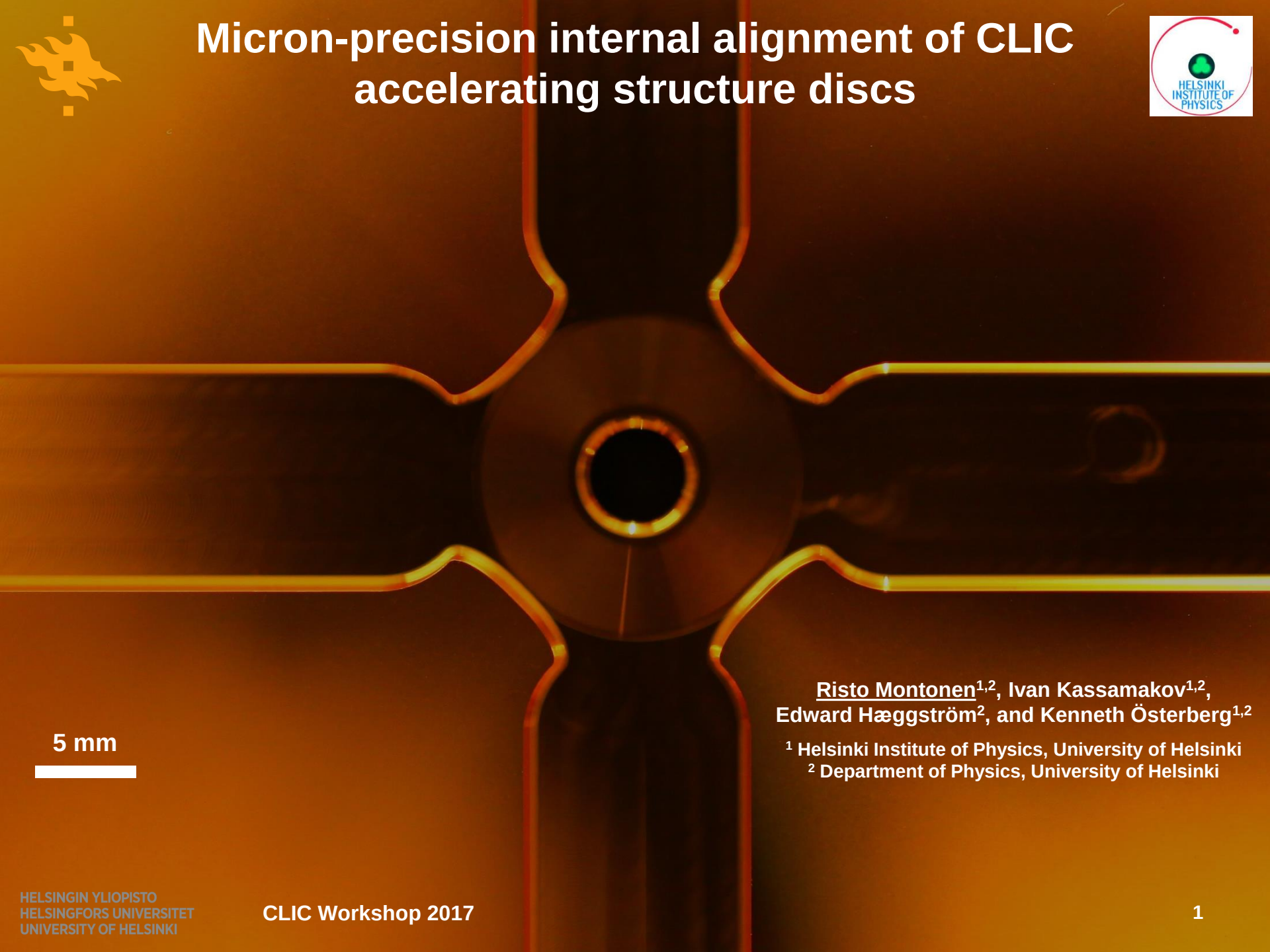
Micron-precision internal alignment of CLIC accelerating structure discs



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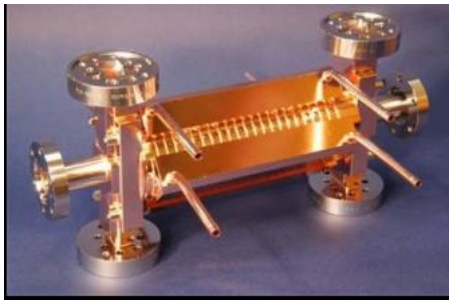
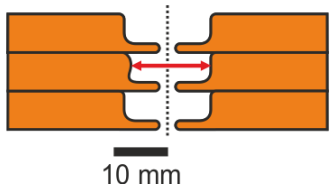
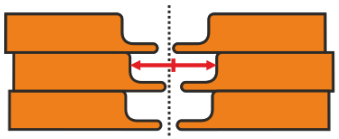
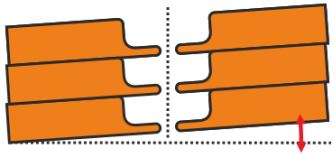
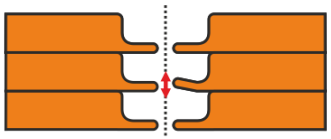
Introduction

