

X-ray Optics Summary

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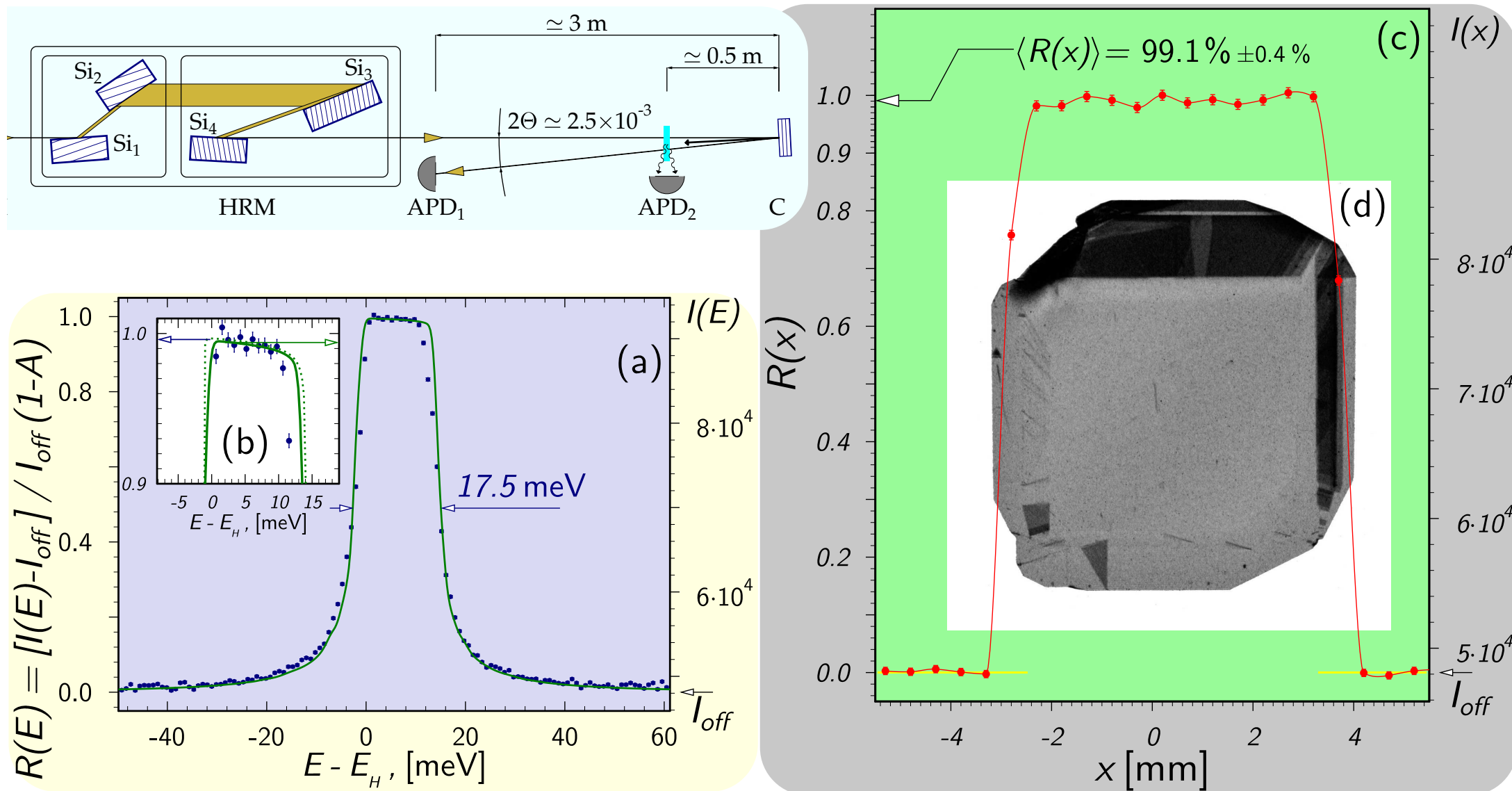
Progress has been achieved in designing, testing key XFEL O components & techniques

