Hartmann Wavefront Measurements at the EUV-FEL FLASH.

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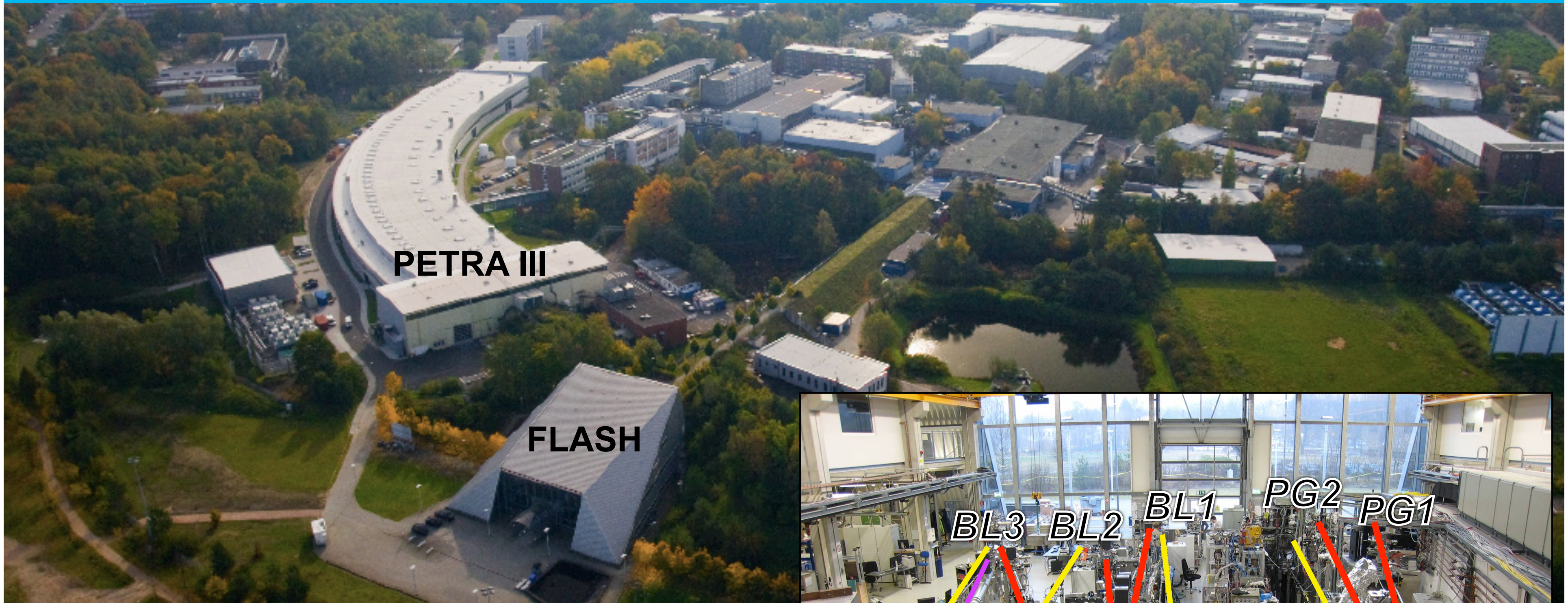
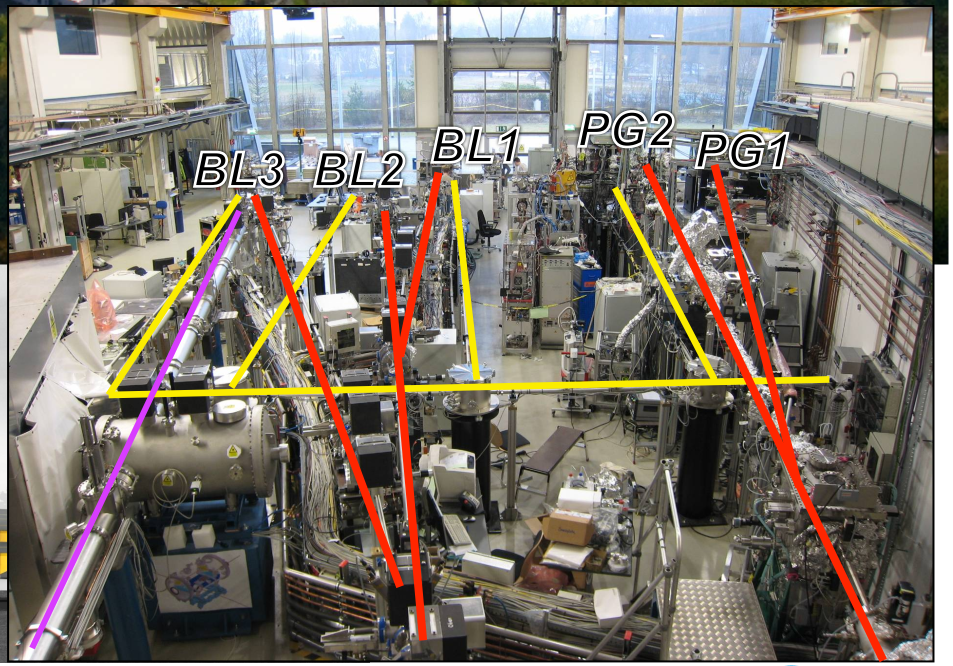
DESY

FLASH.





