



FC2 project status & metrology survey

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outline



- *FC2 project status*
- *Survey of available metrology*

FC2 Instrumentation is fully operational



Diagnostics converge, but variety in measurement techniques persists
How to continue monitoring source development objectively?

Goal of FOM/ISMT Flying Circus Project

- *Development and dissemination of standard measurement procedures for*
 - *Consistent EUV source characterization*
 - *Assessment of EUV source status and key risk areas*

Project Status

- *New version of FC2 tested and made operational*
- *Measurements performed at*
 - *XTREME technologies' GDPP Source*
 - *LPP source at FOM*
- *Initial Cross-calibration of FC2 with Jenoptik energy monitor*
- *Discussions with source developers and tool vendors*
 - *Request of development of 2% bandwidth diagnostics (present BW 4%)*
 - *FC2 imaging for determination of source size/max etendue*

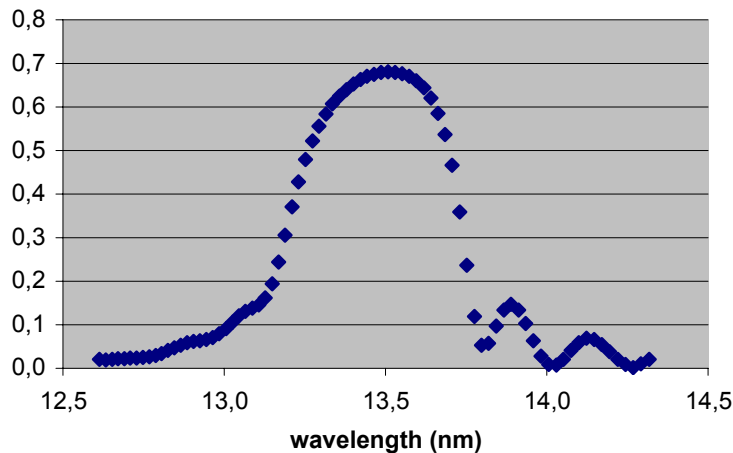
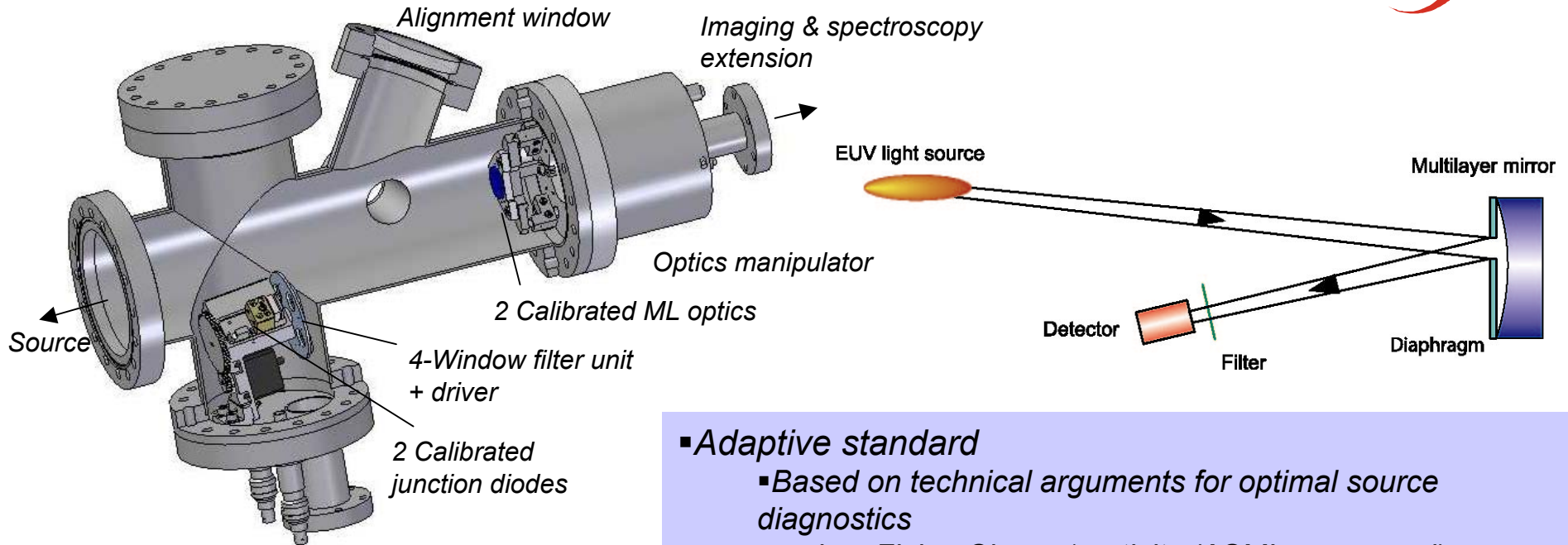
Project Plans

