Commissioning of the XUV-Autocorrelator at FLASH – First Experiments

XUV-Autocorrelator

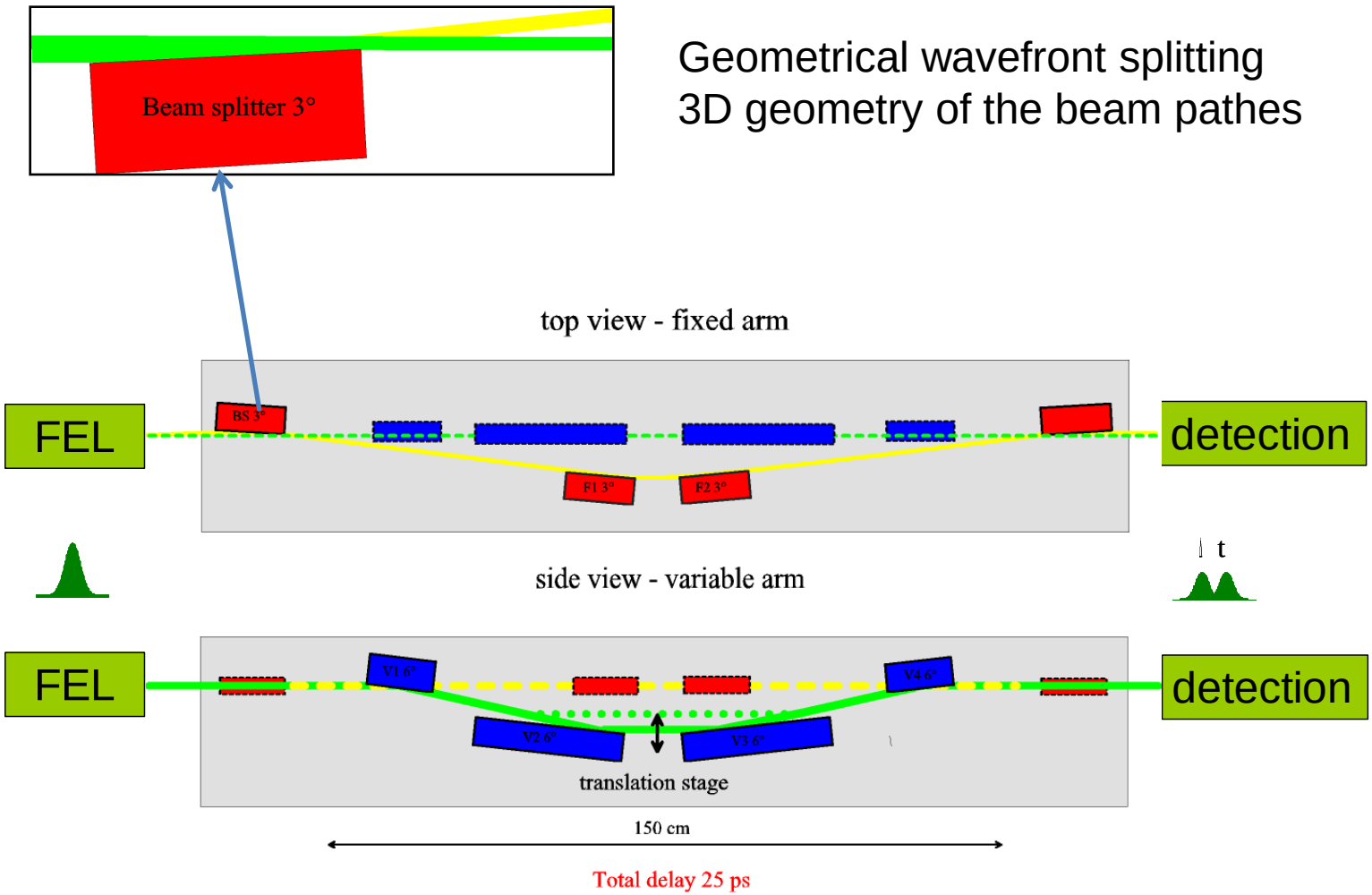
Outline

1. Introduction
   - Optical concept
   - Mechanical design
   - First laser test (visible)

2. Commissioning at FLASH
   - Beamline – experimental setup
   - Linear autocorrelation – temporal coherence of the FEL-beam
   - Nonlinear autocorrelation – determination of pulse length

3. Conclusions and acknowledgement

XUV-Autocorrelator – Optical Concept



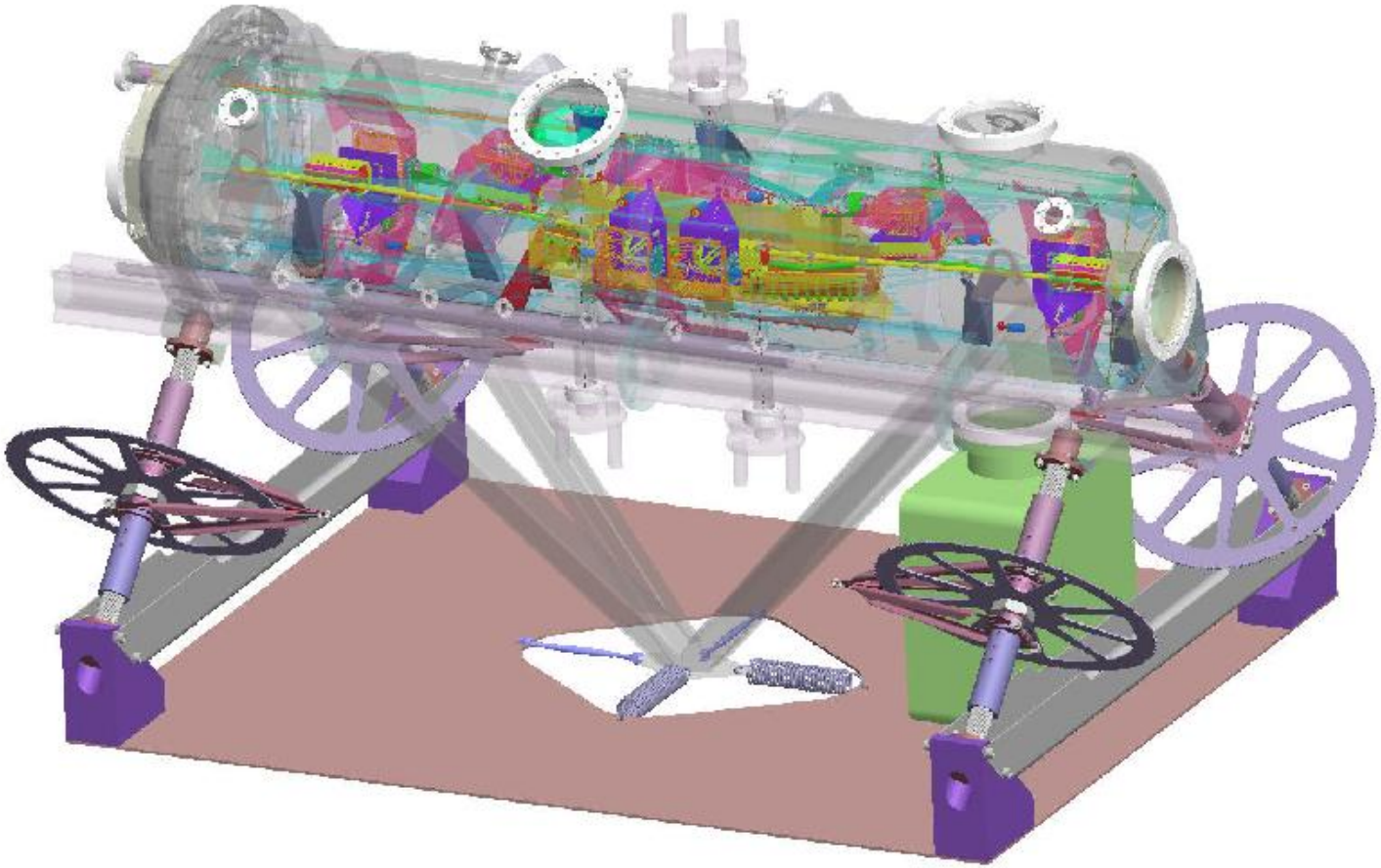
Geometrical wavefront splitting
3D geometry of the beam pathes