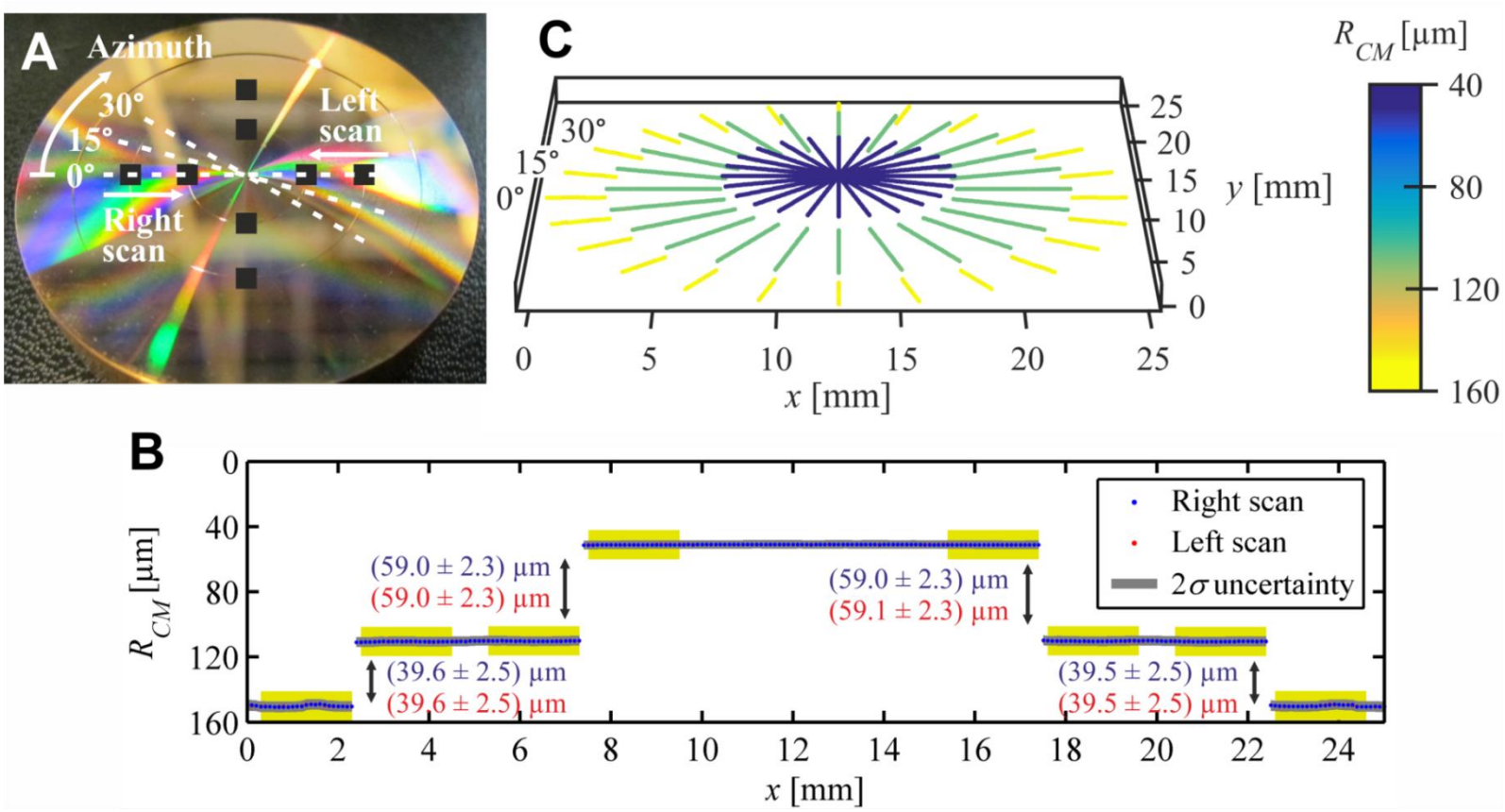


- The accelerator discs (AS) need to be aligned accurately.

Shape error				
Tolerance	1 µm	5 µm	140 µrad	

- Sub-micron accuracy across 10 mm measurement range is required.