- Tunable x-ray cavities
- Diamond single-crystal backscattering optics (TISNCM, Sumitomo, Element-6)
- Focusing and collimating optics (SPring-8 ellipsoidal mirrors, Lengeler Be-CRLs)
- Speckle-free x-ray Be windows and mirrors (PVD and EEM)
- LIGO-type feedback system
- Diamond resilience to radiation damage

Yet to be done/tested

- Multi-axis high-frequency LIGO-type feedback stabilization system.
- Consider laser interferometer feedback as an alternative.
- Refined studies of the radiation hardness of diamond.
- Ellipsoidal mirrors with diamond-like coating for higher reflectivity.
- XFEL diagnostic: coherence characterization, intensity monitoring, polarization control (vertical gap undulator is preferred).
- Optics for science applications:
 - IXS, Mössbauer, XPCS split-delay, etc.
 - Michelson interferometer for FT x-ray spectroscopy
 - Tunable diamond Fabry-Perot interferometer (an alternative)

99% Diamond Reflectivity @ 14.3 keV



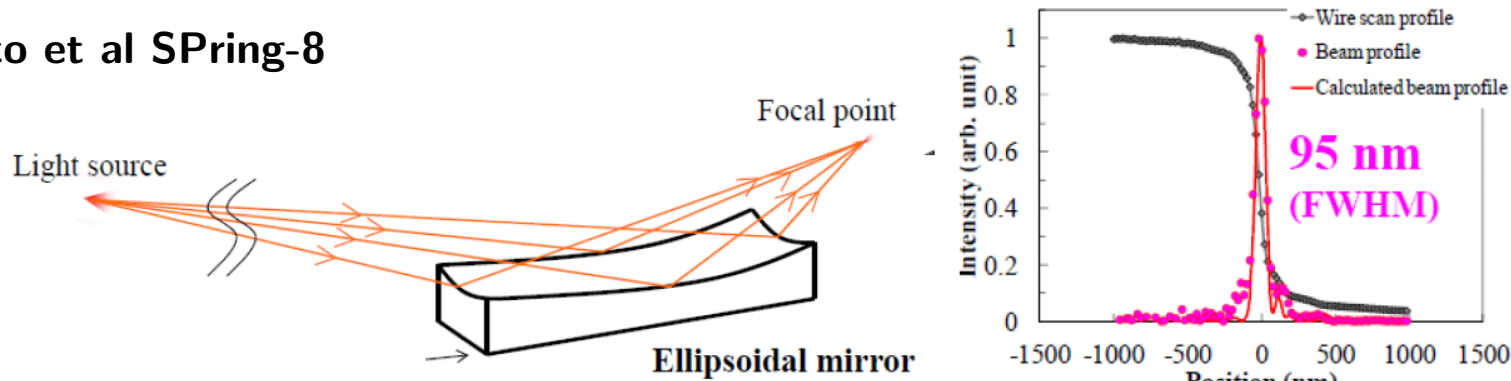
Shvyd'ko, Stoupin, Blank, Terentyev, Nature Photonics 5 (2011) 539

$\approx 99\%$ reflectivity and close to theoretical performance.

Focusing and Collimating Optics

- State-of-the-art x-ray ellipsoidal mirrors may feature close to 99% reflectivity & $\lesssim 0.1 \mu\text{rad}$ figure error