R. Mitzner et.al., Proc. Of SPIE 59200D-1

XUV-Autocorrelator – Optical Concept

XUV-Autocorrelator – Mechanical Design

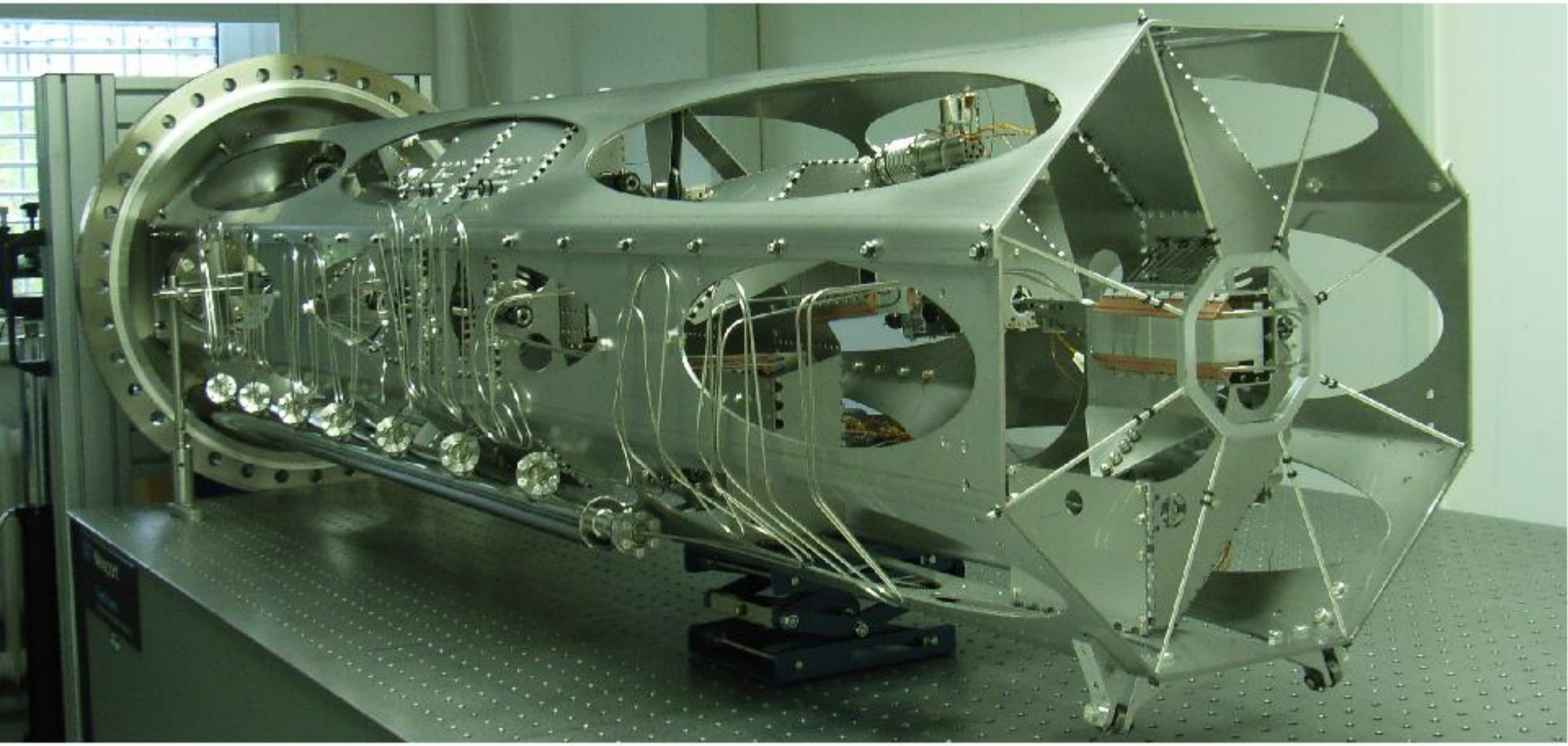
Transparent view of the autocorrelator chamber