Copper step sample results

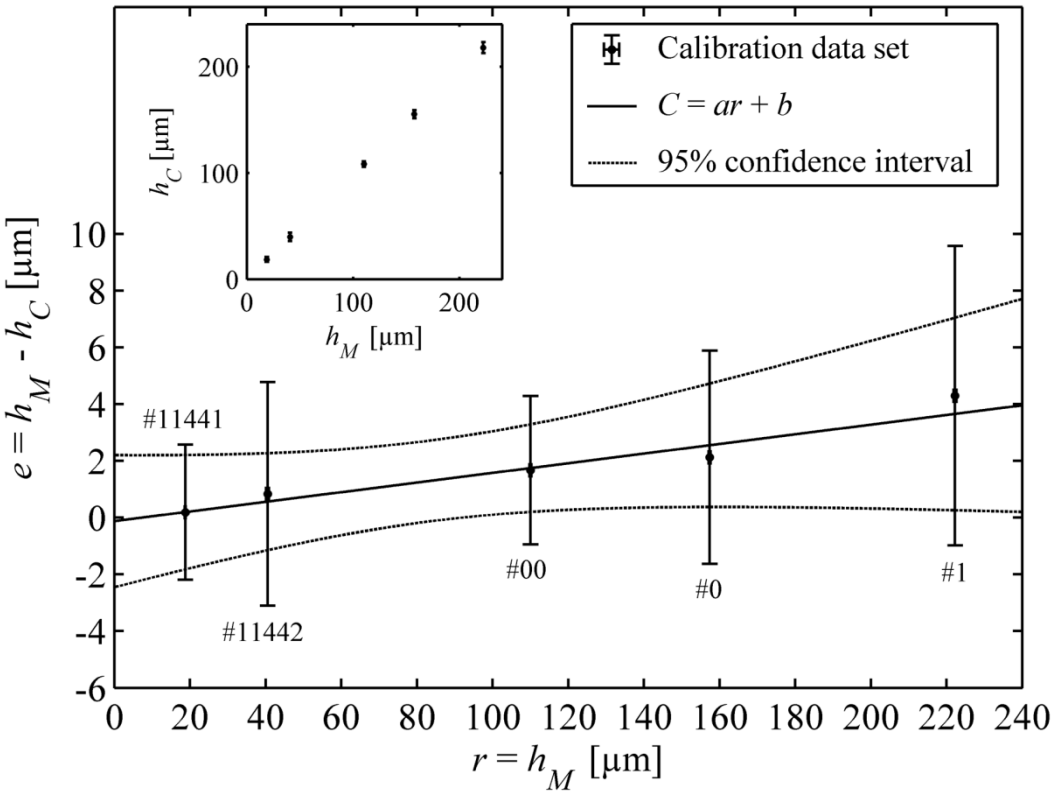


R. Montonen, I. Kassamakov, E. Hæggström, and K. Österberg, "Quantifying height of ultraprecisely machined steps on oxygen-free electronic copper disc using Fourier-domain short coherence interferometry," *Opt. Eng.* **55**, 014103 (2016).

FDSCI	Veeco NT3300
(Step height ± 2σ) µm	
39.6 ± 2.6	40.27 ± 0.14
59.0 ± 2.3	60.44 ± 0.22

Correlated propagation of uncertainty to take into account systematic effects in scanning and calibration

Calibration



R. Montonen, I. Kassamakov, E. Hæggström, and K. Österberg, "Calibration of Fourier domain short coherence interferometer for absolute distance measurements," *Appl. Opt.* **54**, 4635–4639 (2015).

Optical distance r in µm

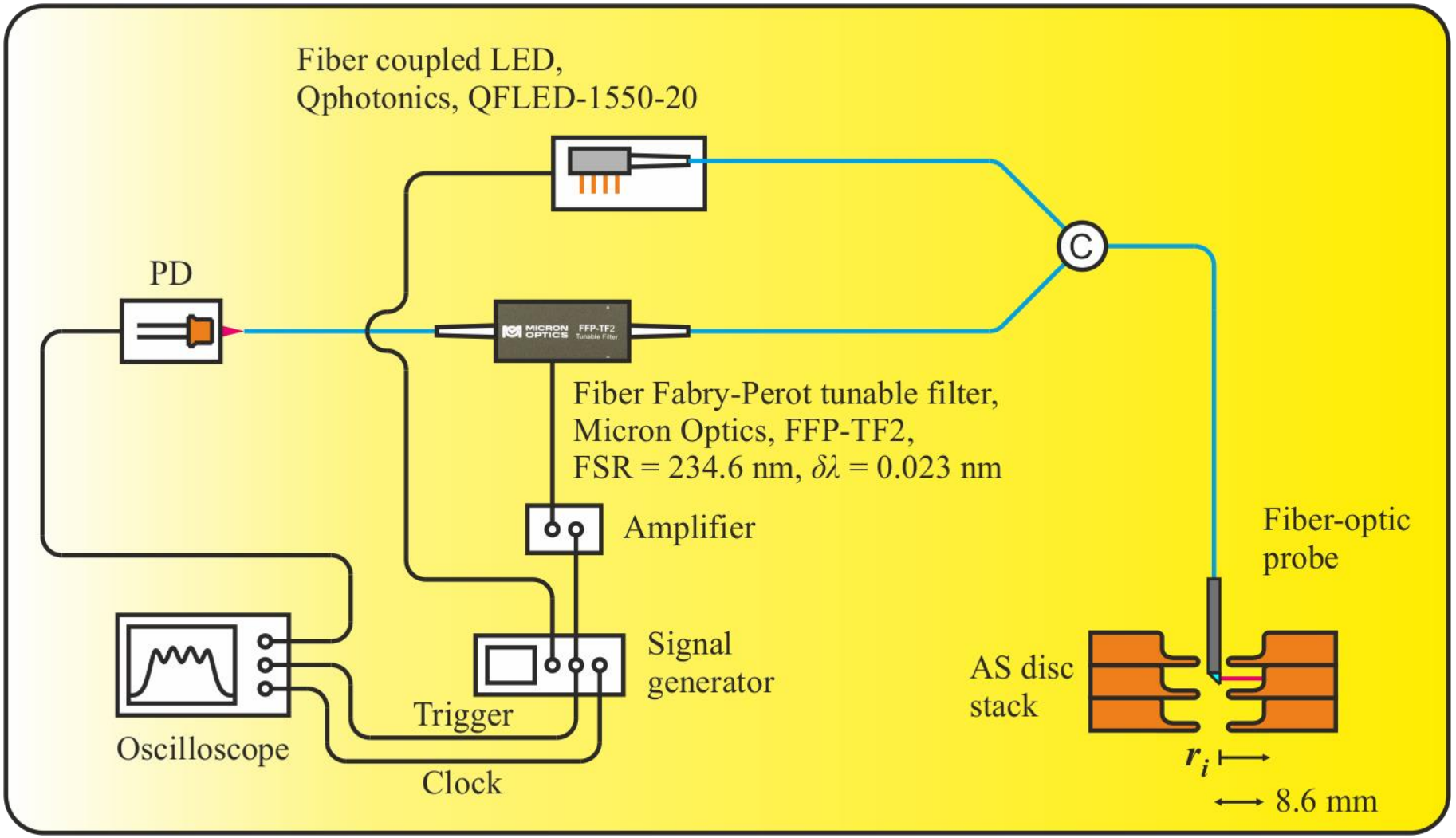
Calibration function:
$C = (0.017r - 0.1)$ µm
at (22.0 ± 1.5) °C