Intention.

> 1. Beamline commissioning

- First implementation and long-term observations of diagnostic tools and optics, e.g. alignment of focussing mirrors and effects of filters and gas attenuator on the FEL wave front.

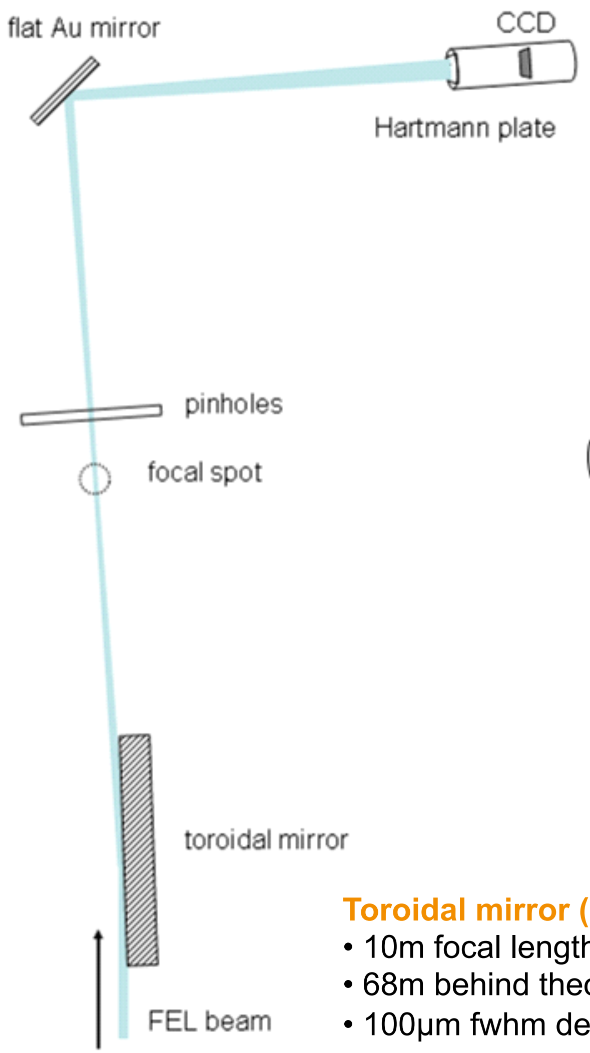
> 2. FEL characteristics

- The FEL source can be analysed in position, shape and size. The beam position and its stability can be documented.

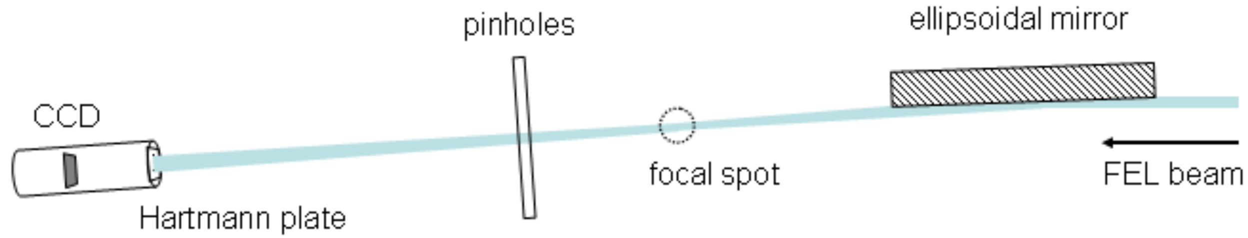
> 3. Diagnostic for user experiments

- Focus size and position can be determined online for single shots, if the main experiment is transparent for the FEL beam.

Experimental setups at FLASH.



Ellipsoidal mirror (BL2/BL3)
- 2m focal length
- 73m behind theoretical source
- 20µm fwhm designed spot size



Distances for compact wave front sensors:

L(mm)	λ=13.5nm	λ=20nm	λ=30nm	λ=40nm	λ=50nm	λ=60nm	λ=65nm
d=5µm	3207	2299	1533	1150	920	766	707
d=10µm	6415	4598	3066	2299	1839	1533	1415
d=20µm	13357	9196	6131	4598	3679	3066	2830

Without pinhole: Hartmann plate about 700mm from focal position

L: distance plate-pinhole
d: diameter pinhole

Toroidal mirror (BL1)
- 10m focal length
- 68m behind theoretical source
- 100µm fwhm designed spot size

Compact Hartmann sensor (first version).

