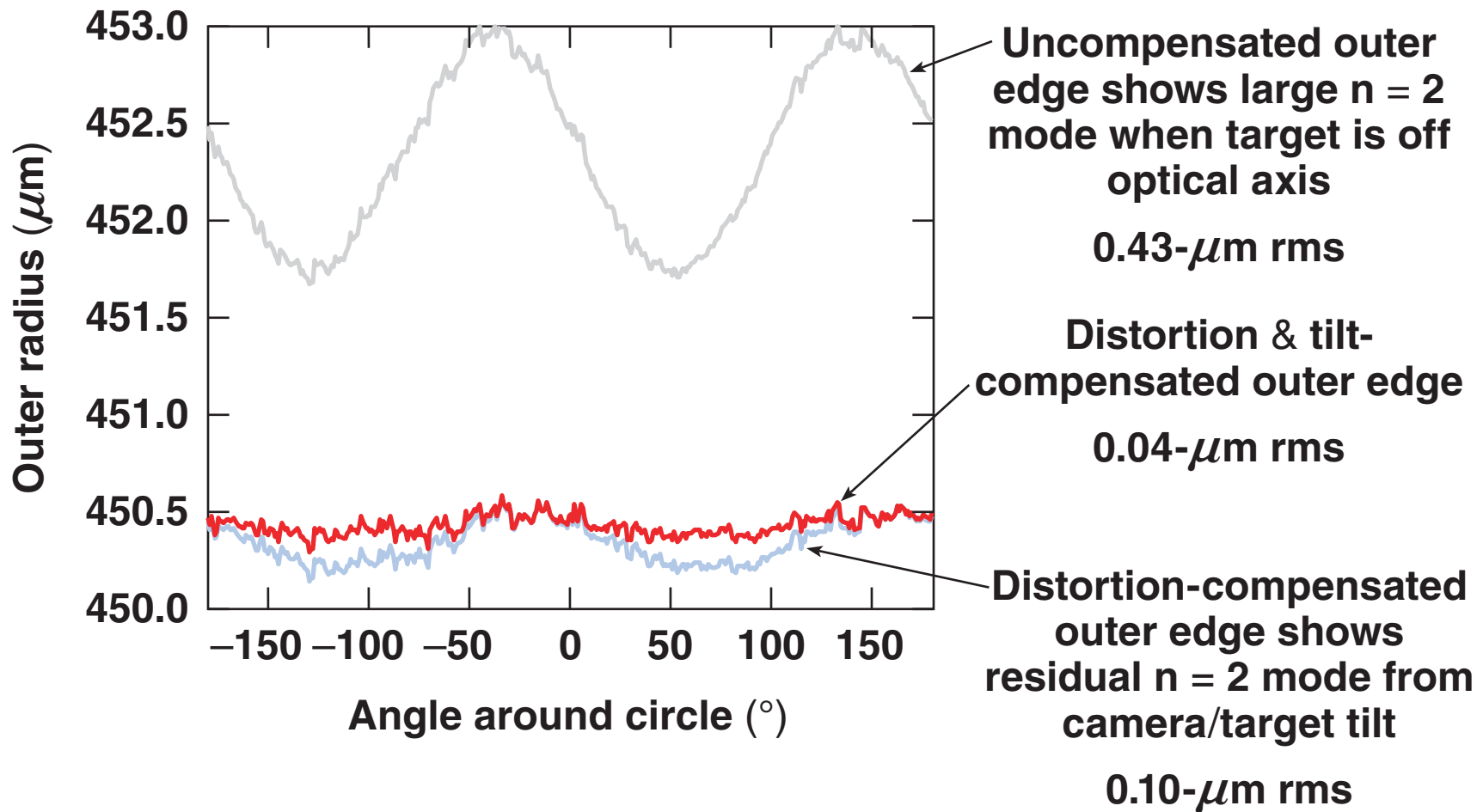
Distortion compensation has been verified using a precision dot-surrogate target