95% confidence level uncertainty:
$(5.9 \times 10^{-3}r + 2.3)$ µm

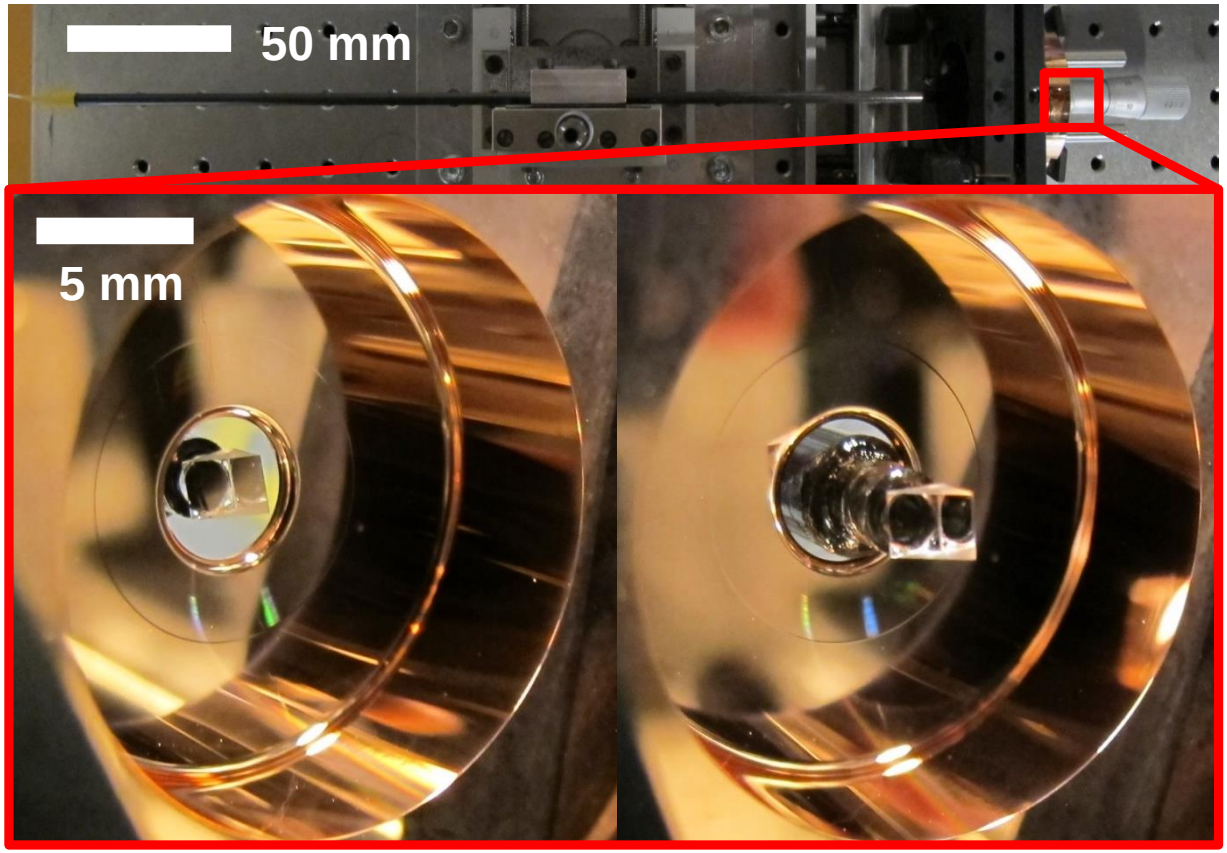
- Most significant uncertainty component in profile measurement