- *Further measurement of EUV source characteristics at US, European & Japanese (?) parties*



MEDEA⁺

'Classic' FC2 diagnostics

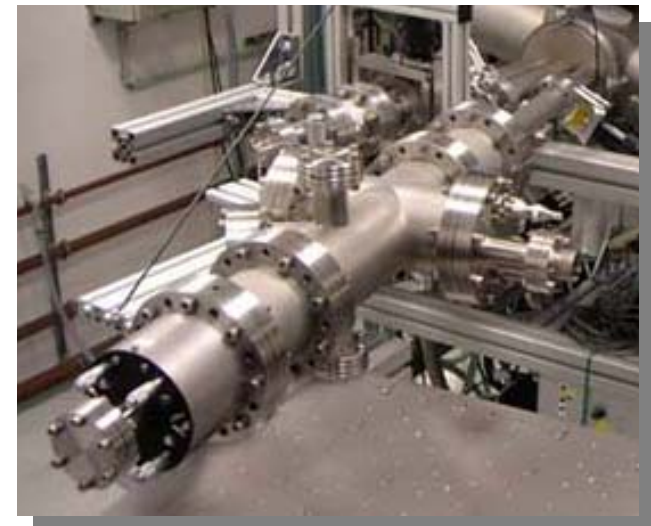
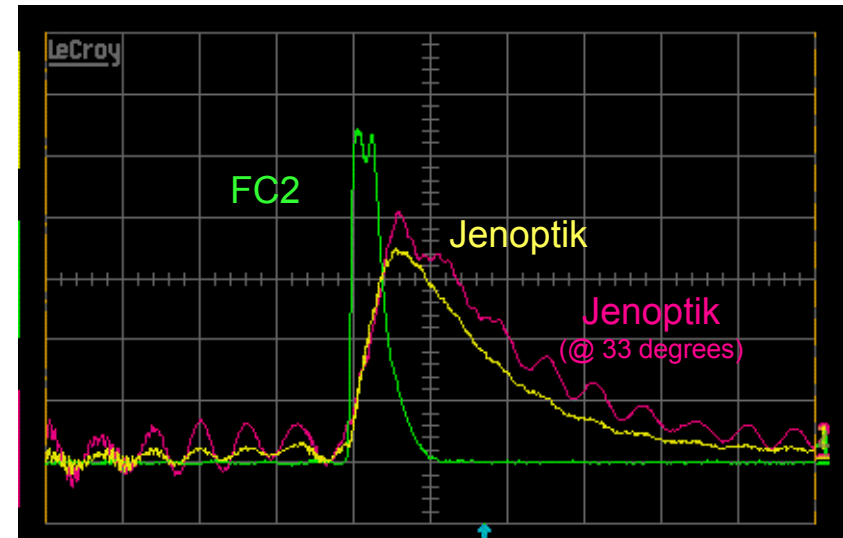


- **Adaptive standard**
 - Based on technical arguments for optimal source diagnostics
 - and on Flying Circus 1 activity (ASML sponsored)
 - Available through subcontractor Scientec Engineering
 - or reproduced by local workshops
- **New extension to imaging & spectroscopy unit**
- **Units installed at majority of source developers**
- **Measurement procedures widely disseminated**
 - R. Stuik, F. Scholze, et al, NIM A **492** (1-2), pp. 305-316 (2002)
 - R. Stuik and F. Bijkerk, NIM A **489** (1-3), pp. 370-378 (2002)

Diagnostic benchmarking confirms FC2 characteristics & 6.8mJ Xtreme's source



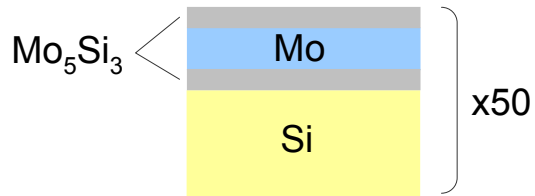
- Power monitor benchmark @ XTREME technologies discharge source
 - Jenoptik energy monitor (2 plane mirrors)
 - FC2 (curved single optic)
- Preliminary energy up to 6.8 mJ/sr 2%
 - @ 1kHz, 12% duty cycle
- FC2 activity shows
 - Potential further accuracy increase by reducing Xe EUV absorption
 - FC2 detection characteristics
 - High resolution, sensitivity & S/N ratio
 - Alignment & purging
 - Essential for reducing Xe backgrounds



**Max Schürmann, Thomas Mißalla
(Jenoptik)**
**Guido Schriever, Denis Bolshukin
(Xtreme technologies)**

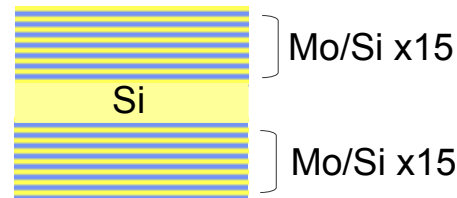
Direct measurement of 2% BW values?