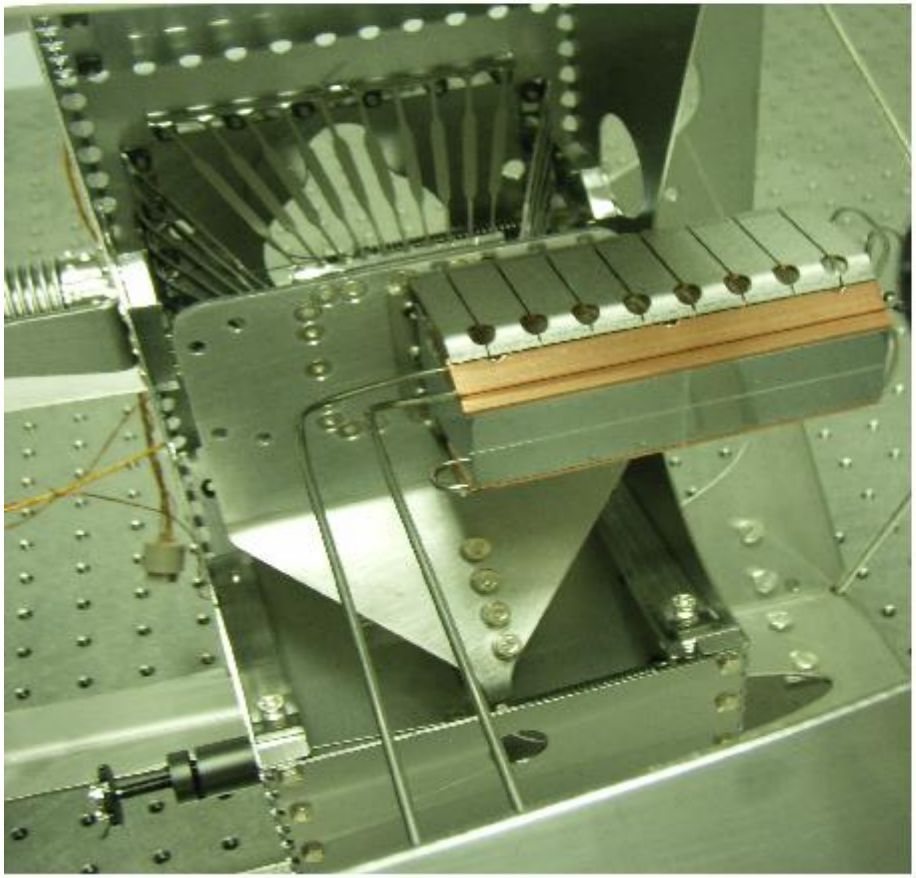
Courtesy of Tino Noll

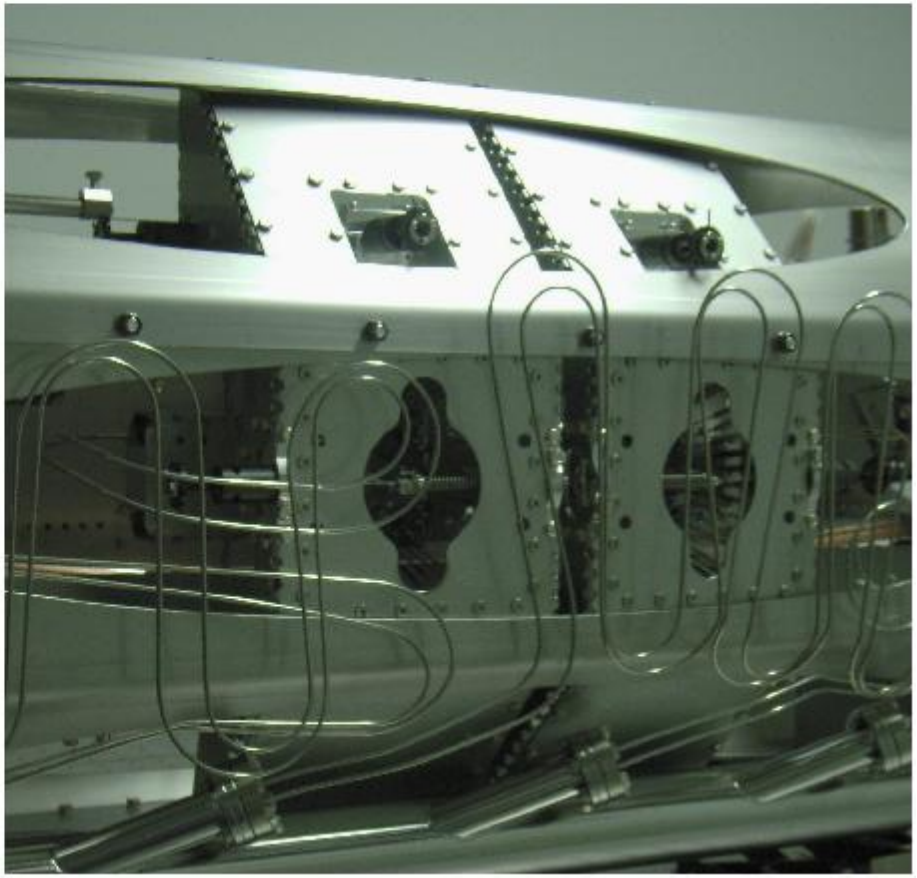
XUV-Autocorrelator – Mechanical Design

Autocorrelator – optical bench 1



Autocorrelator – optical bench 2

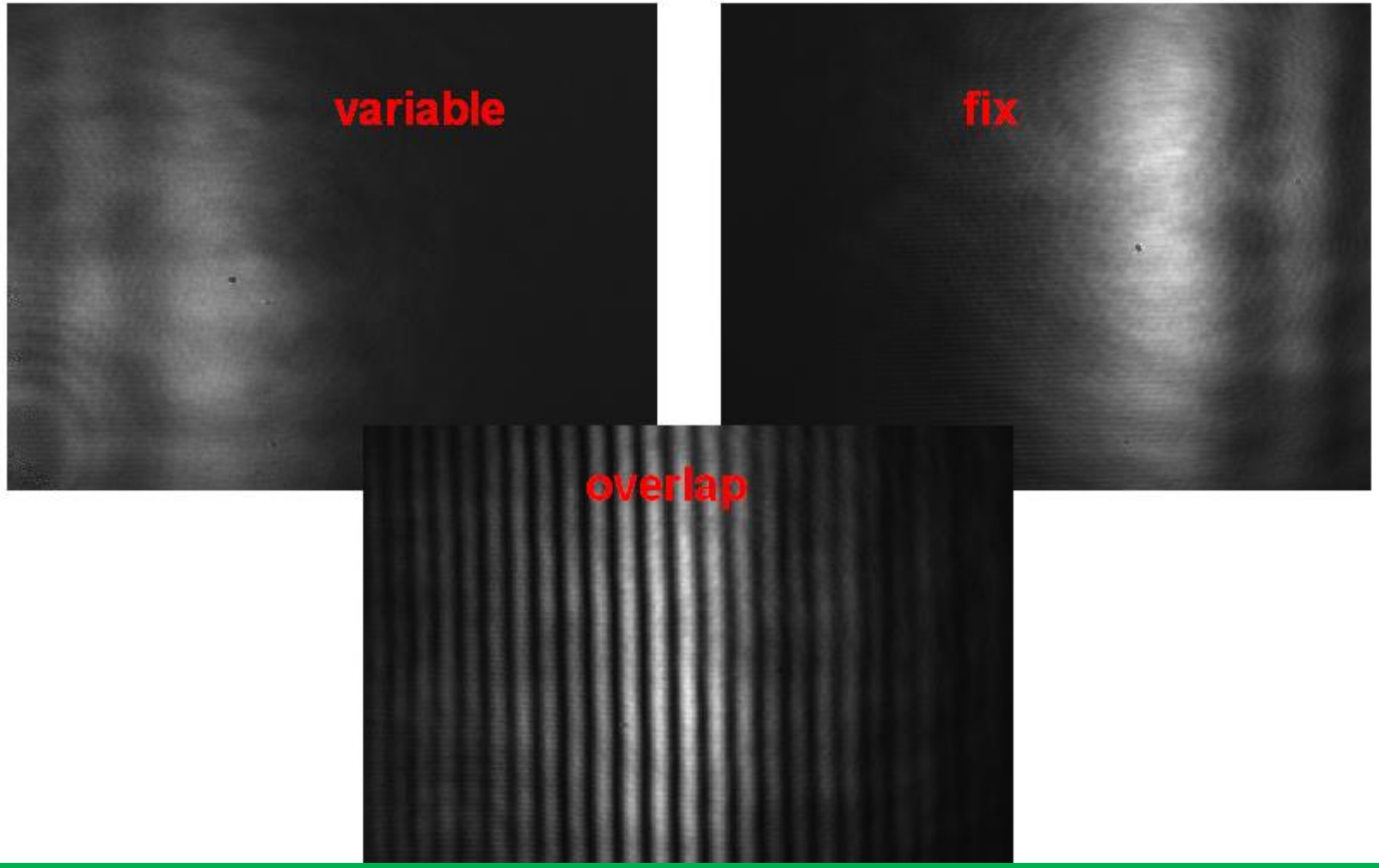




XUV-Autocorrelator – Optical Tests

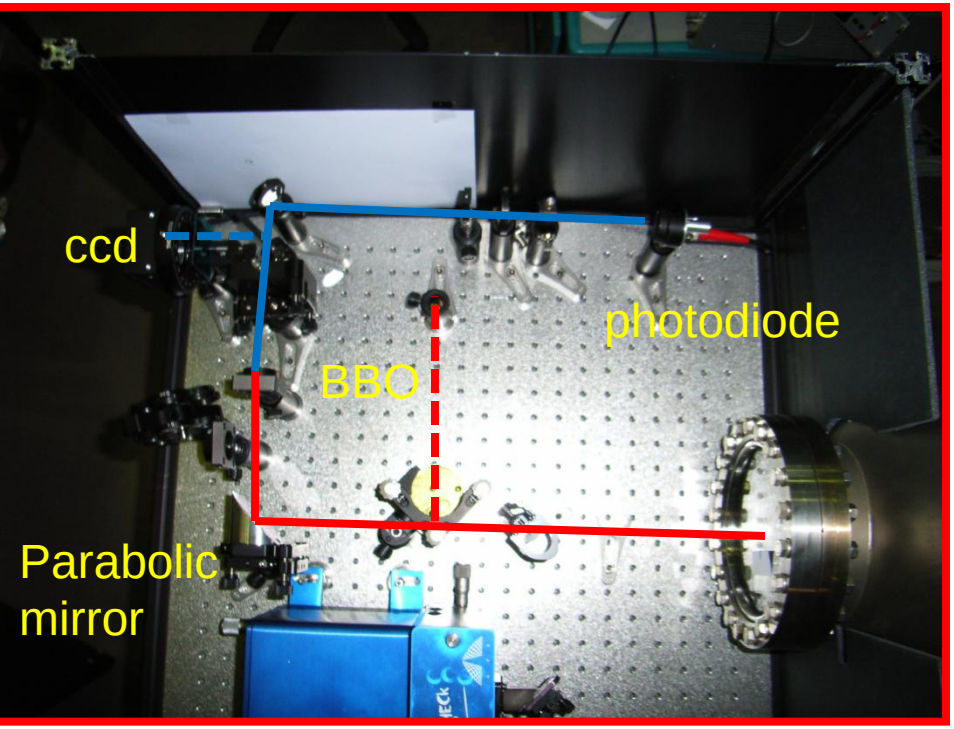
Adjustment of the beam pathes and tests of principle function with a HeNe- Laser

spatial interference pattern of the spatially overlapping beams

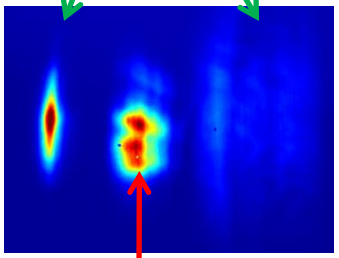


XUV-Autocorrelator – Optical Tests

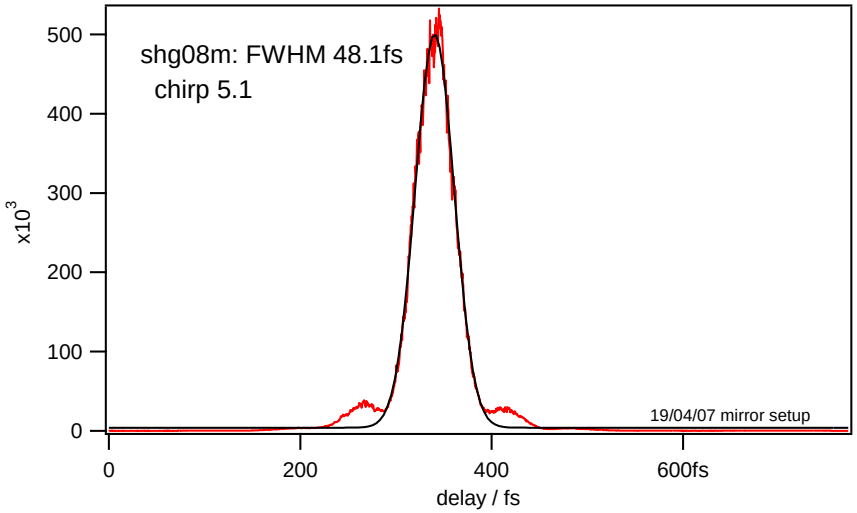
Diagnostics of the fs-laser experiments



SHG from split beams



SHG from overlapped beams



Noncolinear autocorrelation (SHG in BBO) of fs laser pulses (790 nm, ~35 fs FWHM)

XUV-Autocorrelator – Commissioning

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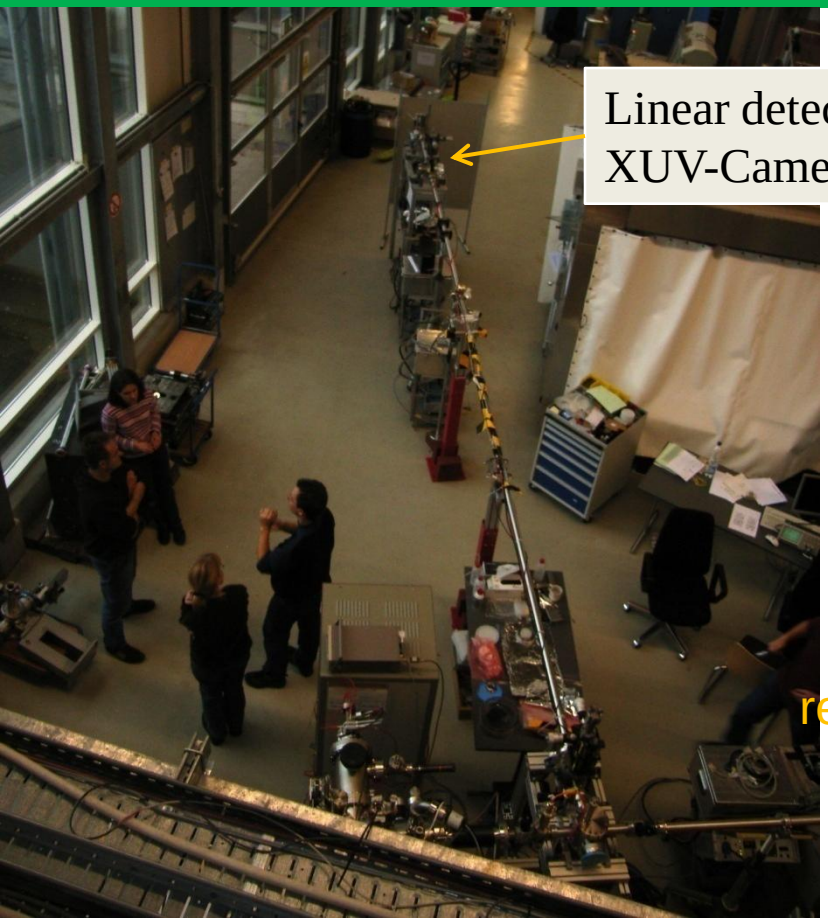
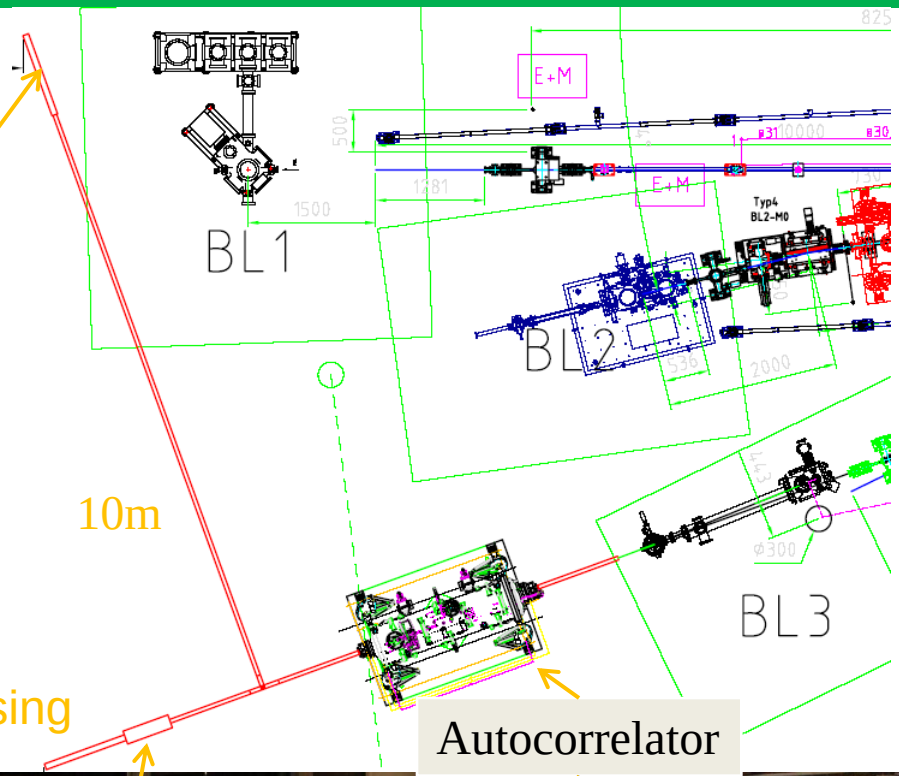
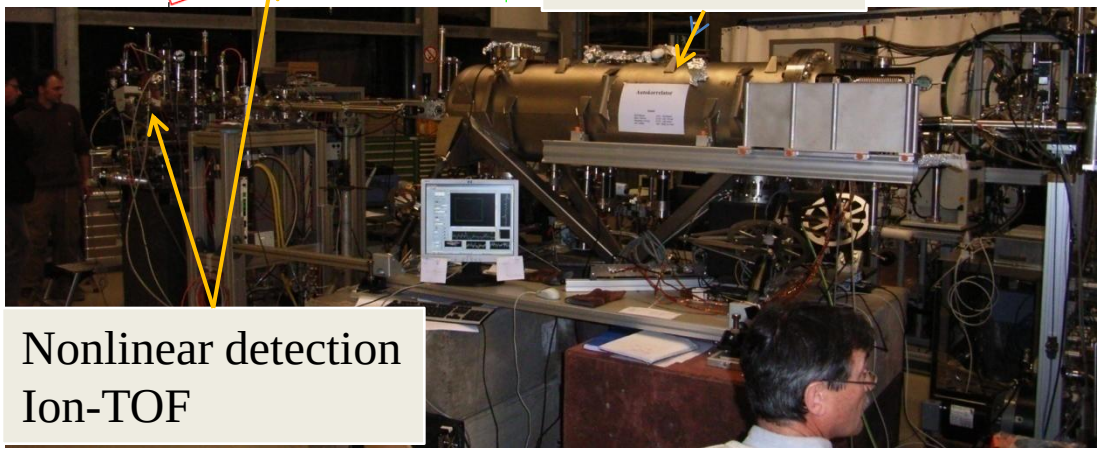
XUV-Autocorrelator – Commissioning