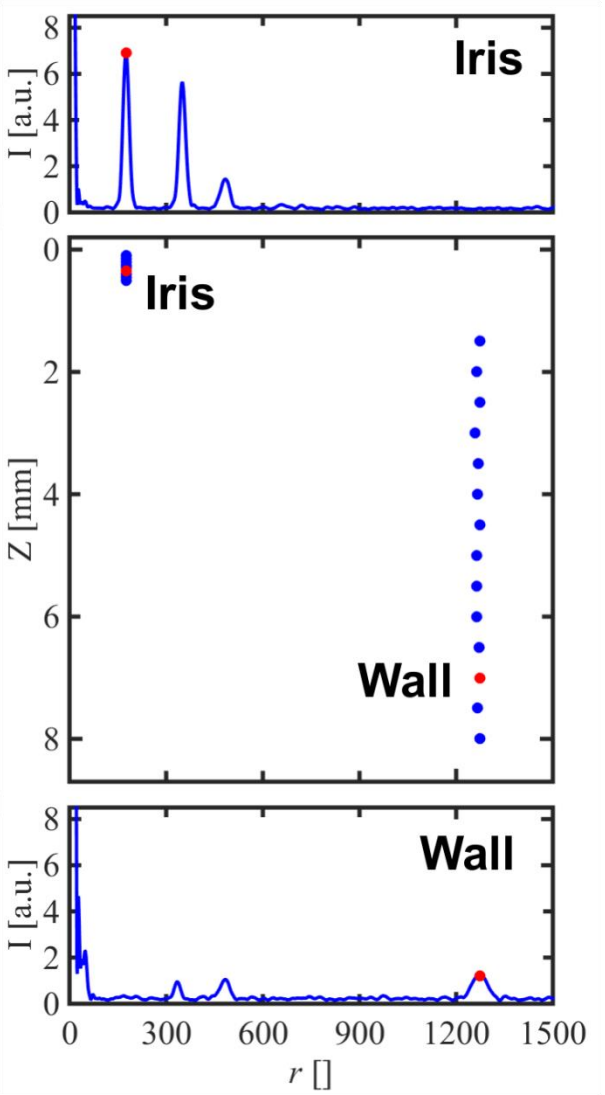
Calibrated optical distance:
$r_C = r - C$

Fiber-optic Fourier domain short coherence interferometer (FDSCI)