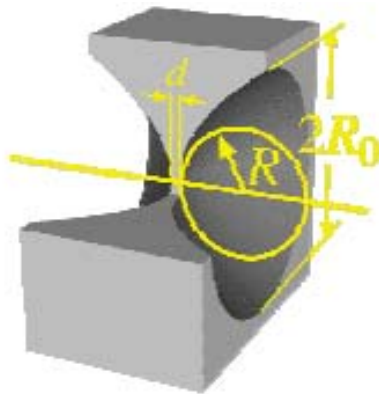
Yumoto et al SPring-8



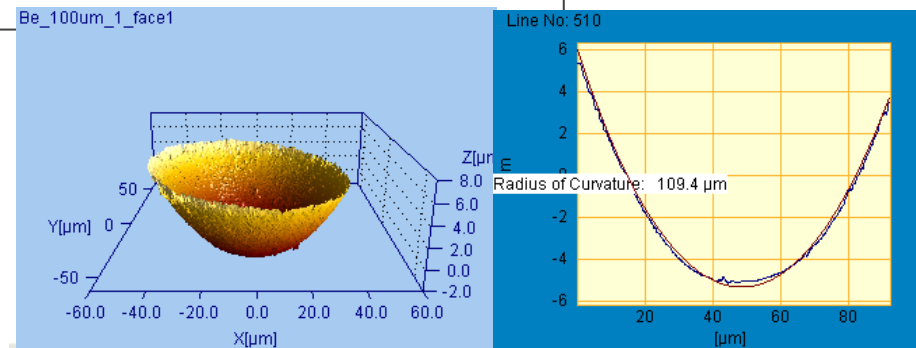
Yumoto-san

- Paraboloidal Be compound refractive lenses (CRL) may feature high transparency $\simeq 99\%$ for large focal length $\gtrsim 20 \text{ m}$.

A. Snigirev et al & B. Lengeler et al ESRF



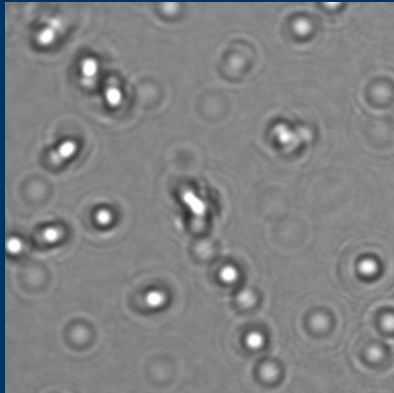
For 14.4 keV, $f = 21.1 \text{ m}$, $d = 30 \mu\text{m}$, $\sigma_r = 28 \mu\text{m}$,
 Crystalline Be, IF 1 grade: $Tr = 99.74\%$
 PS20 E grade (atten. length 60% of IF-1): $Tr = 99.56\%$



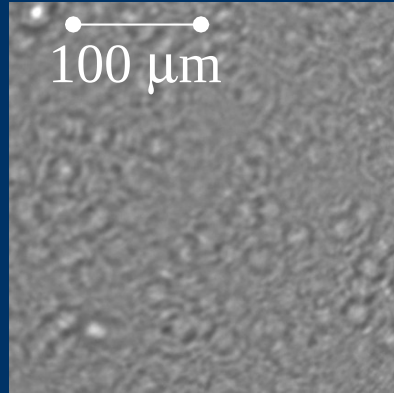
Speckle-free mirrors & Be foils

Be window

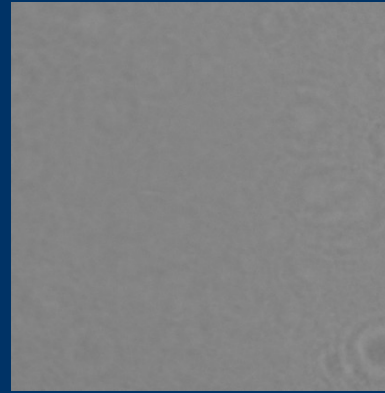
Goto et al. Proc. SRI 2007, 1057



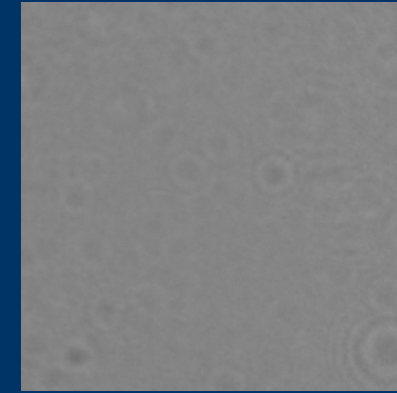
Polished O-30
(HIP powder foil)
100 nm p-v