Standard ML stack

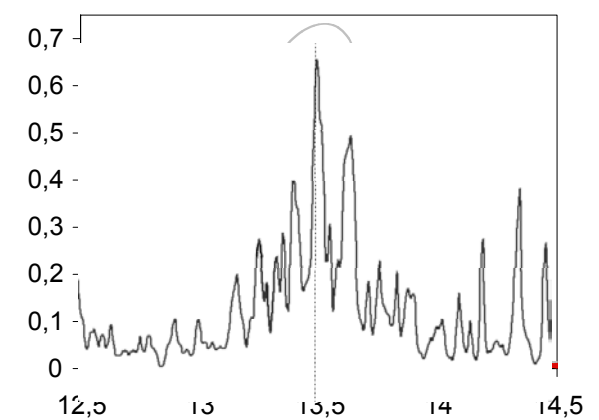
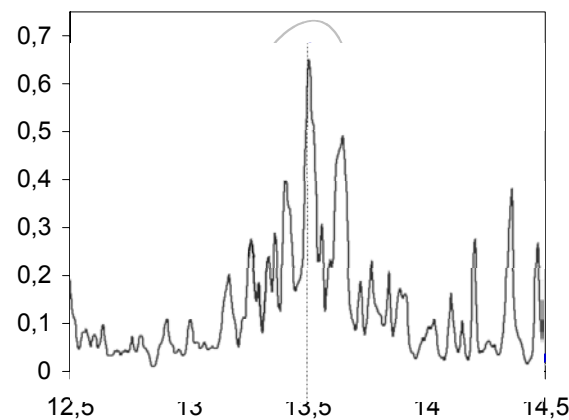
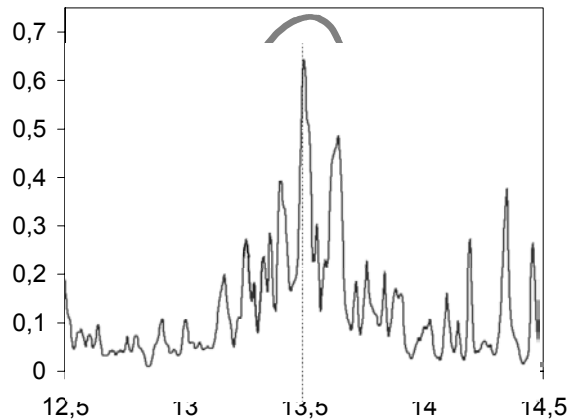
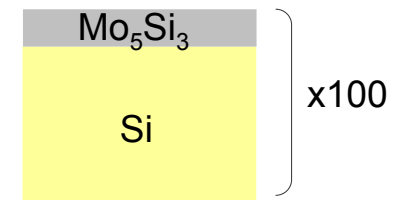


Fabry-Perot ML etalon

M.P. Bruijn, et al, Opt. Engin. **26** (7), p. 679 (1987)



“ML Bragg crystal”

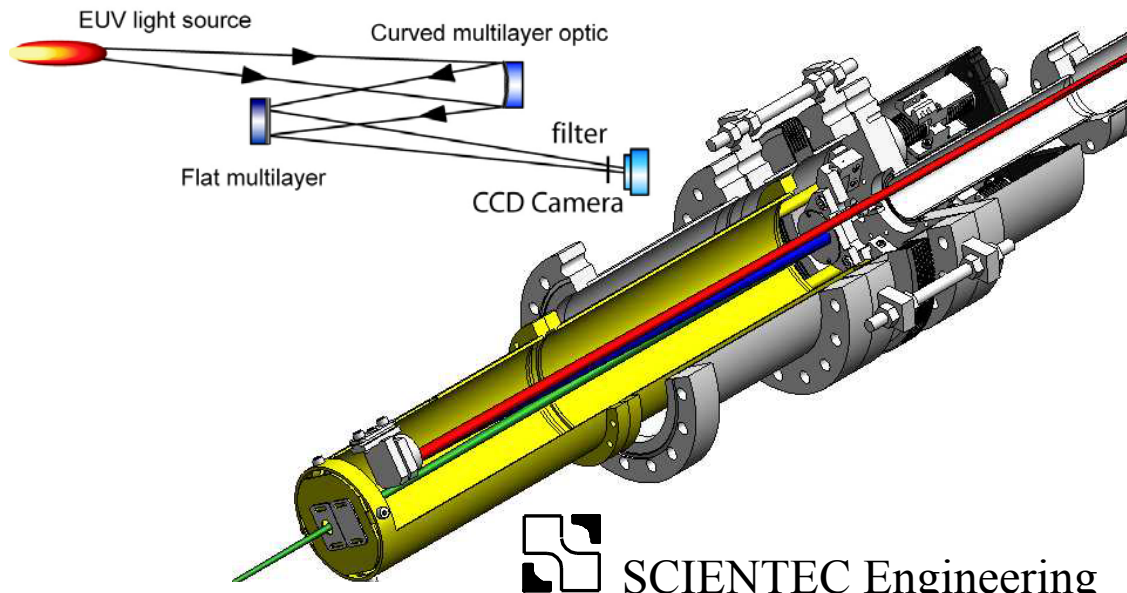


- *ML Bragg crystal provides 2% BW value from single device w/o need for spectral information*
 - *Band pass 11 element tool mimicked analogously*
- *Realistic ML fabrication process*