Fiber-optic FDSCI

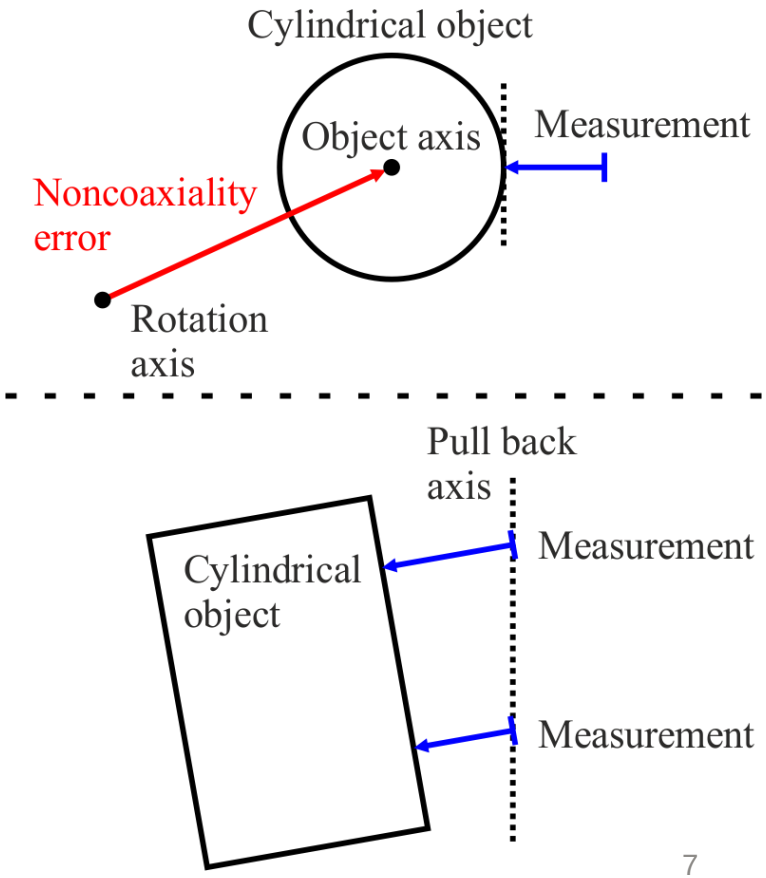




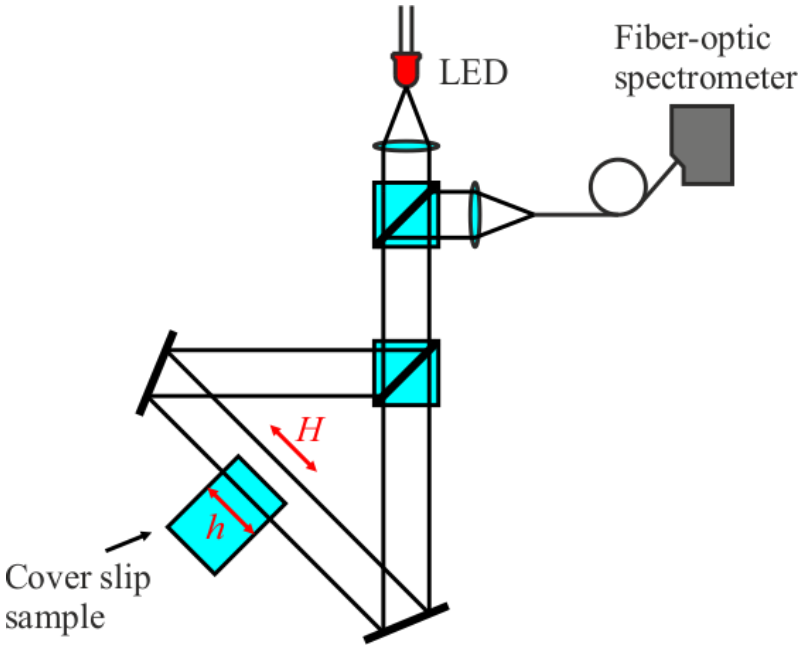
- 500 µm spot size, common path configuration

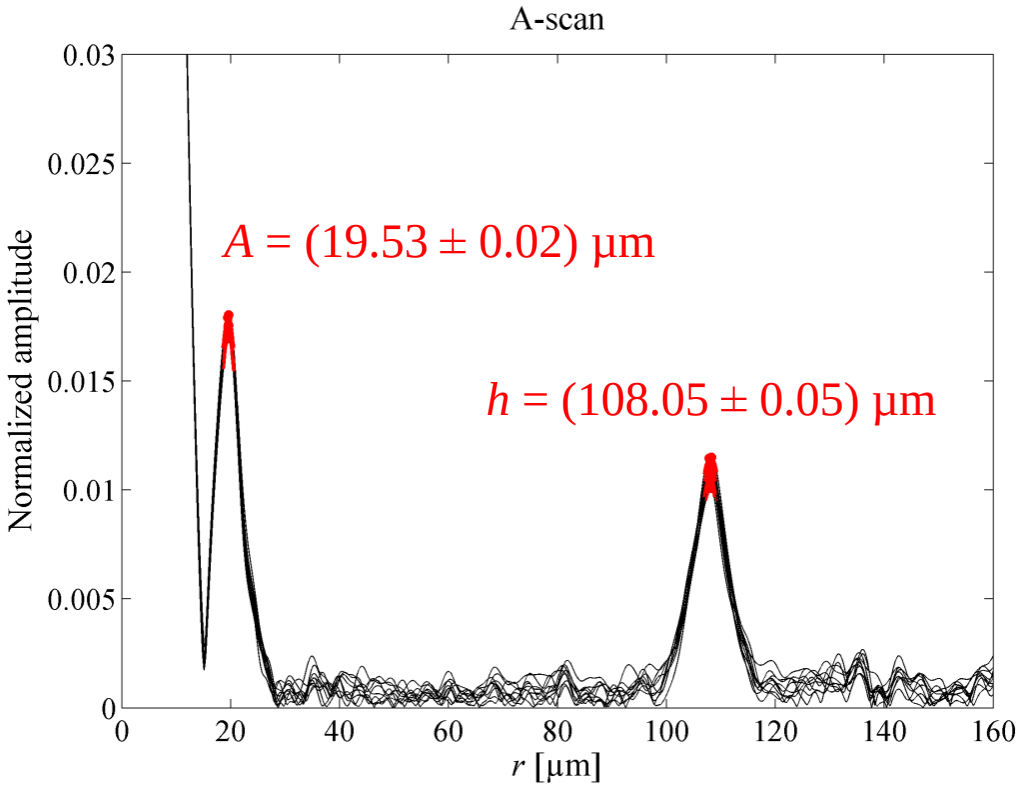
Upcoming challenges

- A-scan extraction
  - Extra echoes in A-scan
  - Nonlinear Fabry-Perot tuning ➔ No direct FT, linearization using phase information
- Disc stack scanning
  - Nerd effects arising from non-coaxial disc stack rotation and nonparallel probe pull back
- Calibration
- Referencing