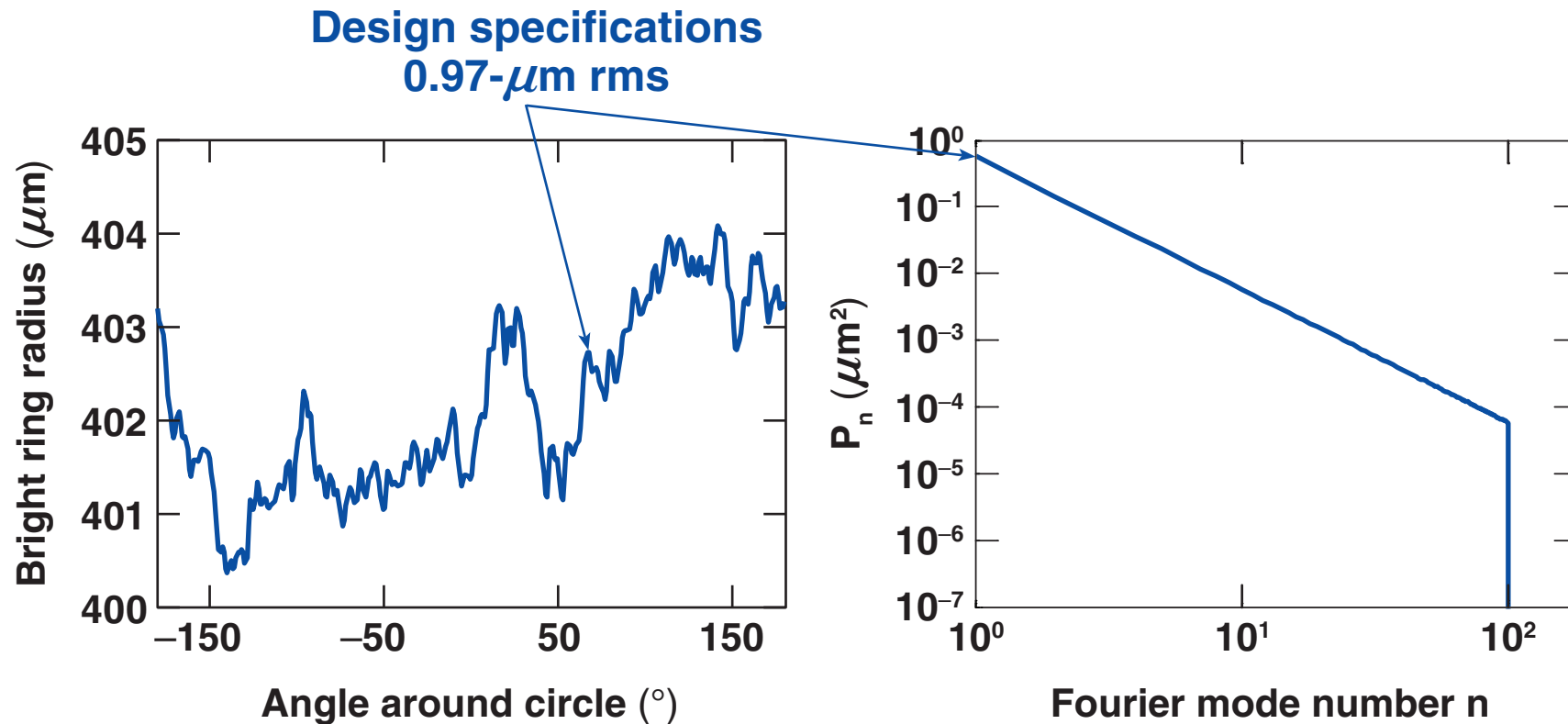
Distortion compensation has been verified using a precision dot-surrogate target



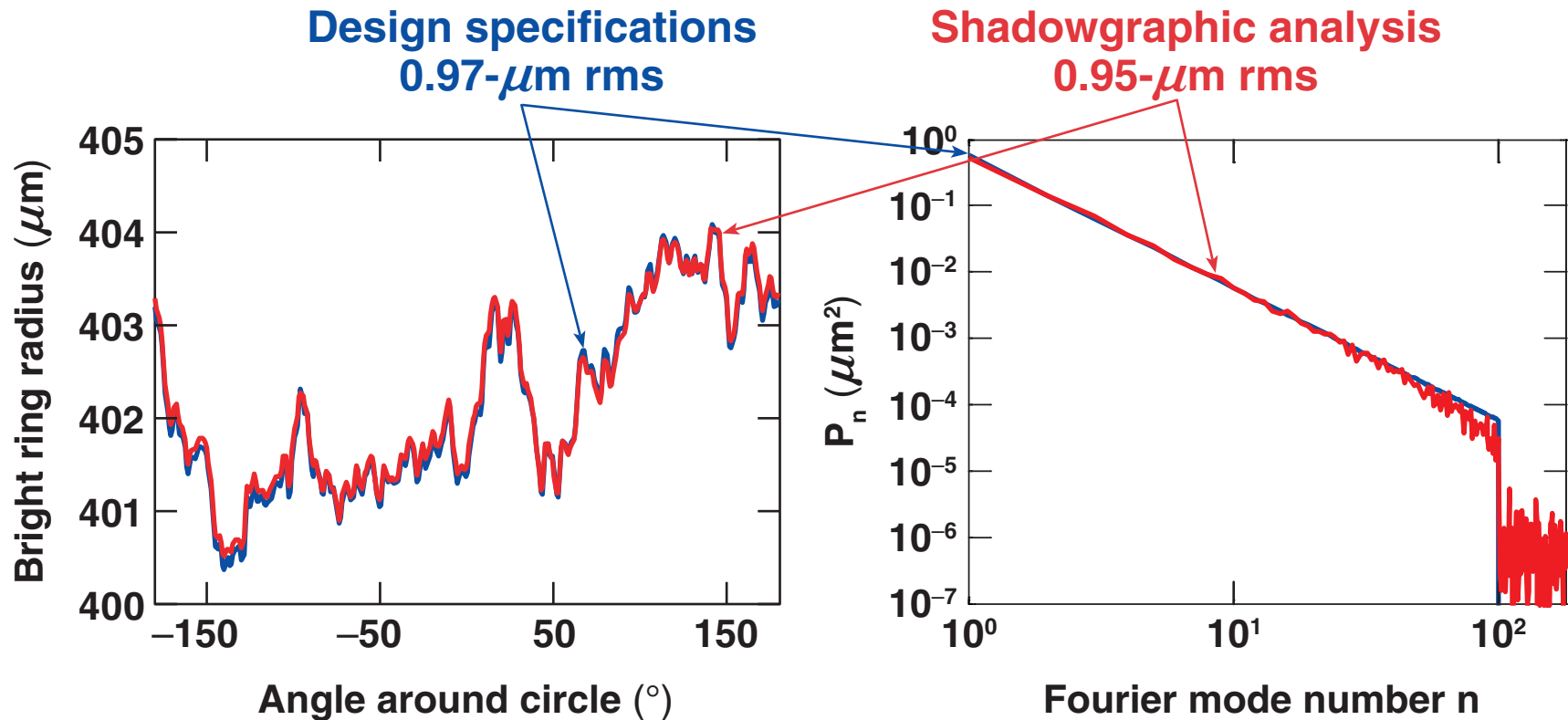
Distortion compensation has been verified using a precision dot-surrogate target