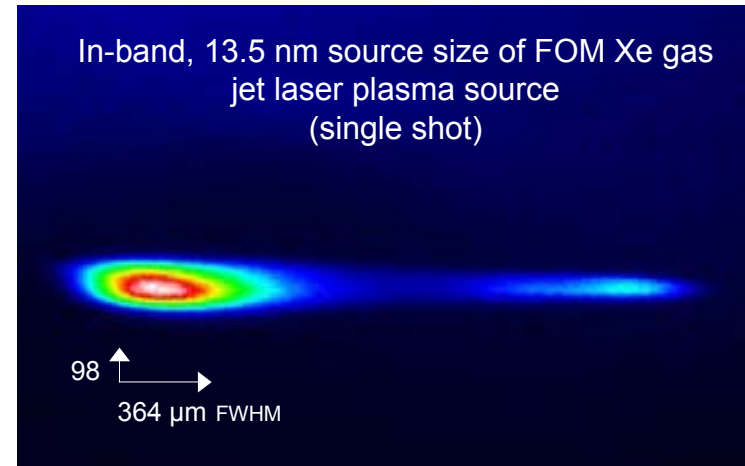
FC2 allows in-band imaging



- 2-8% narrow-band EUV imaging
- Determination of
 - Collectable etendue
 - Source p-p stability
 - 2D source intensity distribution
- Two-bounce spherical optic design
 - High quality, 69% multilayer optics

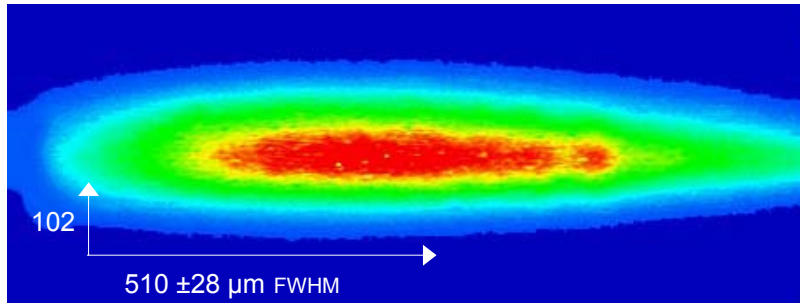


 SCIENTEC Engineering

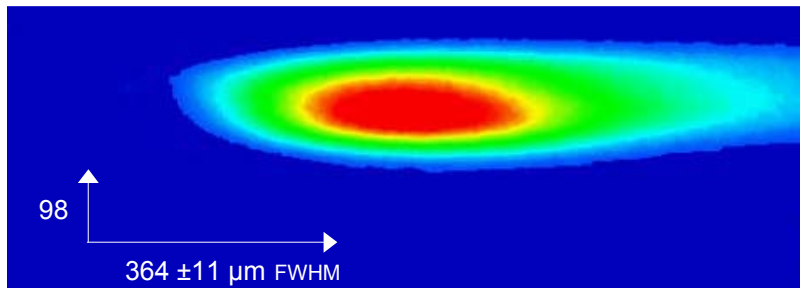


- Addresses issue on limited collection efficiency due to etendue of collector optics
- Widely used pin-hole camera images show broad-band source size, which can result in incorrect estimation of collectable power

FC2 imaging: EUV source can be smaller then concluded from pinhole images

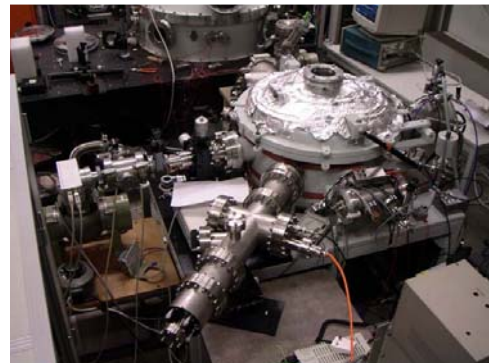
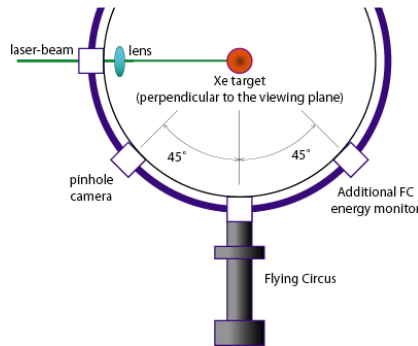