Wave front sensor (6 – 30nm)

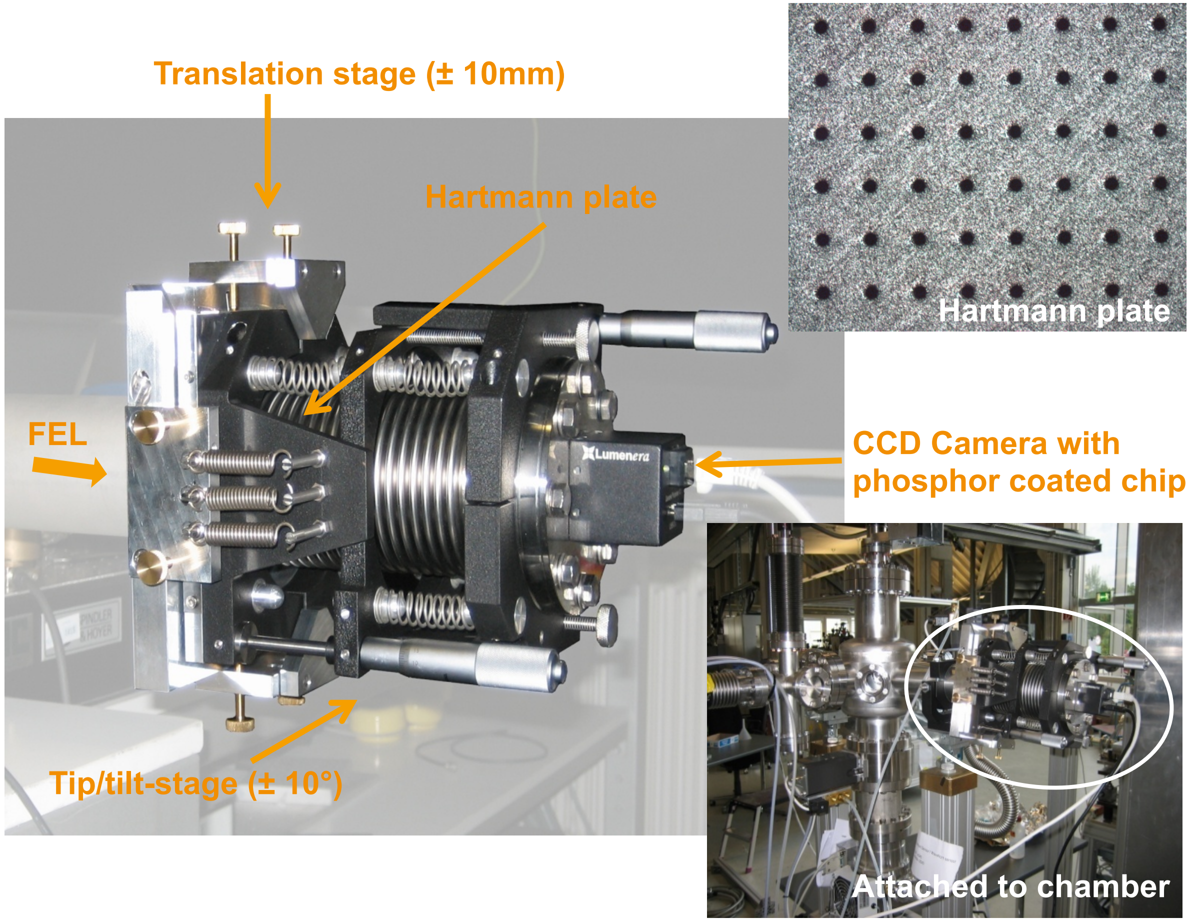
Hartmann plate:
-7µm tantalum foil with circular laser-drilled holes in a squared grid (pitch 320µm, diameter 65µm)
-20µm Ni foil with electroformed holes in a squared grid (pitch 250µm, diameter 75µm)

CCD (LM165 12bit):
field of view: 8.25mm x 6.6mm
1280 x 1024 pixel, 6.45µm pixel size, chip with phosphorescent coating (Gd_2O_2S:Tb, grain size 1-2µm, central emission wavelength 545nm)

Plate – CCD Chip: 97.08mm
Plate – Flange: 100mm

Repeatability (wave front rms):
- $\lambda_{13.5nm}$/90 for tantalum foil

Software by LLG (MrBeam 3.5.0)



Collaboration with Laser-Laboratorium Göttingen e.V. (LLG)
B. Flöter et al., New J. of Phys. 12 (2010), 083015

Compact Hartmann sensor (second version) .

Wave front sensor (6 – 30nm)

Hartmann plate:
20µm Ni foil electroformed holes in a squared grid (pitch 250µm, diameter 75µm)

CCD (MR285MC 14 bit):
field of view: 8.98mm x 6.71mm (HxV)
1392 x 1040 pixel, 6.45µm x 6.45µm pixel size, chip with phosphorescent coating (Gd_2O_2S:Tb, grain size 1-2µm, central emission wavelength 545nm)
Peltier cooling possible