Polished IF-1
(Ingot foil)
100 nm p-v



Polished
PVD 50 nm
p-v



Kapton



Mirror

Mori et al. Proc. SPIE 2001,

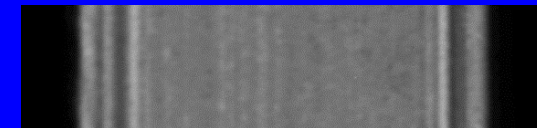
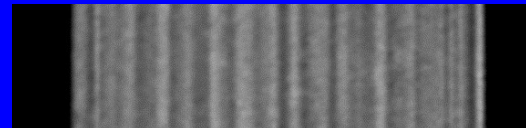
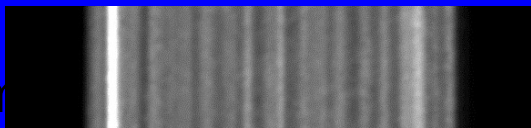
4

Distance: Pre-machined

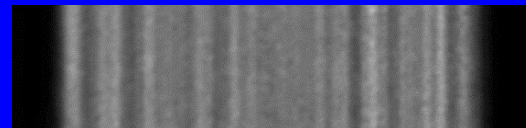
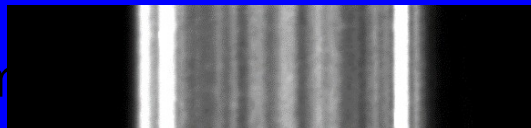
30 PCVM

PCVM+EEM

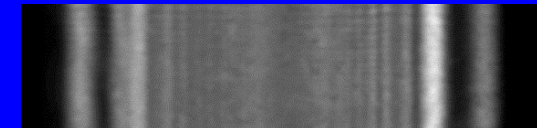
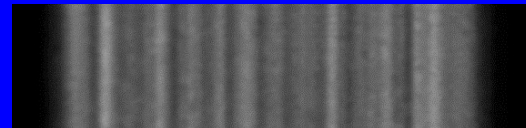
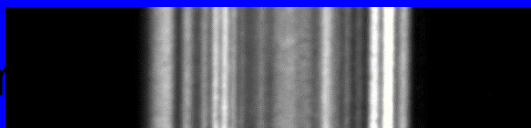
166 mm



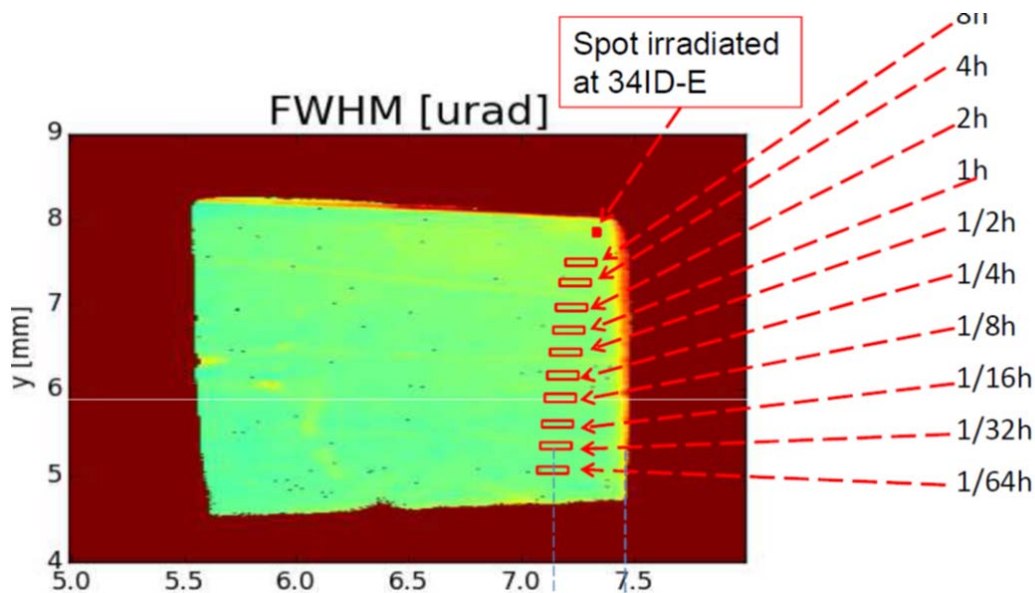
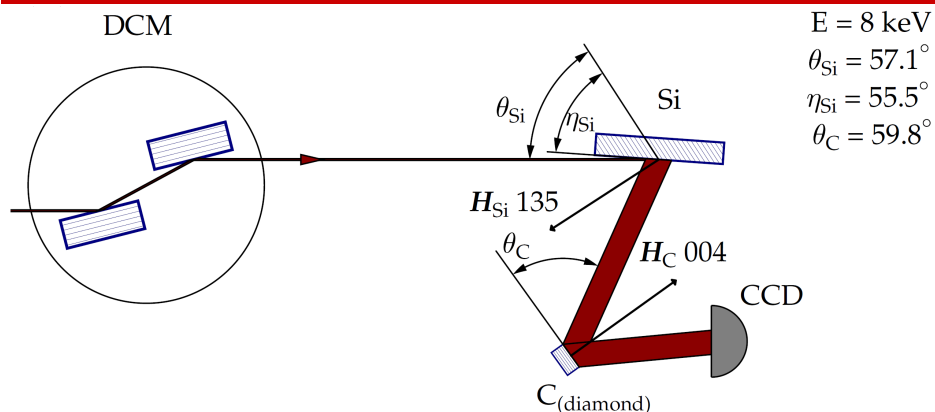
566 mm