Precision dot-surrogate target analysis shows the error of the bright ring measurement to be $\sim 0.1 \mu\text{m}$

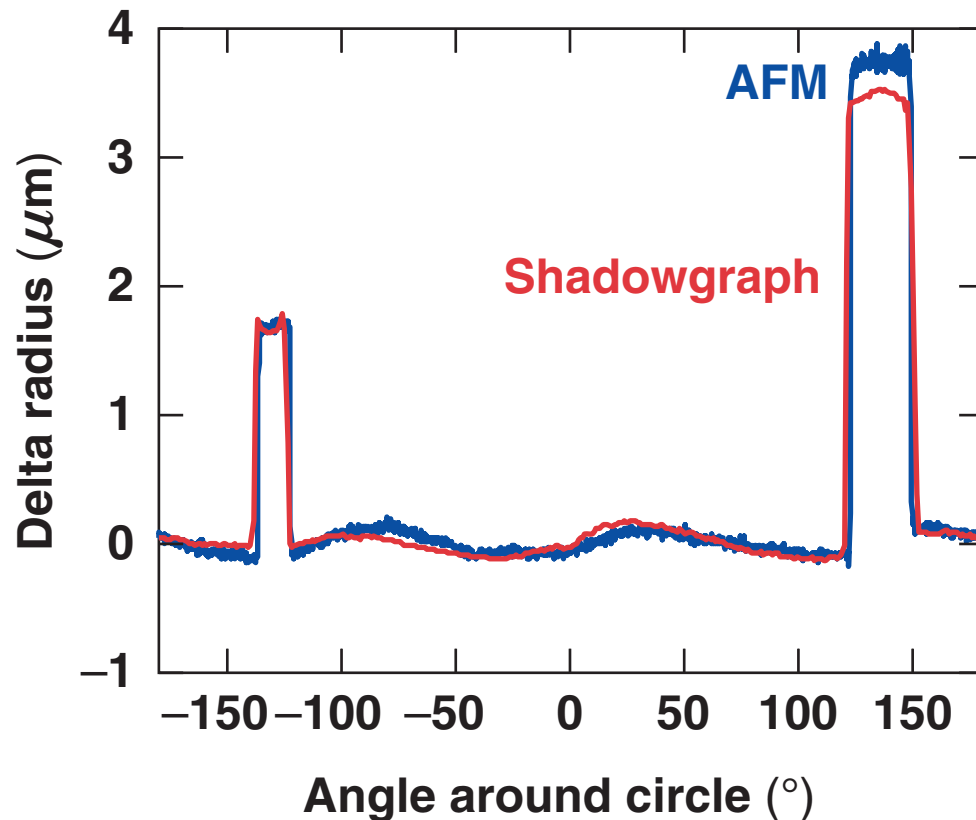


Precision dot-surrogate target analysis shows the error of the bright ring measurement to be $\sim 0.1 \mu\text{m}$



Mean bright ring error: $0.06 \mu\text{m}$
Ice-surface rms error: $0.02 \mu\text{m}$

A sapphire calibration target confirms the accuracy of the outer surface measurements



- Sapphire sphere with two gold dots deposited on it
- AFM & shadowgraph characterizations for “similar views” are compared
- $\sim 0.1\text{-}\mu\text{m}$ error (outside of dots)
- Differences partially due to uncertainty in views and AFM data

Summary/Conclusions

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