Plate – CCD Chip: 198.251mm
Plate – Flange: 131mm

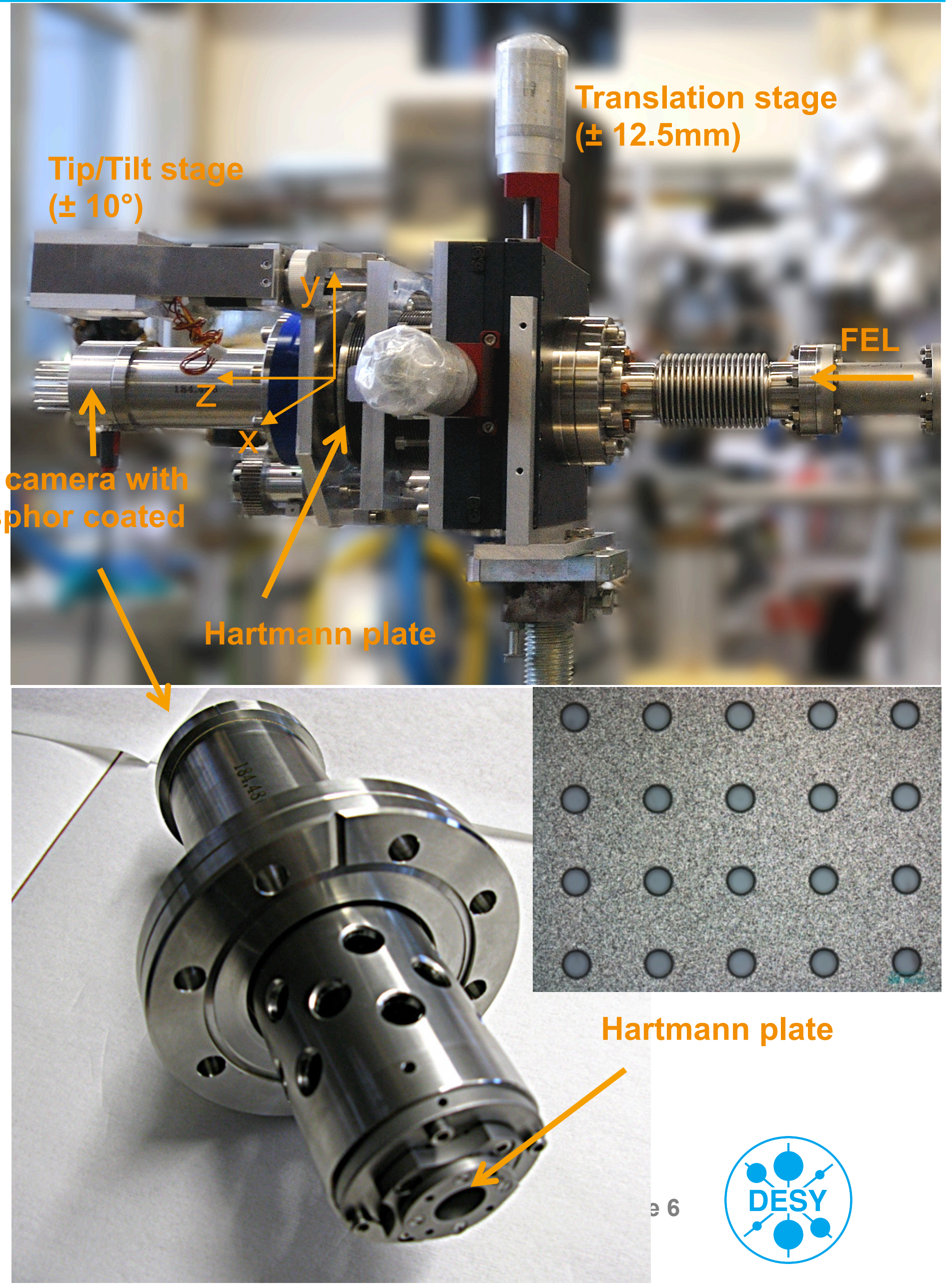
x/y and tip/tilt stages: motorized

New design: higher machanical stability

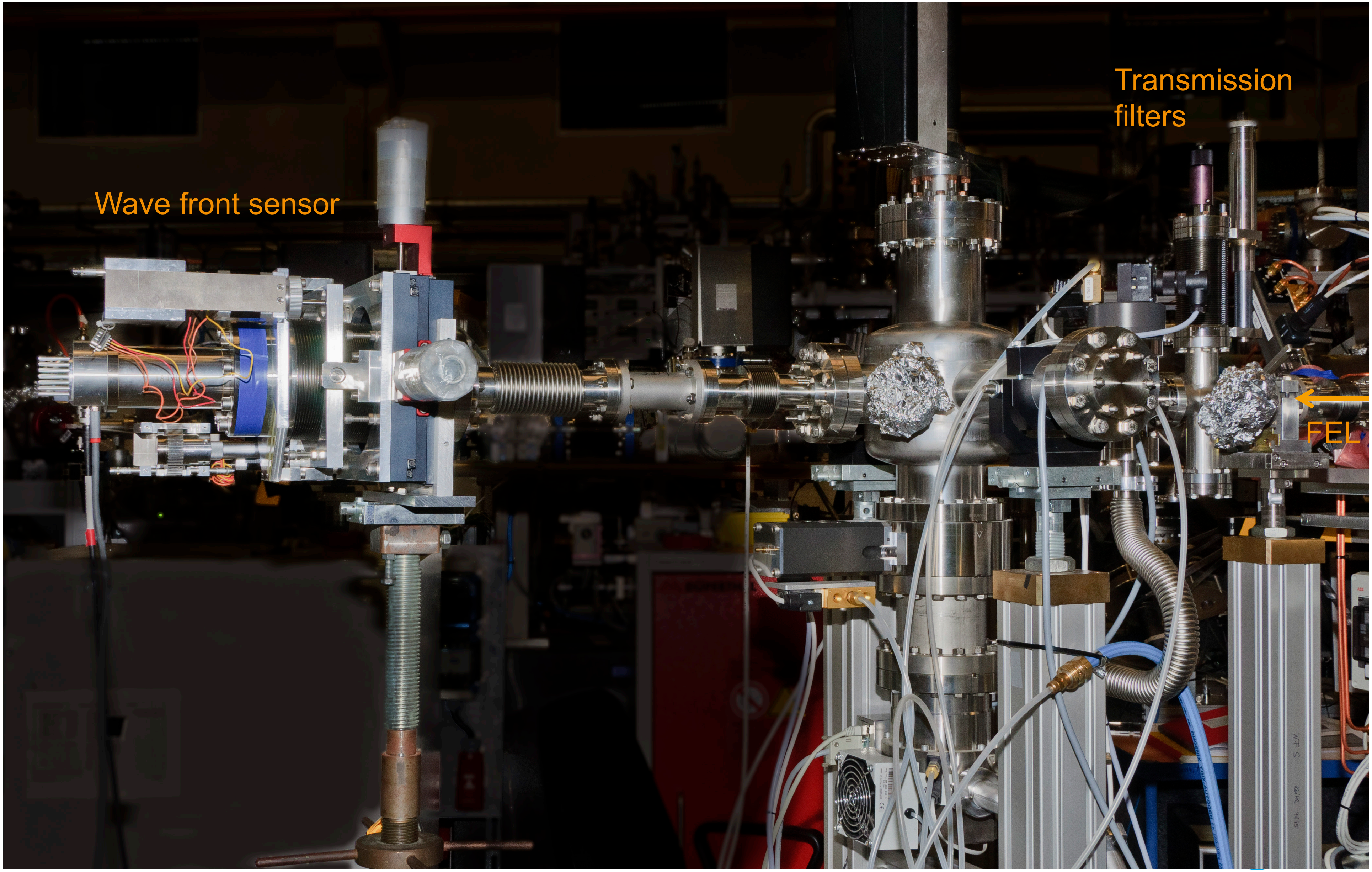