Linear detection
XUV-Camera



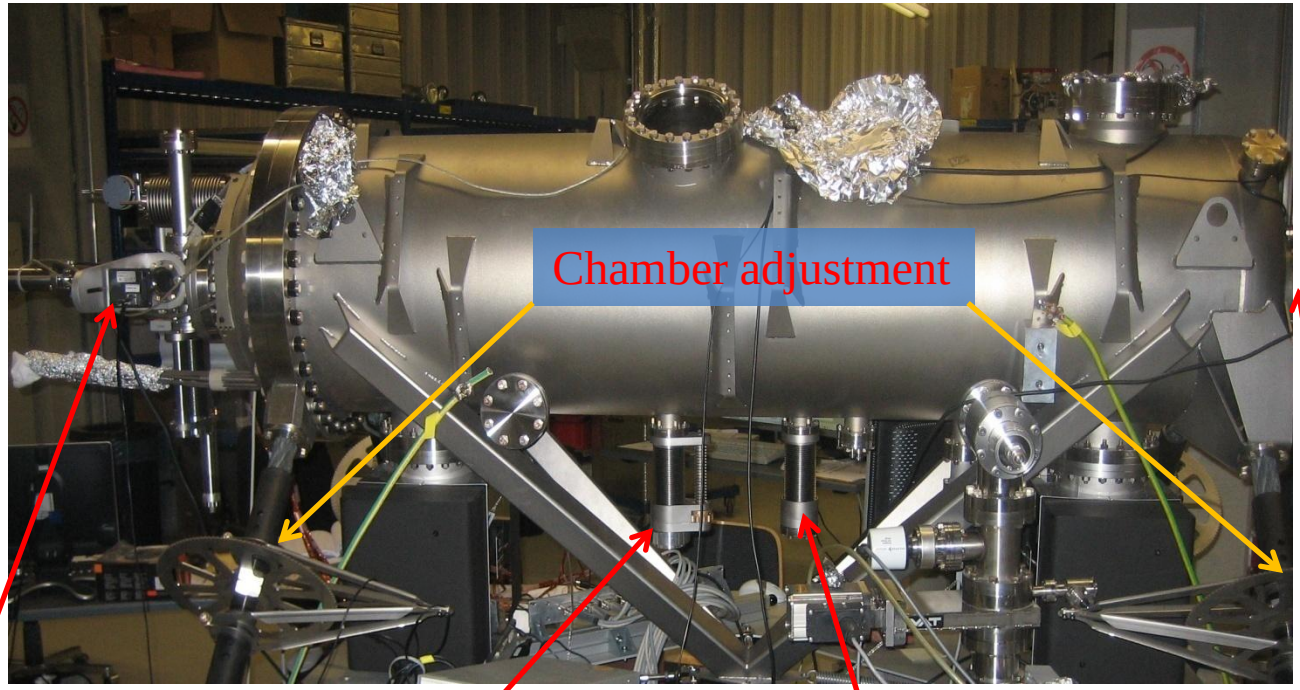


Nonlinear detection
Ion-TOF

FEL : 5 Hz, single bunch
13 nm: 2 … 20µJ
24 nm: 2 … 15µJ

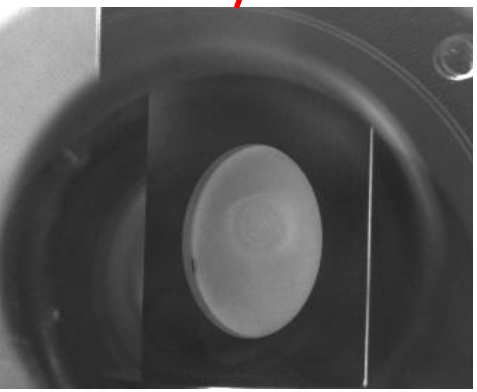
XUV-Autocorrelator – Commissioning

FEL →



screens

in



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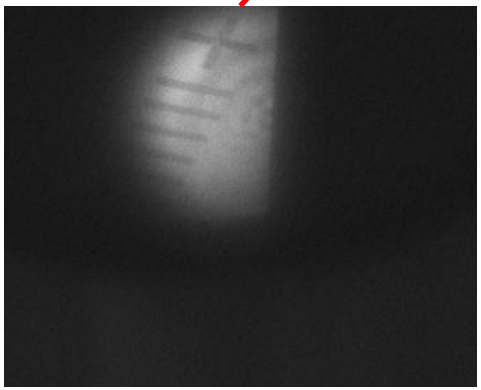
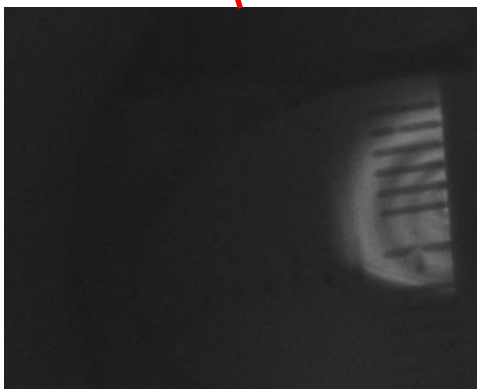
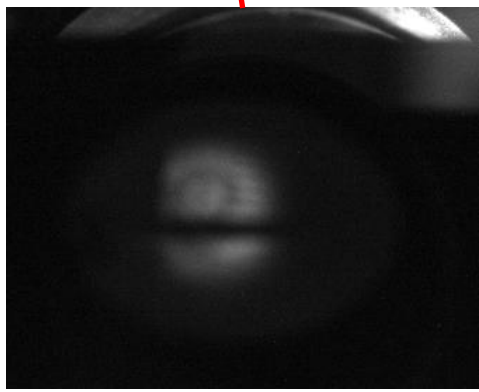