Refractive index measurement

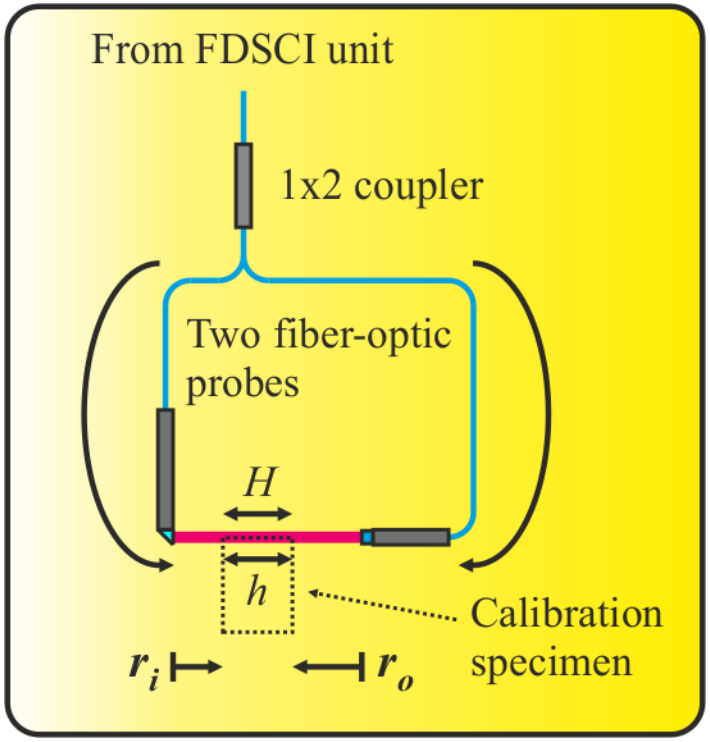


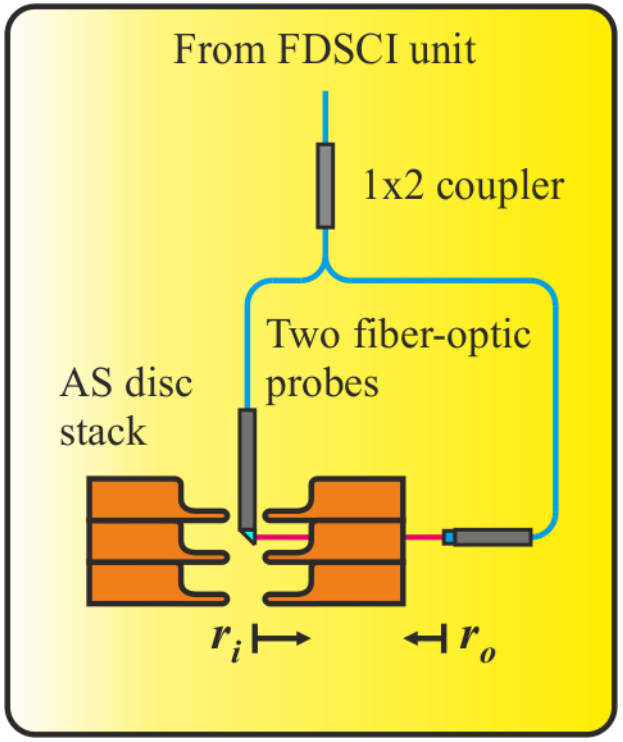


$$A = \frac{h - H}{2} \Leftrightarrow H = h - 2A = (68.99 \pm 0.02)\ \mu\text{m}$$

$$n_g = \frac{h}{H} = \frac{h}{h - 2A} = 1.5663 \pm 0.004$$

Fiber-optic FDSCI calibration and referencing





- Interfering waves in Sagnac-cavity ensure beam parallelity
- Calibration by glass specimens
  - Absolute length
  - Inter-probe distance

- Internal topography fixed to external topography

Conclusions

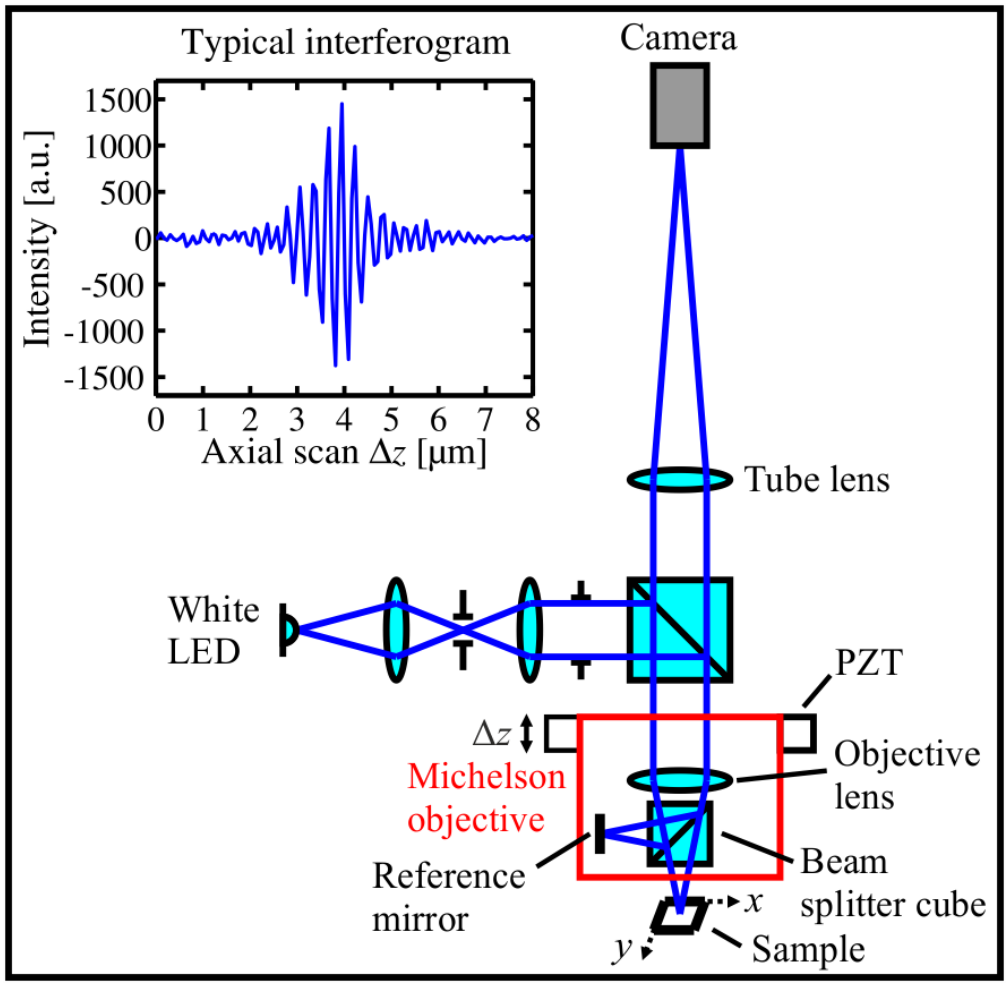
- Hard-to-reach metrology of AS internal surfaces has been achieved.