Repeatability (wave front rms):
-$\lambda_{13.5nm}$/116 for Ni foil

Software by LLG (MrBeam 3.5.2)

Collaboration with Laser-Laboratorium Göttingen e.V. (LLG)



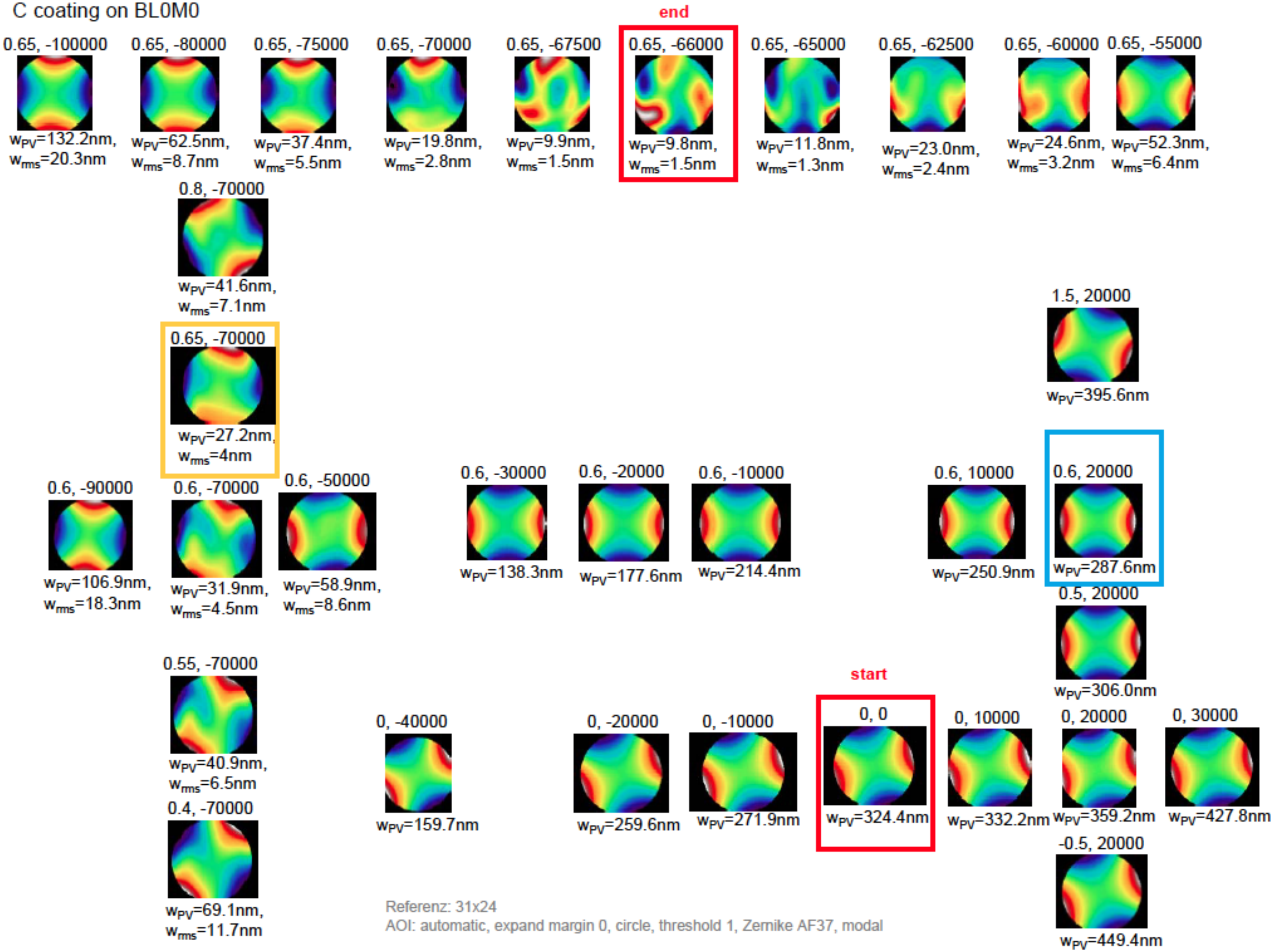
Setup at BL3.