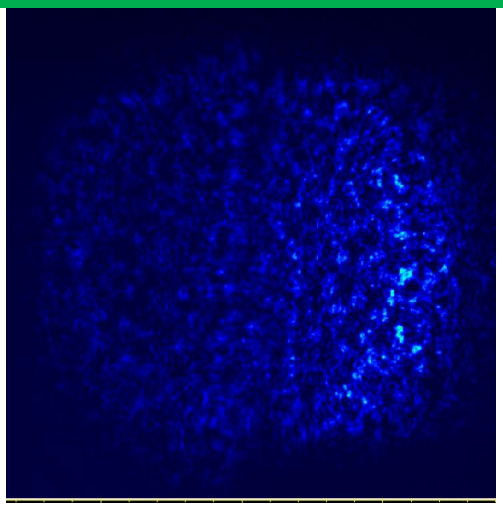
variable

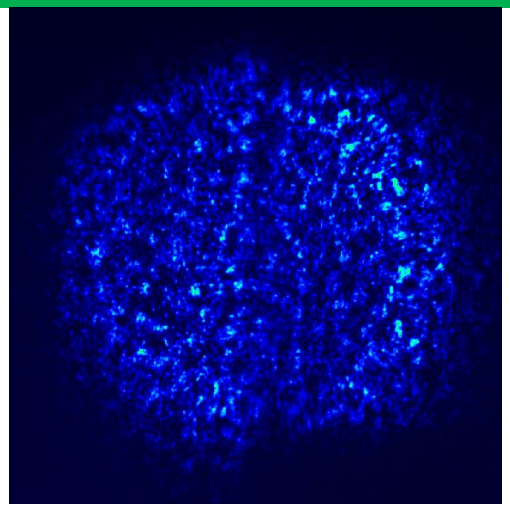


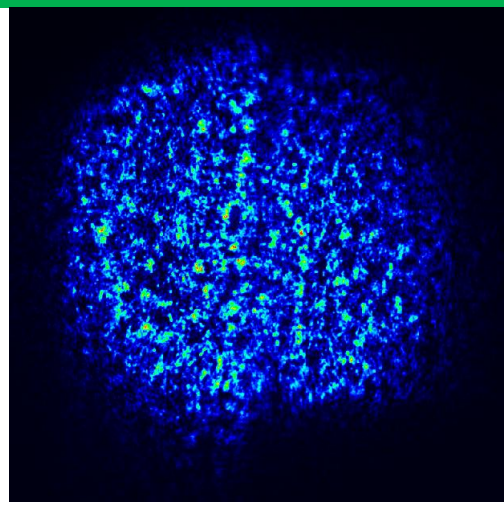
out



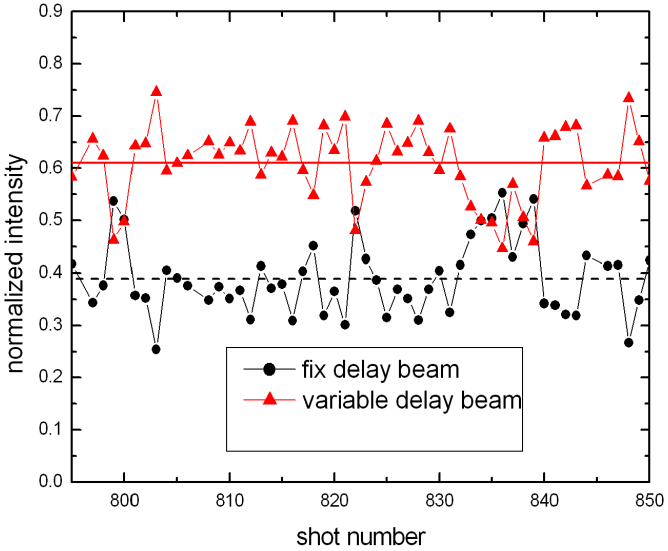
XUV-Autocorrelator – Commissioning







Intensity of the split beams



Total transmission depends on wavelength, pinholes in the beamline and adjustment

13 nm / 3 mm pinholes: 60%

24 nm / 3 mm pinholes: 48%

24 nm / 5 mm pinholes: 37%

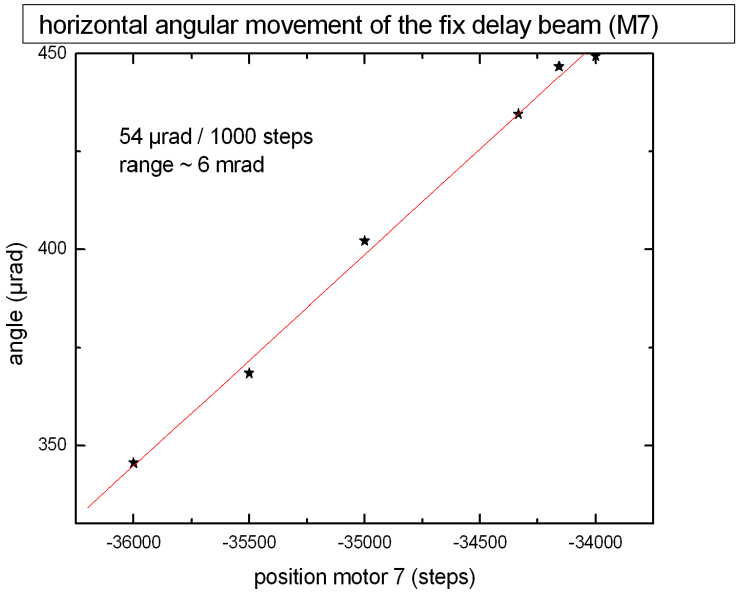
Splitting ratio

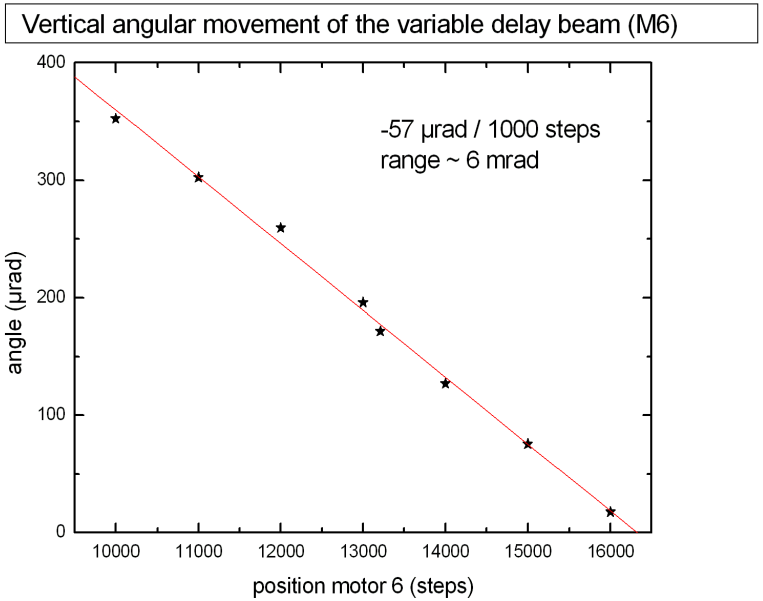
Fluctuations of ratio (pointing stability of the beam)

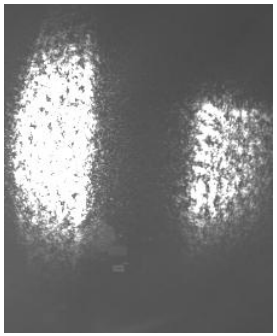
Speckles $d=\lambda L/D$ (size d~70-130µm)

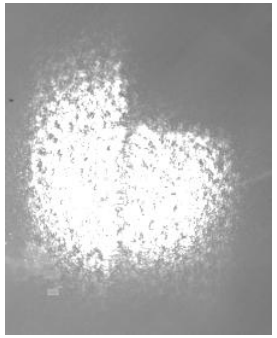
XUV-Autocorrelator – Commissioning

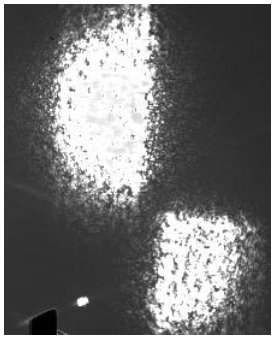
Manipulation of the split beams – angle, distance

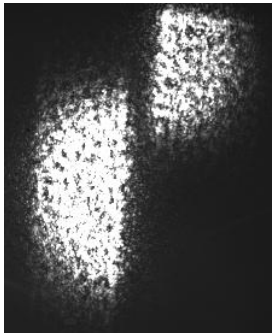












XUV-Autocorrelator – Linear Autocorrelation

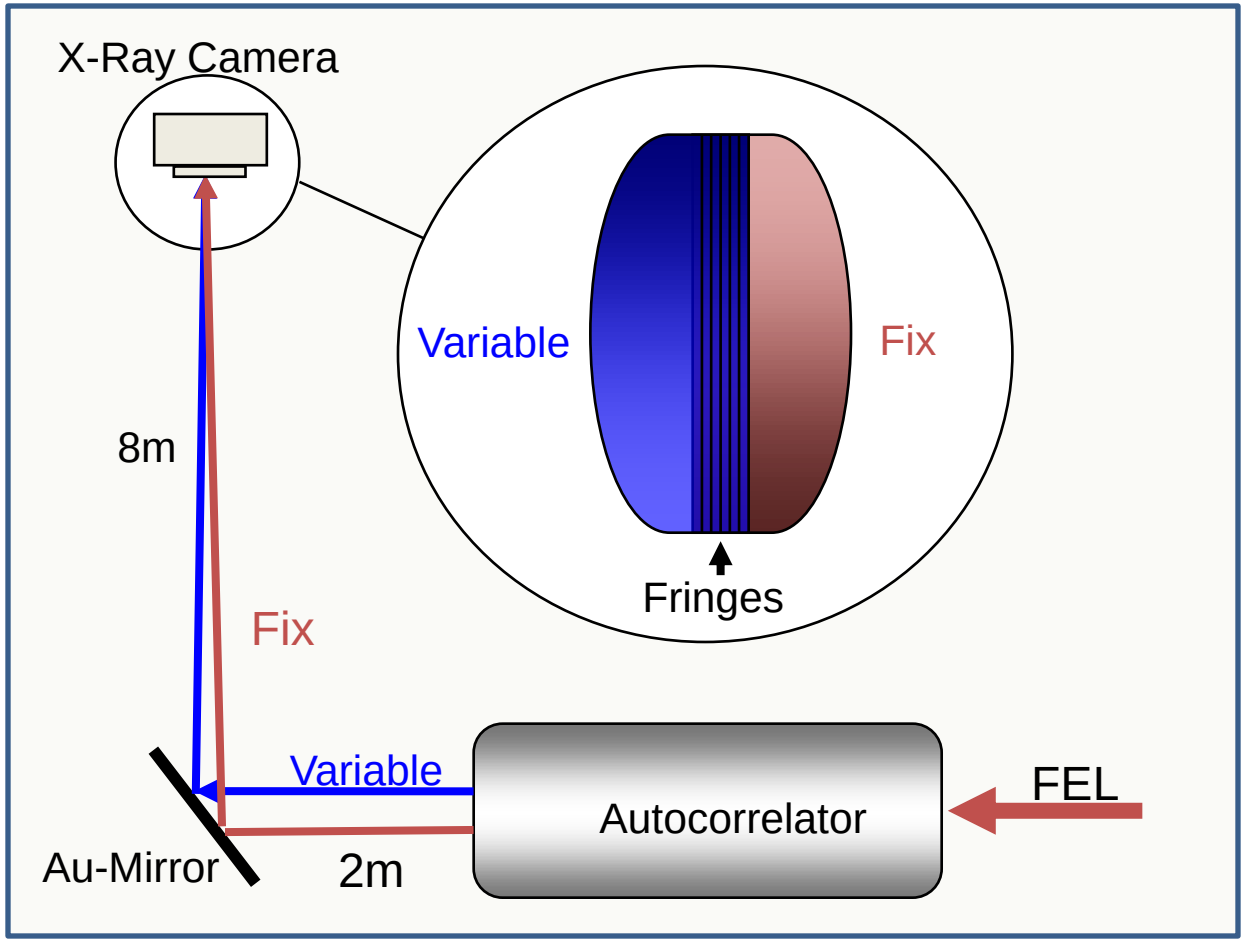
Objectives
- spatial and **temporal** coherence properties of the FEL beam
- **zero** delay