- Broad band EUV pinhole image
- 6.5 to 16.8 nm (FWHM, 211 nm Zr)
 - 50 μm pinhole, M 13 x
 - 10 shots



- In-band EUV ML telescope image
- 2.8% BW @ 13,50 nm (FWHM)
 - M 2 x
 - single shot

*Images shown at same scale
Perpendicular viewing angle*



FC2 imaging shows >40% smaller source size @ FOM

- direct relevance for collectable power estimations
- G.H. Derra, W. Singer, SPIE 5037-90

outline



- *FC2 project status*

- *Survey of available metrology*

Survey metrology vendors

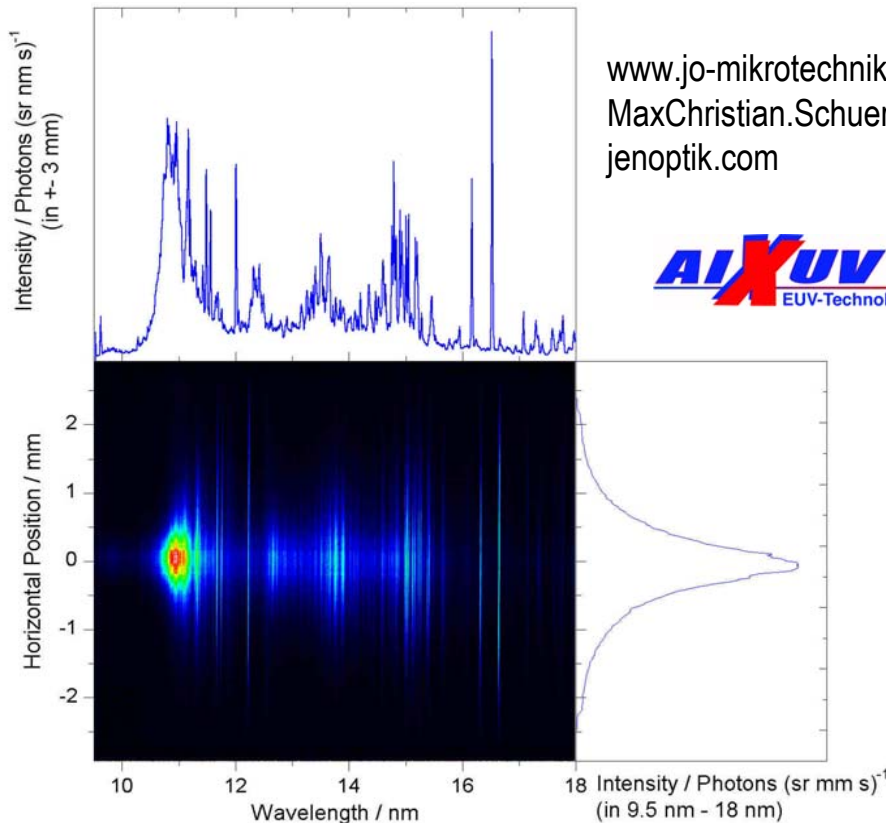


- *Metrology tools*
 - *Jenoptik Mikrotechnik/AIXUV (Fraunhofer)*
 - *Scientec Engineering (FOM)*
 - *McPherson*
 - *Acton Research*
 - *Schulz SI (ISAN)*
 - *Moxtek (Lebedev)*
 - *Phystex (Ioffe, IPM)*
 - ...
- *Components*
 - *IRD*
 - *Luxell*
 - *Lebow*
 - *Osmic*
 - *Zeiss*
 - *Hitachi*
 - ...

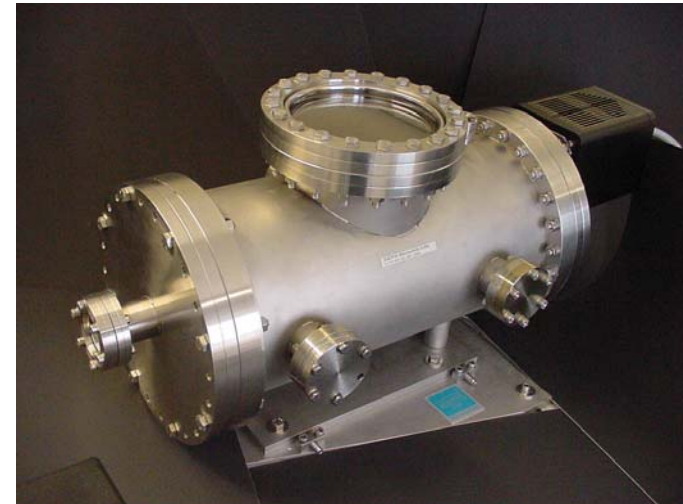
FC2 project: promote further use of FC for local diagnostics cross-calibration