Settings.

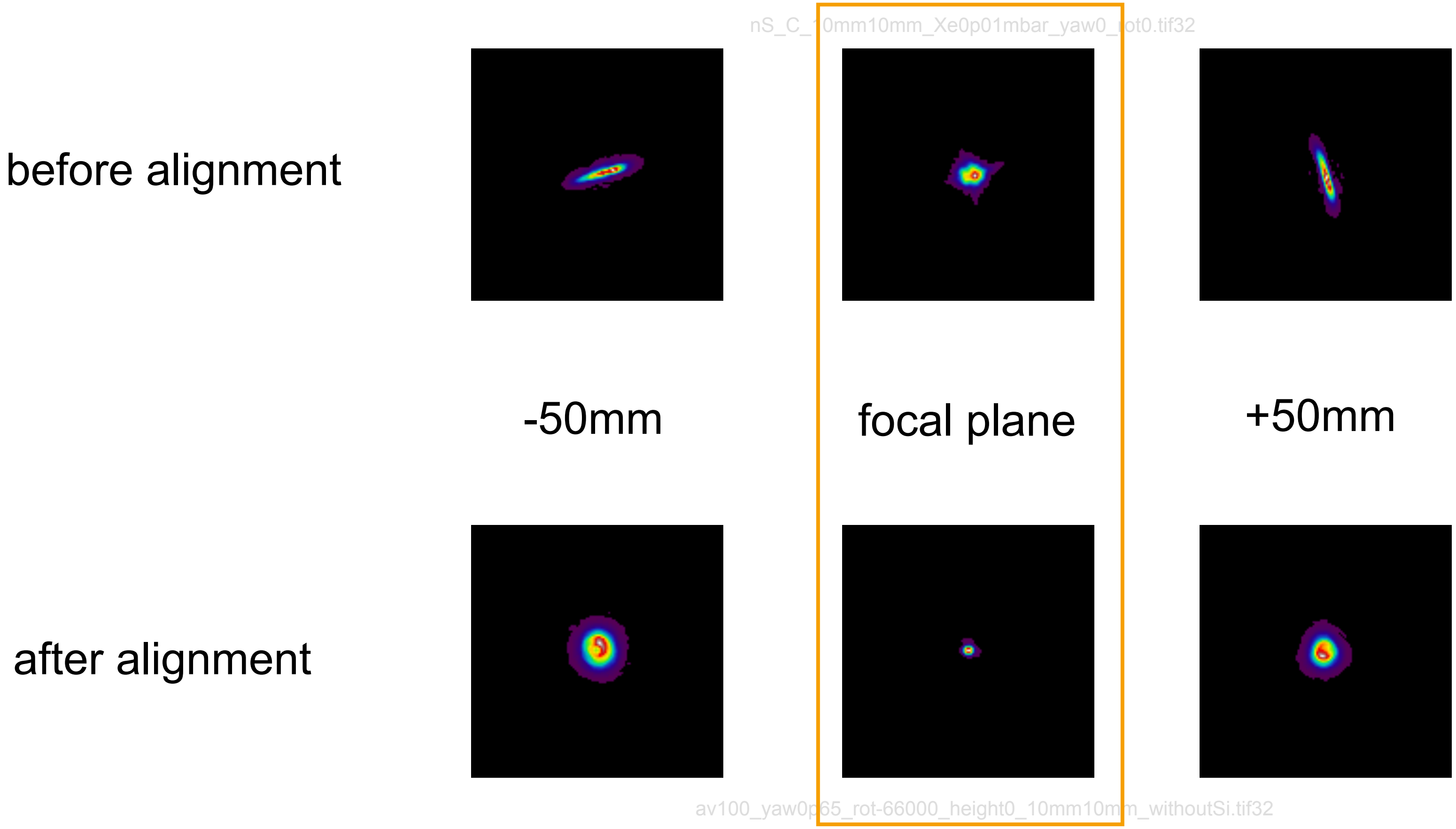
- Single bunch
- 13.3nm
- 0.01mbar Xe in attenuator -> attenuation to about 2µJ per pulse
- both 10mm apertures in tunnel
- no transmission filters used, but checked that
  - 200nm Si filter (Luxél) shows nearly no effect on the wave front
  - 137nm Al (Uni Frankfurt) influences the wave front due to bad filter quality
- CCD camera triggered by fast shutter