visibility

$$v = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

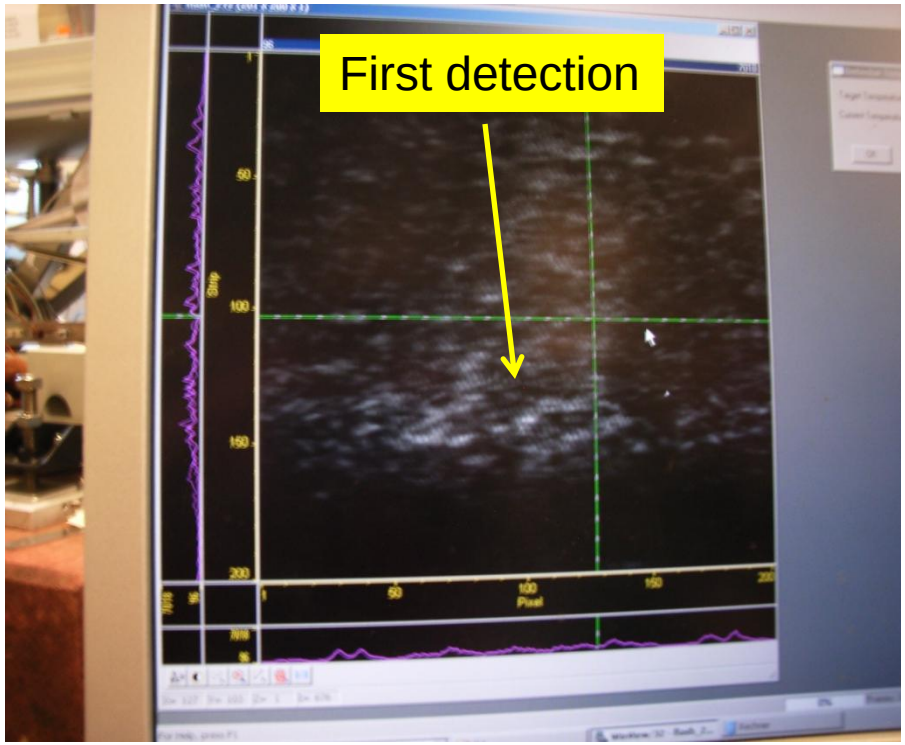
Fringe detection
- small angle between the beams needed
d= λ / sin(α)
- single shot detection

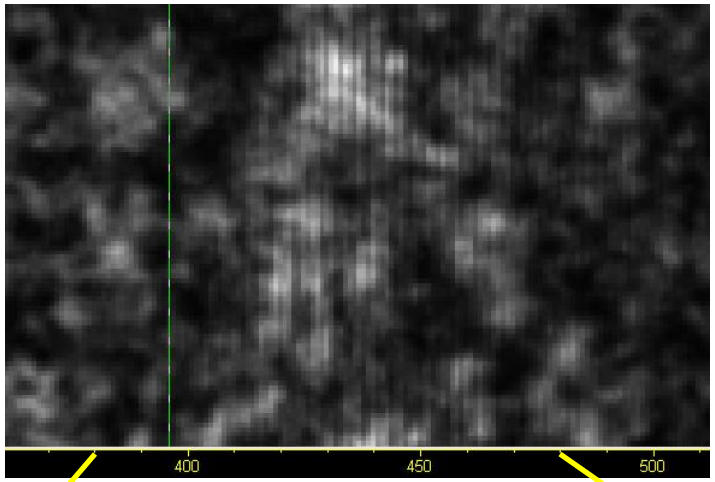
Setup of the two-beam-interference experiments

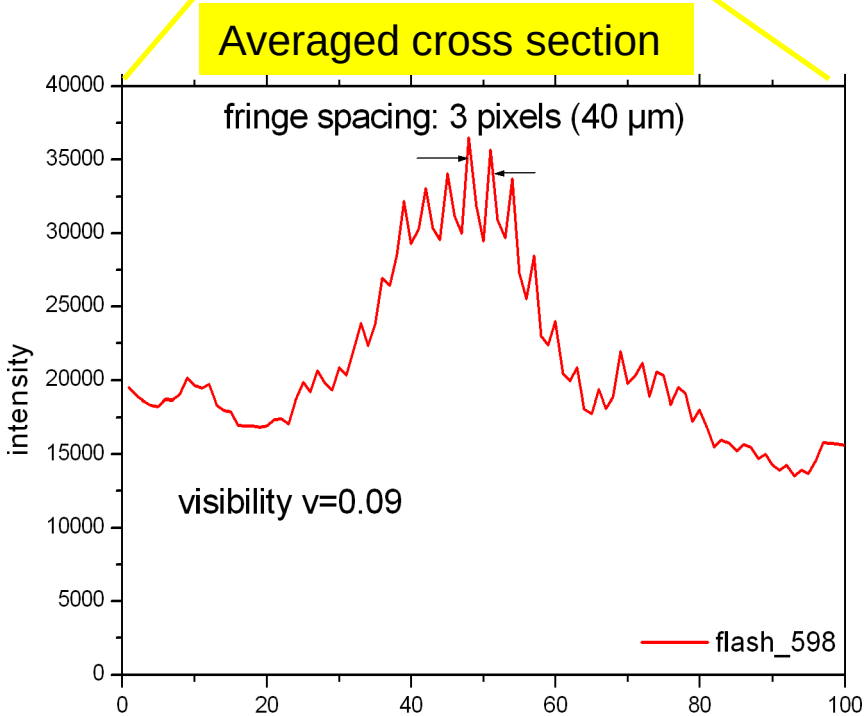


XUV-Autocorrelator – Linear Autocorrelation

Two-beam-interference at 13nm
- strong fluctuations
- minor contrast
- only rought determination of zero delay ($\Delta t \sim 6$fs)





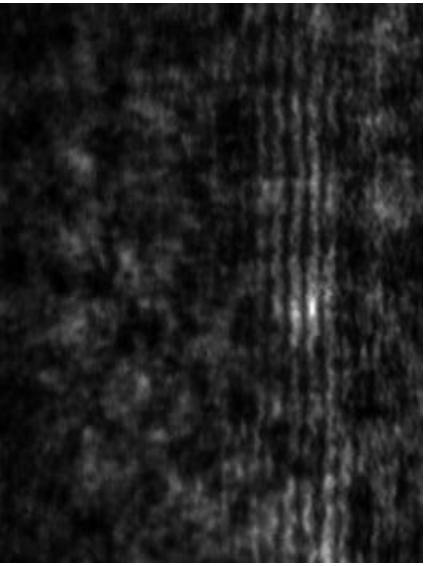


XUV-Autocorrelator – Linear Autocorrelation

Two-beam-interference at 24nm

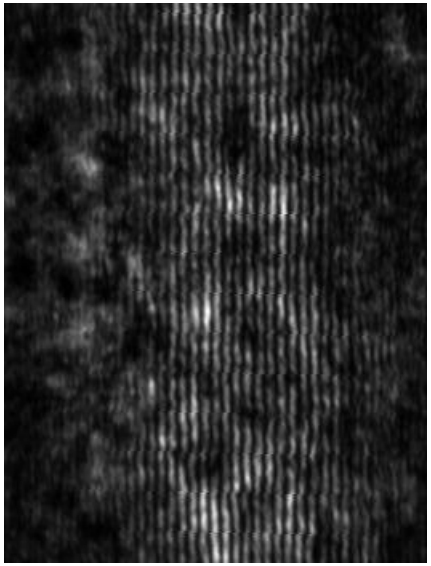
Spatial fringes detected at various crossing angles