- Using two fiber-optic probes in Sagnac configuration allows us to measure the AS internal and external topography simultaneously.

- **ADDITIONAL TOPIC**
  - Noncontact roughness quantification based on coherence function modulation


Thank You

Roughness quantification by coherence modulation



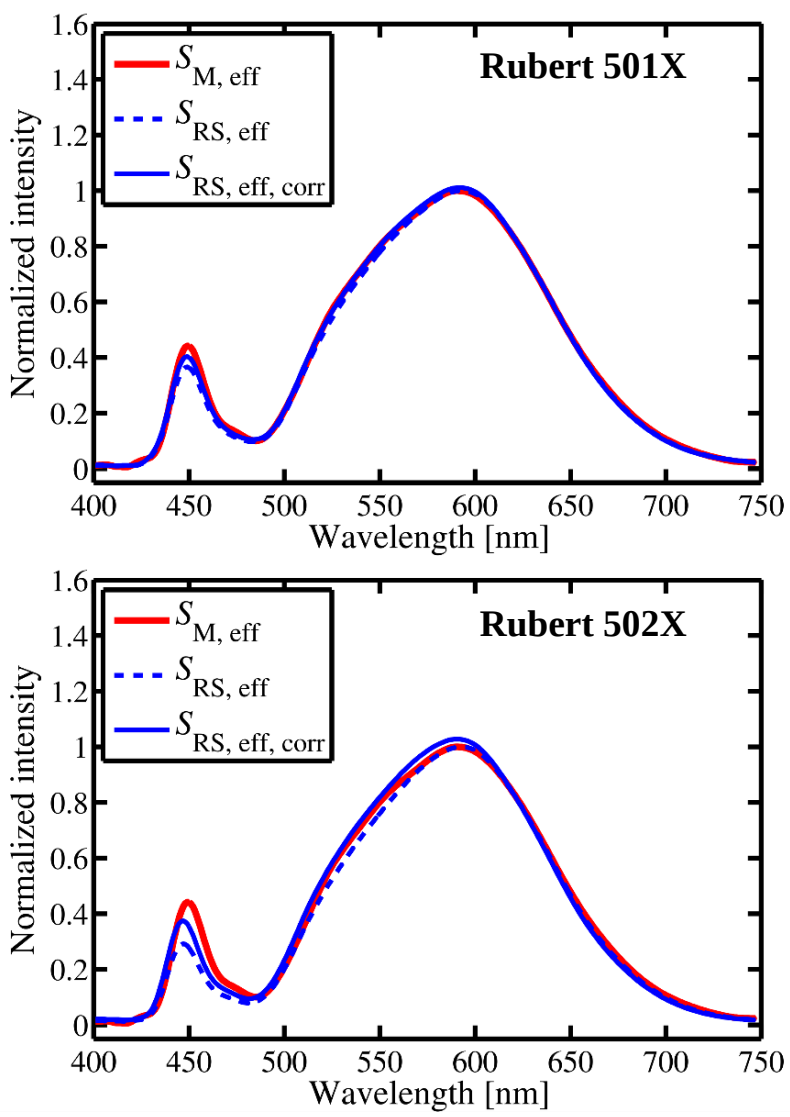
- Surface roughness is important for RF operation
- Scanning white light interferometer with Nikon 5x/0.13 Michelson objective
- Coherence modulation by sample roughness

$$\exp\left[-\frac{1}{2}\left(\frac{2\pi}{\lambda}\right)^2\left(2\delta_{\mathrm{RS}}\cos\theta_{\max}\right)^2\right]$$

λ = wavelength of light
δ_{RS} = RMS roughness
$\theta_{\max} = \sin^{-1}\mathrm{NA}$

Gaussian height distribution assumed

Roughness quantification by coherence modulation



- Interferograms averaged over 160 µm * 160 µm area
- Effective spectrum extracted by Fourier transform
- Silver mirror calibrates the system roughness
- Rubert 501X specimen
  Nominal Ra = (20 ± 2) nm
  Measured Ra = (20.9 ± 1.8) nm
- Rubert 502X specimen
  Nominal Ra = (30 ± 3) nm
  Measured Ra = (32.9 ± 2.6) nm

Manuscript under preparation

R. Montonen, A. Nolvi, S. Tereschenko, P. Kühnhold, P. Lehmann, E. Hæggström, and I. Kassamakov, “System spectrum conversion from white light interferogram”.