BL3M2 adjustment 29./30.1.11
C coating on BL0M0



Referenz: 31x24
AOI: automatic, expand margin 0, circle, threshold 1, Zernike AF37, modal

Simulated beam profiles.

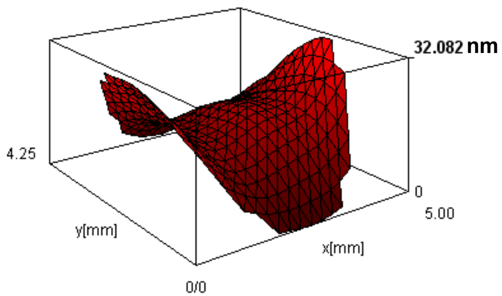


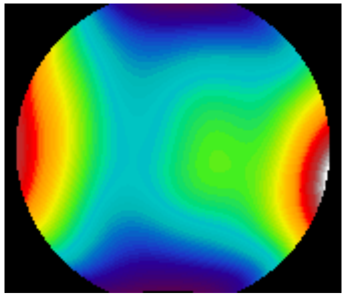
Numerical propagation via Kirchhoff-Fresnel integral

BL2 mirror alignment November 2010.

- Sensor (Hartmann plate) 1096mm behind expected focal position
- M0 with Ni coating
- 0.12 mbar Xe in attenuator, no transmission filters
- λ=13.4nm, single bunch with ~50µJ
- Average of 20 frames measured (integrated on chip)

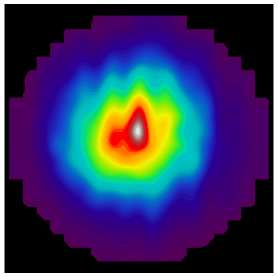
Before adjustment
Rotation: 15000steps ~ 214.3µrad,
Yaw: -60µrad



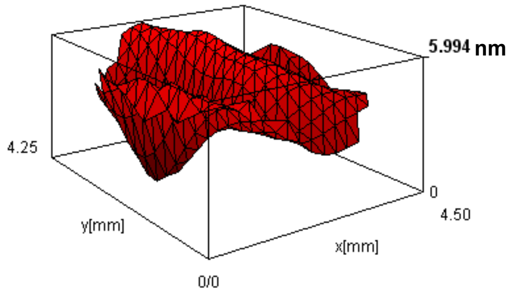


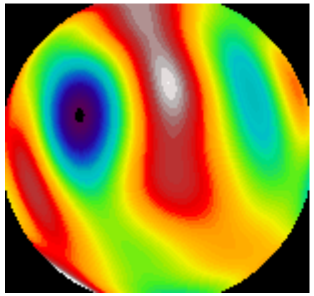
w_{PV}=32nm
w_{rms}=3.9nm ~ λ/3

Astigmatism Y²-X²: -15.760nm
Astigmatism XY : -2.868nm



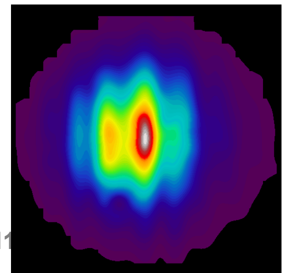
After adjustment
Rotation: 3000steps ~ 42.8µrad,
Yaw: -90µrad