α=0.18mrad



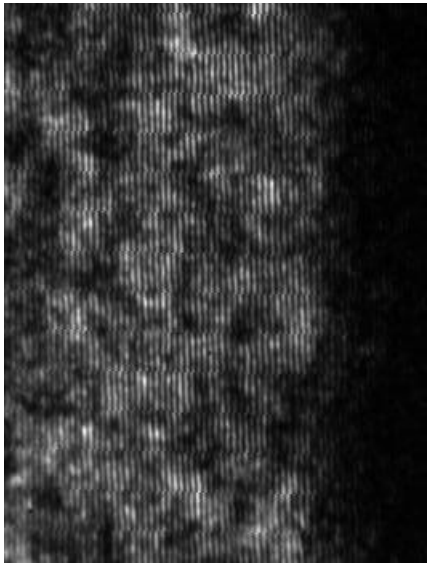
130 µm

α=0.27mrad



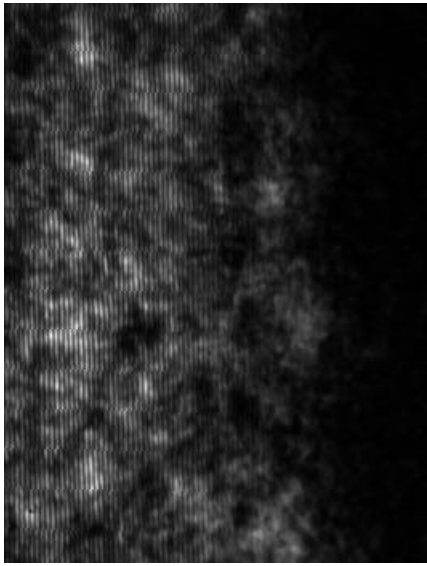
90 µm

α=0.51mrad



45 µm

α=0.75mrad

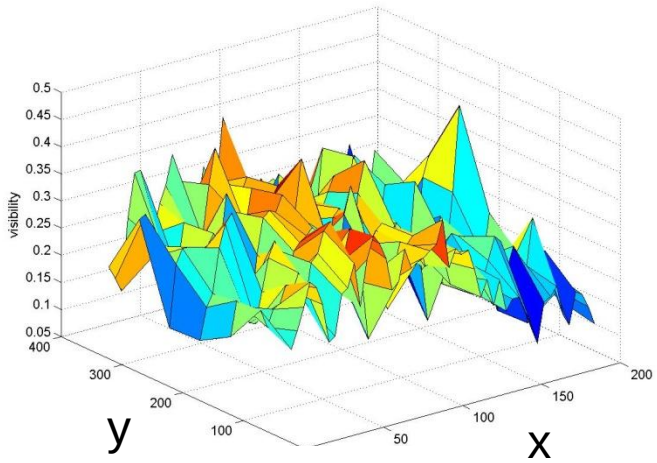


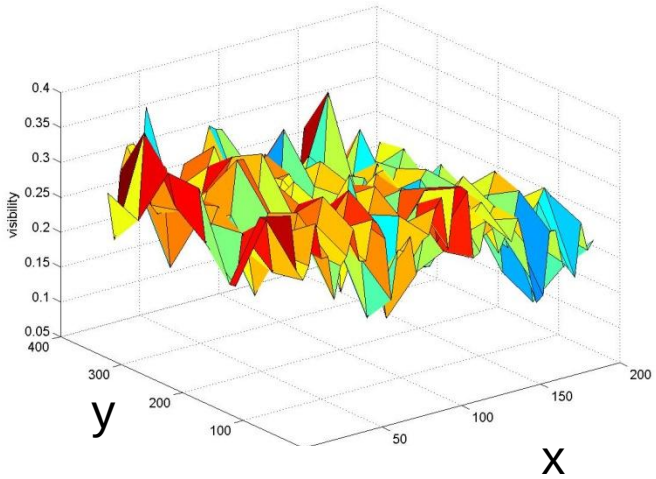
32 µm

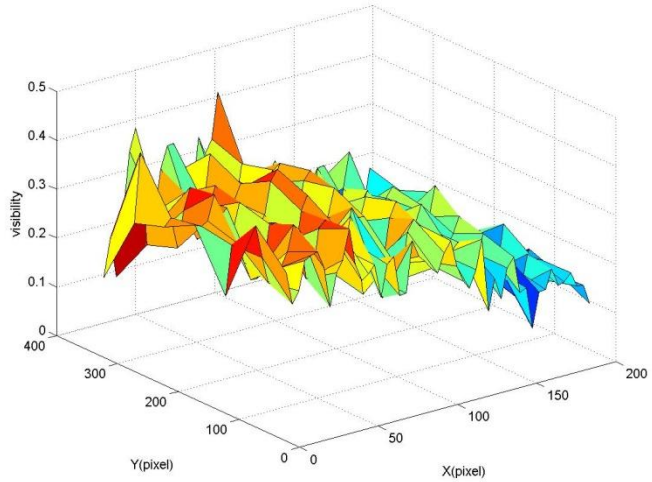
Distance of the fringes = $\sin\alpha / \lambda$

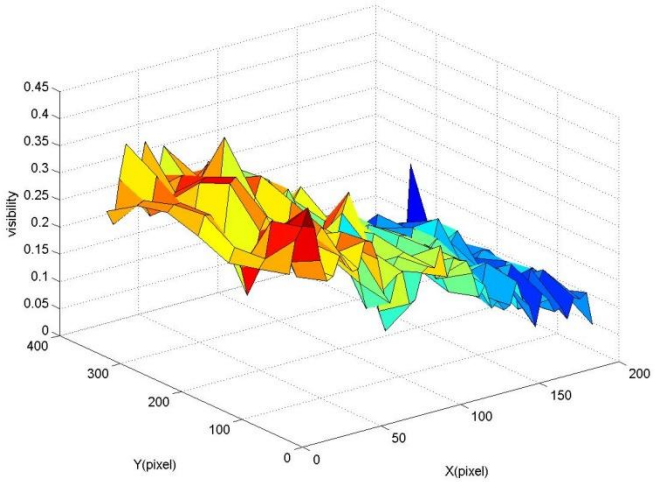
XUV-Autocorrelator – Linear Autocorrelation

Spatially resolved visibility of the fringes of fully overlapping beams





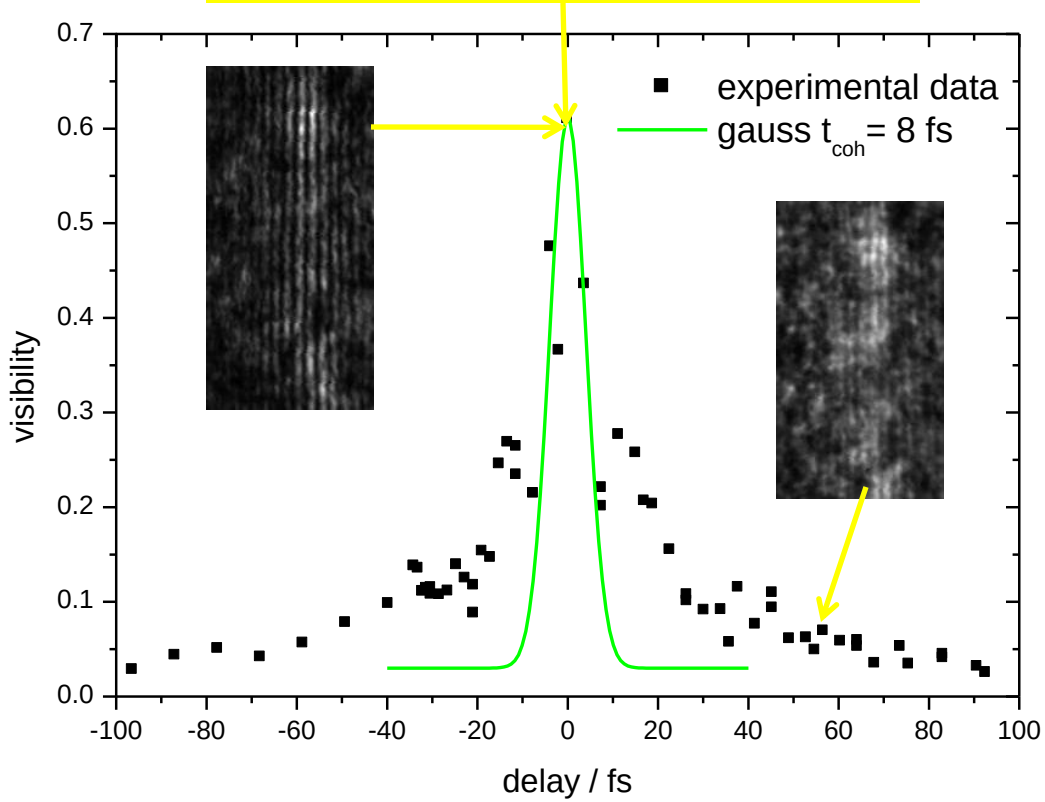




XUV-Autocorrelator – Linear Autocorrelation

Variation of fringe visibility with delay (path difference) for slightly overlapping beams

Precise determination of zero delay



coherence length

$$l_{coh} = \frac{\lambda^2}{2\Delta\lambda}$$

λ= 24 nm
$\Delta\lambda$=0.12 nm
l_{coh}= 2.4 µm
t_{coh}= 8 fs

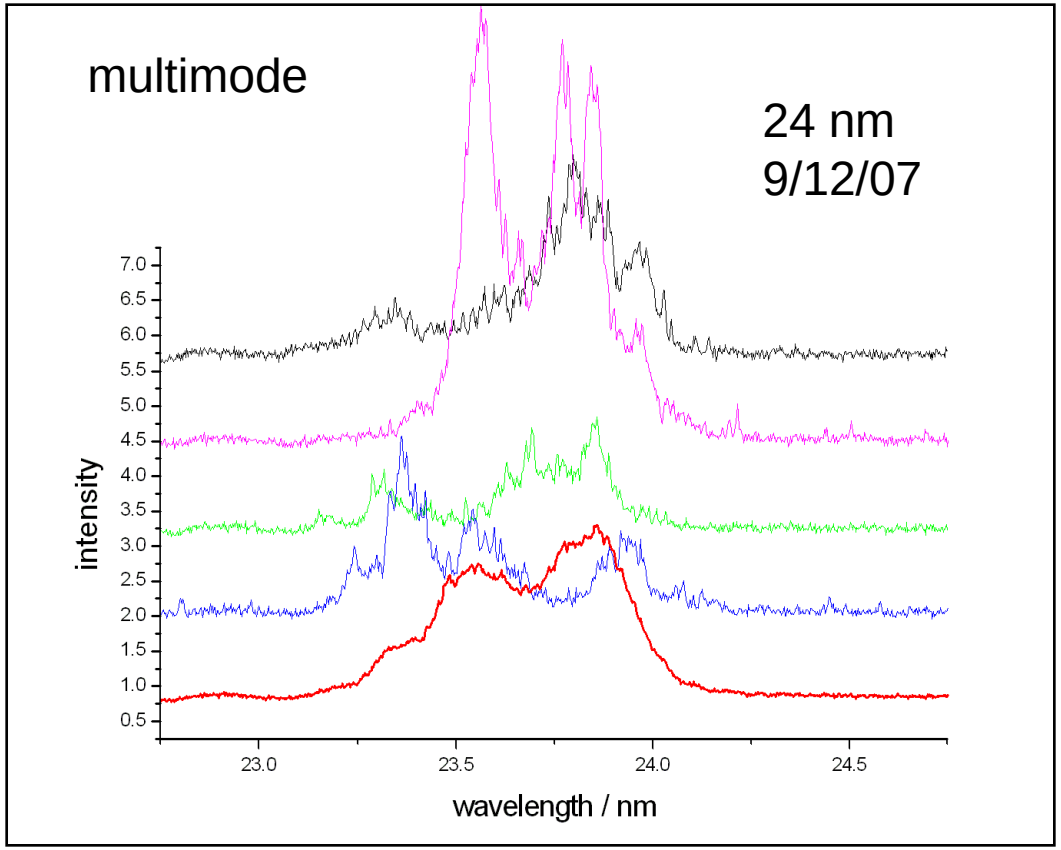
- structured correlation function
- strong fluctation of coherence
- sporadic fringes even at Δt=100fs

XUV-Autocorrelator – Linear Autocorrelation

Properties of the given FEL beam(beamtime) and its coherence

- SASE not saturated
- several spectral modes
- transversal fluctuations (modes)
- several longitudinal modes can be expected
- chirp?
- bandwidth of spectral modes?