EUV Spectrograph “E-Spec”

- spatially resolved spectroscopy
- absolutely calibrated



www.jo-mikrotechnik.com
MaxChristian.Schuermann@
jenoptik.com



Advantages

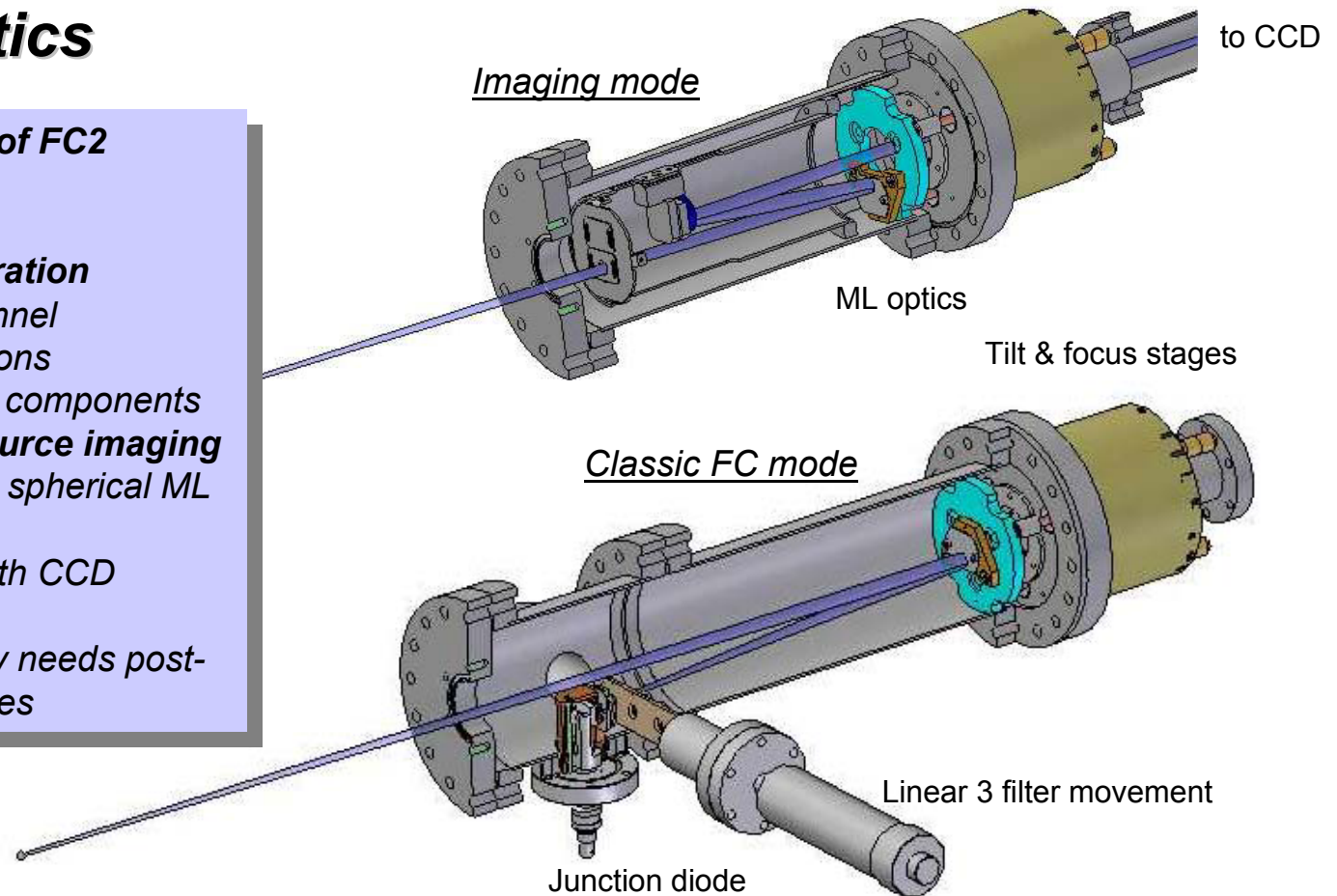
- high resolution ($\lambda/\Delta\lambda \approx 600$)
- absolute calibration in 9 - 18 nm regime
- high sensitivity (≈ 1 count / photon)
- spatially resolved spectroscopy
- very low stray light background

Disadvantage

- expensive gratings

FC3 diagnostics

- 'Economy' version of FC2 hardware
- Allows
 1. Classic FC operation
 - Single λ -channel
 - 3 Filter positions
 - All calibrated components
 2. In-band EUV source imaging
 - Two-bounce spherical ML optic
 - Combined with CCD
- Disadvantage
 - Highest accuracy needs post-calibration facilities