w_{PV}=6nm
w_{rms}=1.5nm ~ λ/9

Astigmatism Y²-X² : 0.658nm
Astigmatism XY : 0.265nm

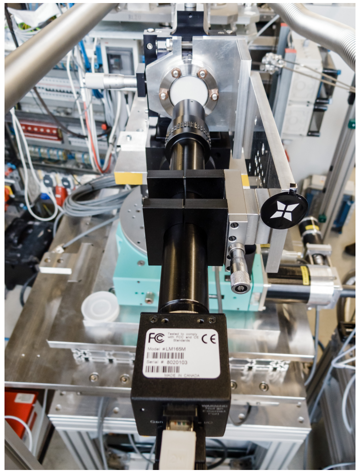


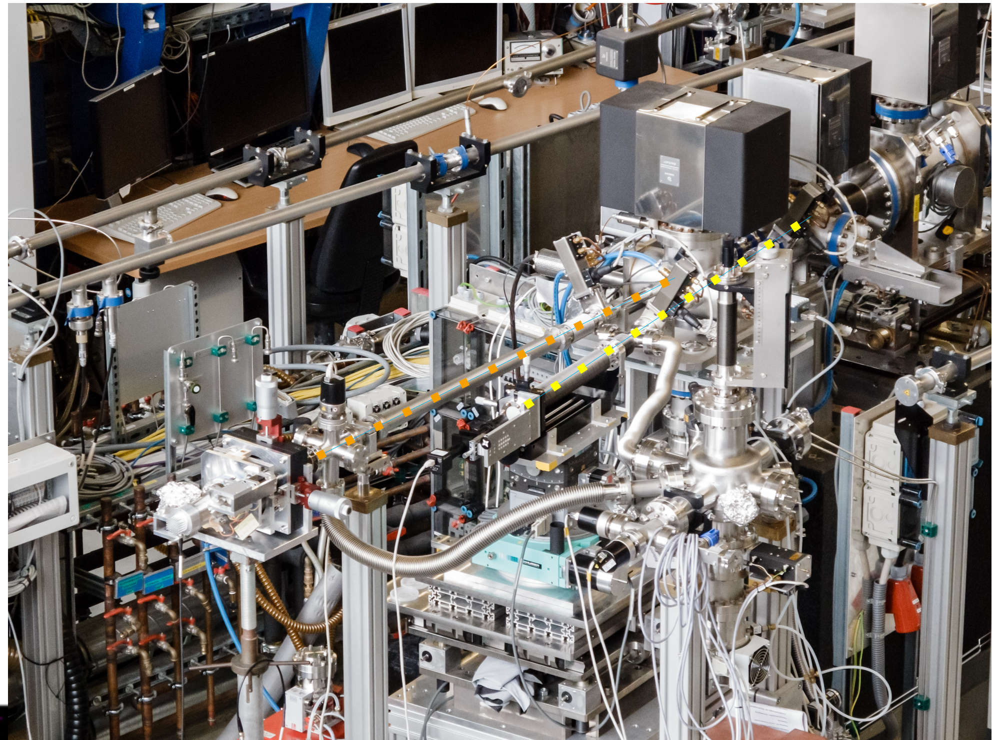
Summary.

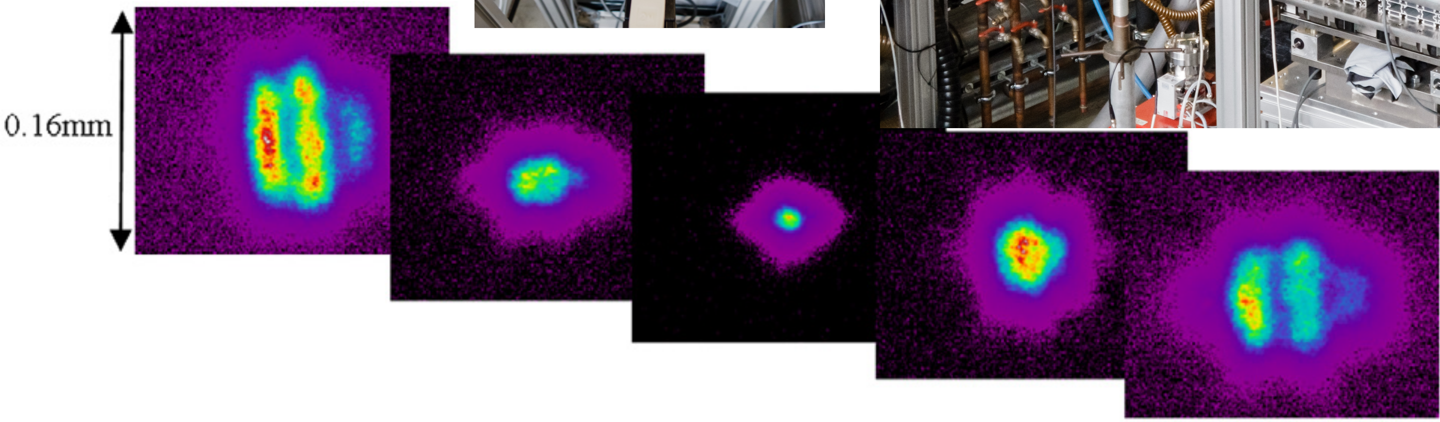
- The compact Hartmann sensor proved to be a valuable diagnostic tool during at FLASH.
- Online diagnostic (wave front, aberration, focus position,…) for single pulses is possible.
- A high sensitivity and resolution of the Hartmann sensor is required for the high beam quality of the FEL.

Perspectives.

- Quantitative determination of the Wigner distribution function.







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Acknowledgements

to the FLASH team!

The work was partially supported by IRUVX-PP, the preparatory phase of the EuroFEL consortium under grant agreement no. 211285.
Support of the FLASH user facility, in particular the funding of wavefront sensors through the BMBF programme FSP301-FLASH is greatfully acknowledged.