Single shot and averaged (red) spectra of the FEL



Nonlinear detection of the autocorrelation

- nonresonant two-photon ionization (2PPE)

40 eV (Ne 2s, 10^{-53}cm^{4}s, 10µJ, 50fs, 0.01torr)
2PPE **20** electrons per pulse
200 eV (Ar 2s, 10^{-55}cm^{4}s, 10µJ, 50fs, 0.01torr)
2PPE **1** electron per pulse

- resonance enhancement of 2PPE

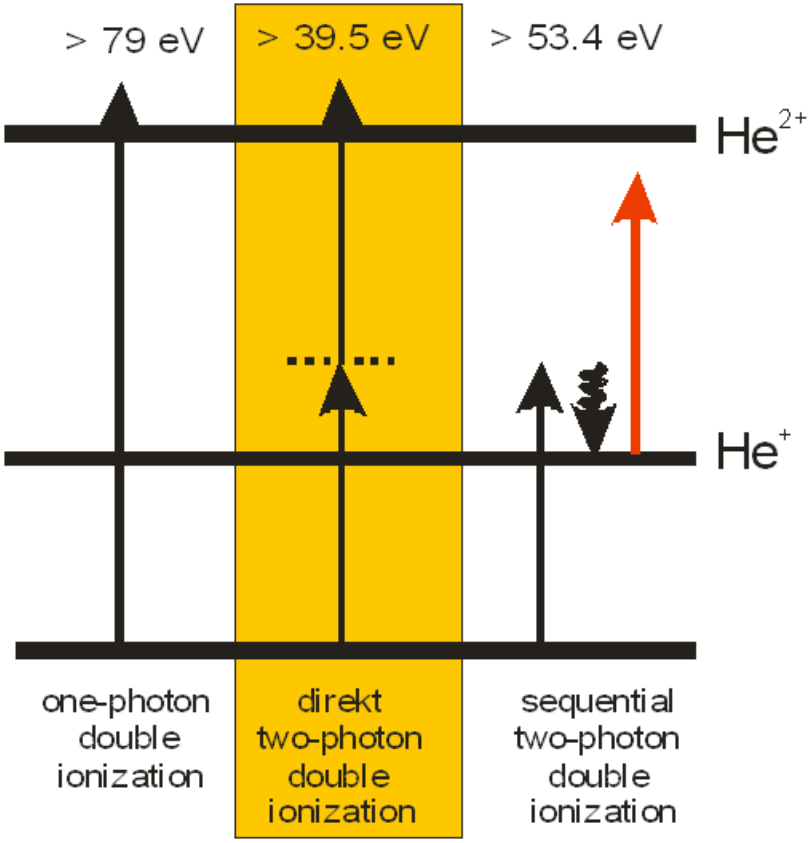
giant resonances at **Xe** (80- 110eV; prolongation ~3fs)

- direct two photon double ionisation

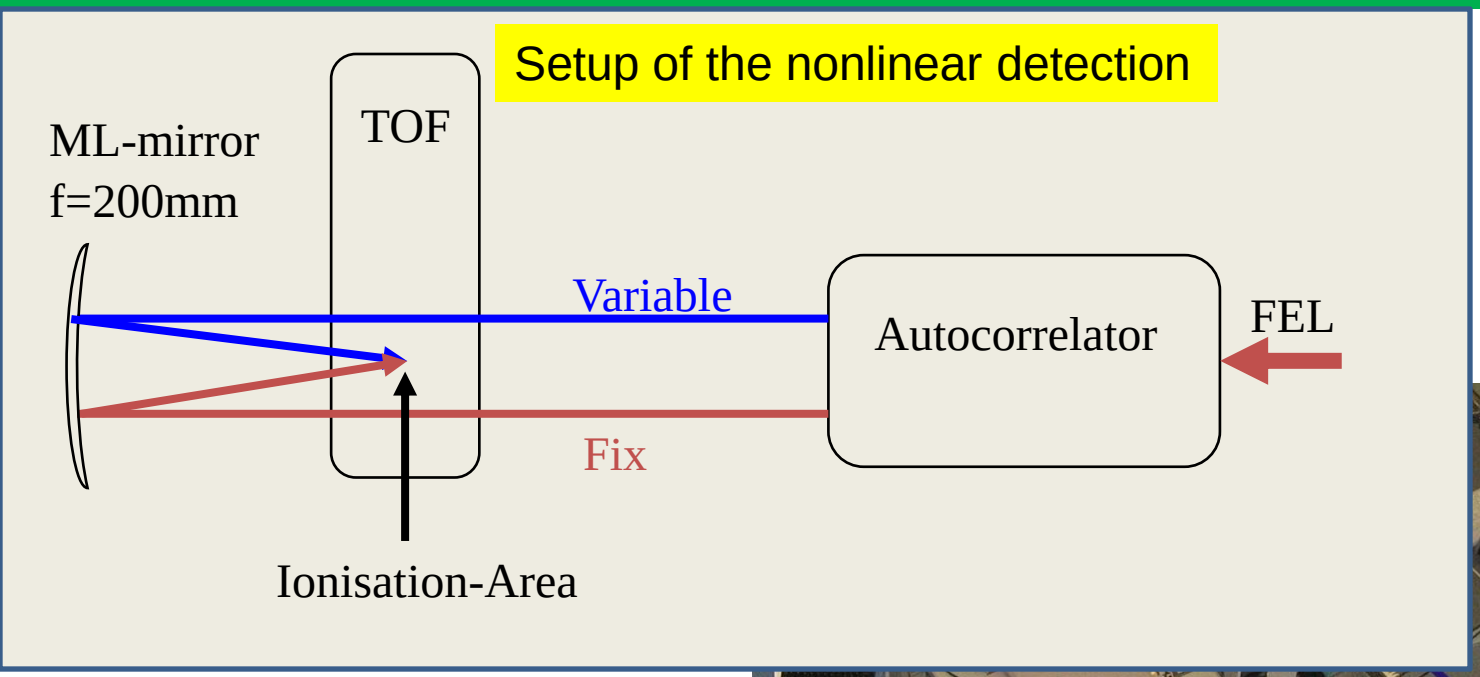
Ne (31.3 – 41 eV)

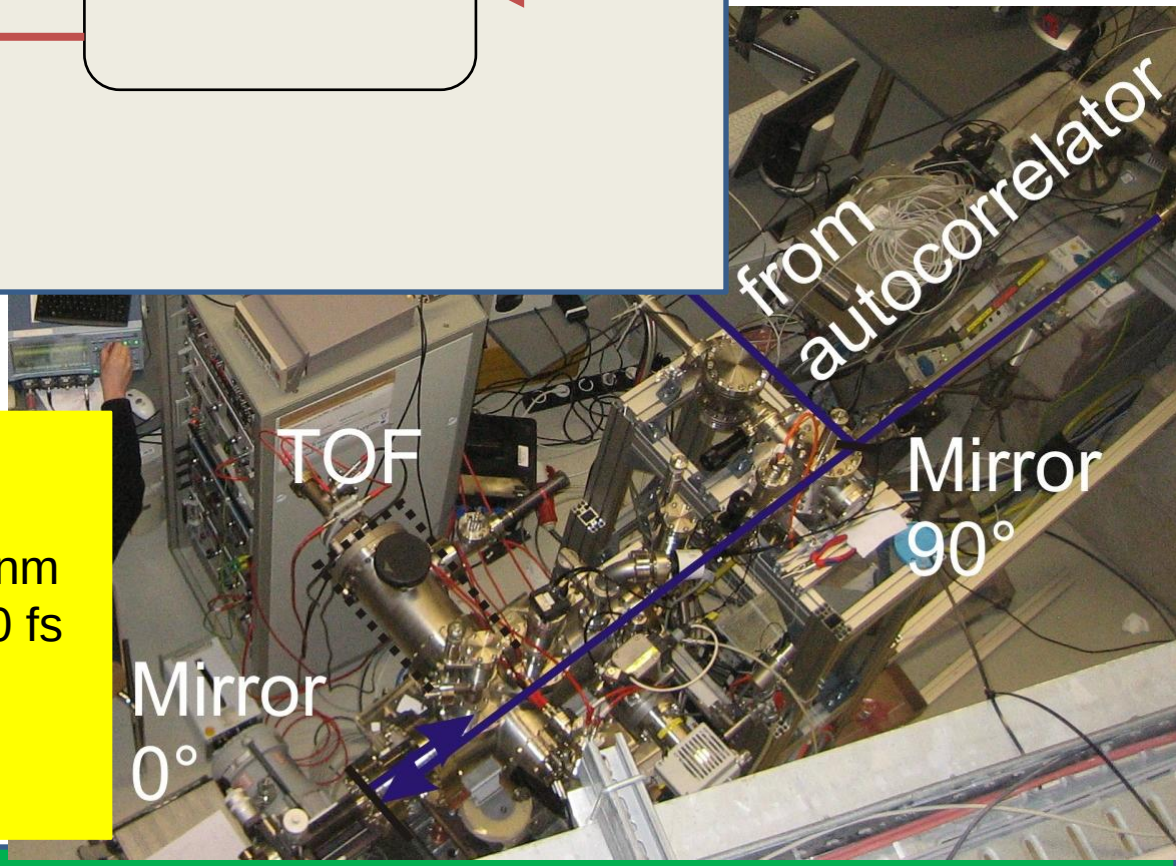
He (39 -53.4 eV)

Y. Nabekawa et.al.,Phys. Rev. Lett. **94**, 0043001 (2005)
A.A. Sorokin et.al., Phys. Rev. Lett. **99**,213002 (2007)



XUV-Autocorrelator – Nonlinear Autocorrelation





Result
- Measurement of nonlinear auto-correlation of the FEL pulse at 24 nm
- FWHM of the autocorrelation ~50 fs
- corresponds to a gaussian pulse length (FWHM) of 35 fs

Participants and acknowledgements

P. Juranic
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No FEL – No Party!

* Holography **Nonlinear autocorrelation