Flat Field Toroidal Grating Spectrometer

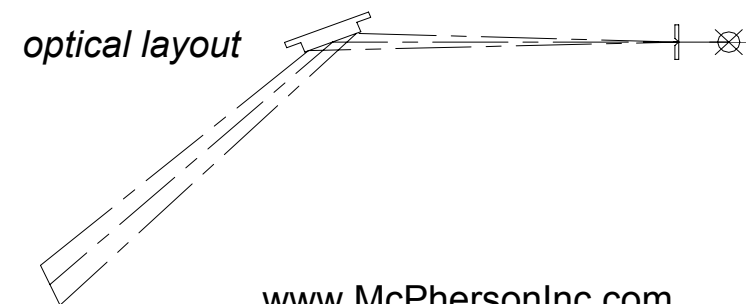
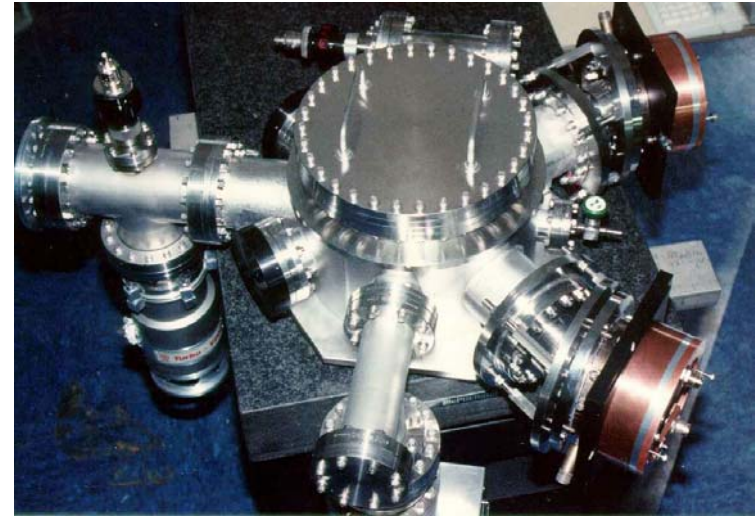
- fixed grating and wavelength range
- CCD detection or
- microchannel plate: fast gating/temporal studies

Advantages

- Fixed grating and wavelength range
- $\lambda/\Delta\lambda \approx 260$ FWHM resolution
- 10 to 30-nm region
- Flat field aberration corrected
- UHV construction
- > 20 units in use for EUV diagnostics

Disadvantage

- Limited selection and expensive gratings



www.McPhersonInc.com
EDS@McPhersonInc.com

Grazing Incidence Spectrometer with time resolution

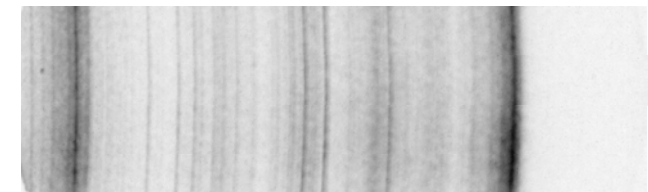
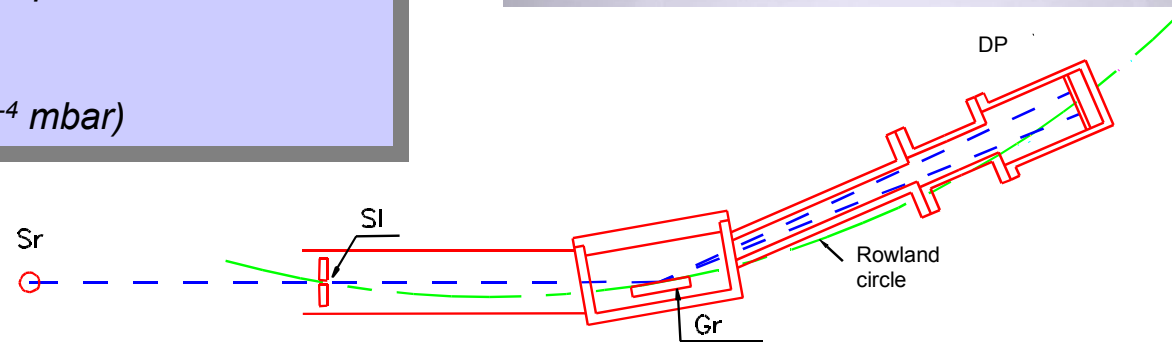
- MCP gating for high time resolution
- CCD readout

Advantages

- *time resolution (down to 3 ns)*
- *different gratings/spectral ranges*
- *high spectral resolution up to 600-1400 when in Rowland geometry*