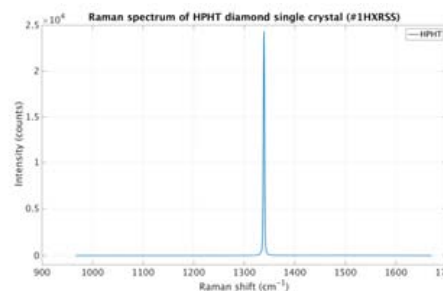
966 mm



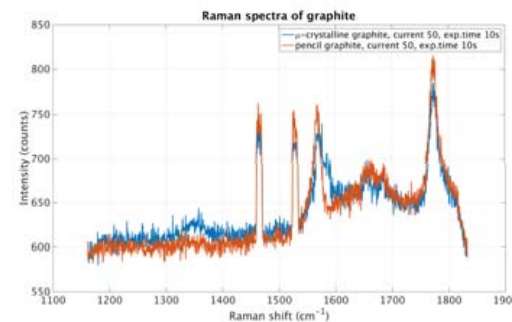
No Structural Changes are Observed with Medium Resolution (10^{-6}) X-ray Topography



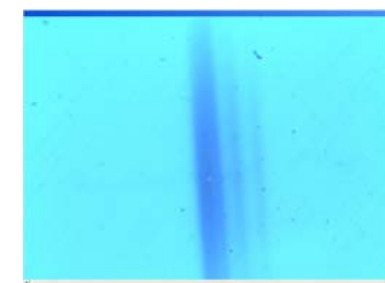
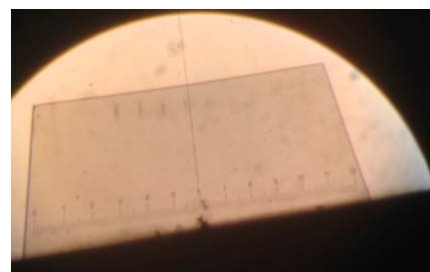
Raman spectra