Disadvantage

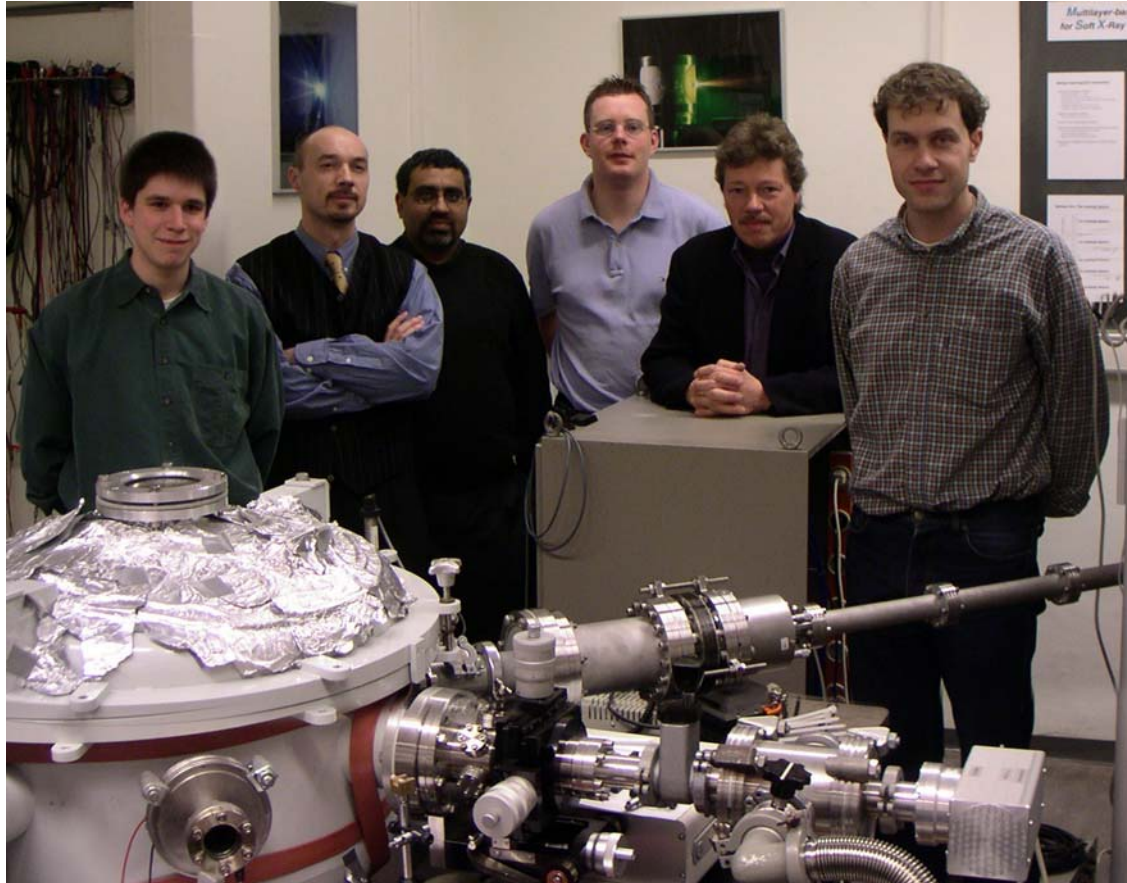
- *MCP requires HV ($<10^{-4}$ mbar)*



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- **FC2 was demonstrated at the FOM laser plasma source, and the XTREME technologies' discharge plasma**
 - *Demonstration of in-band source imaging capability at 13.5 nm*
 - *FC characterization EUV source of XTREME technologies*
 - *EUV diagnostics was benchmarked with the Jenoptik energy monitor*
- **Direct 2% BW measurements are possible from a single device**
- **Current sources may prefer adaptive, flexible diagnostics**
- **Standardization of measurement procedures needed for further cross-correlation of source results**
 - *definition of standard source interface for the diagnostics*
 - *standardized procedures for diagnostic or component calibration*

Acknowledgements



- PTB (Frank Scholze)
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- Xtreme Technologies (Guido Schriever, Denis Bolshukin)

- 1) C.C. de Bruijn, K.N. Koshelev, et al, JQSRT (2003)
- 2) R. Stuik, F. Scholze, et al, NIMA **492**, 1-2, pp. 305-316 (2002)
- 3) R. Stuik, F. Bijkerk, NIMA **489**, 1-3, pp. 370-378 (2002)
- 4) R. Stuik, F. Bijkerk, SPIE **4688** (2002)
- 5) F. Bijkerk, et al, *Flying Circus 2, metrology and planning*, EUVL Symp., Dallas (2002)
- 6) F. Bijkerk, et al, SPIE **3157**, pp. 236-240 (1997)
- 7) M.P. Bruijn, J. Verhoeven, et al, Opt. Engin. **26** (7), p. 679 (1987)