HPHT diamond



graphite

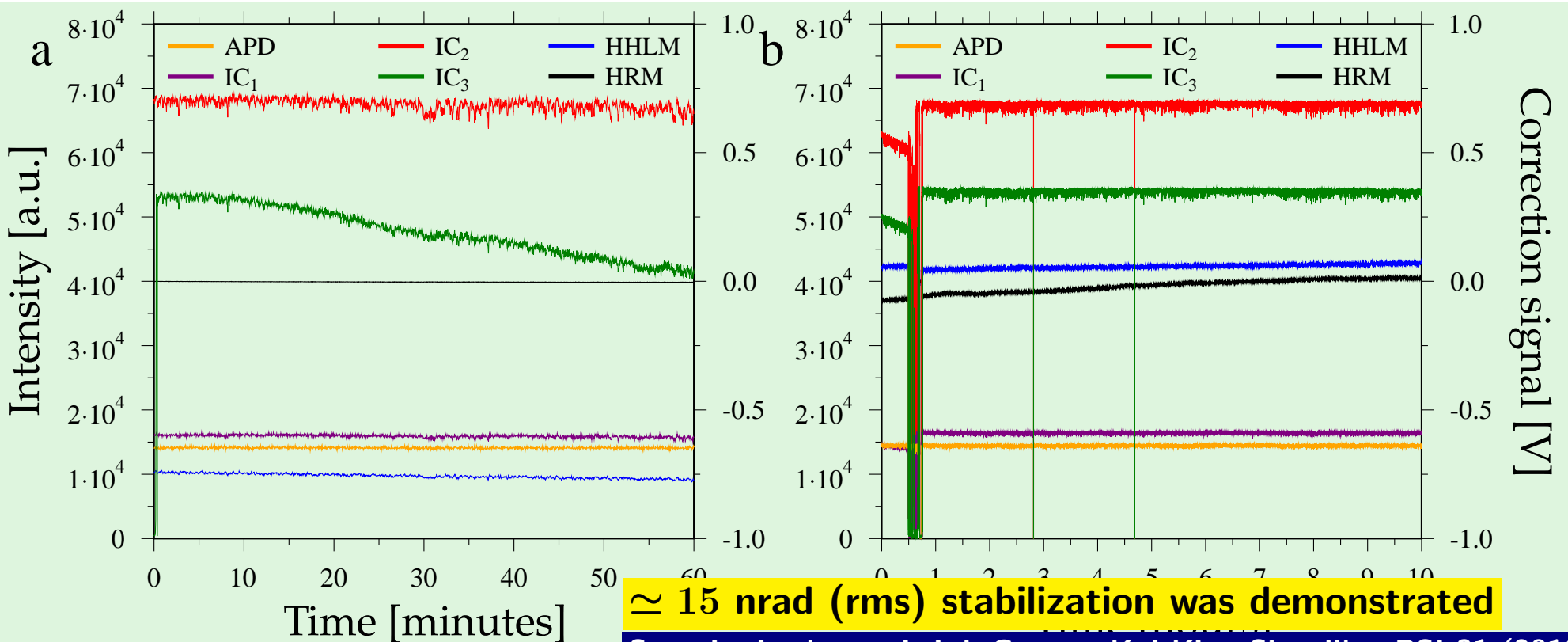
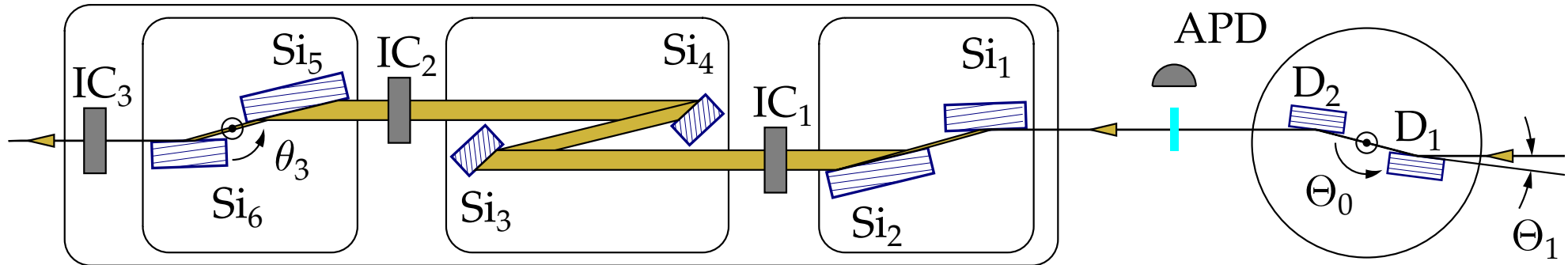


Optical microscope images

HERIX Monochromator Stabilization

HRM T. Toellner, D. Shu

HHLM



Stoupin, Lenkszus, Laird, Goetze, K-J Kim, Shvyd'ko, RSI 81 (2010) 05510