Wave front sensors at FLASH.

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Intention

> 1. Beamline commissioning

- A first implementation as well as long-term observations of diagnostic tools and optics can be facilitated.
- Alignment of focussing mirrors
- Effects of filters and gas attenuator on FEL wave front

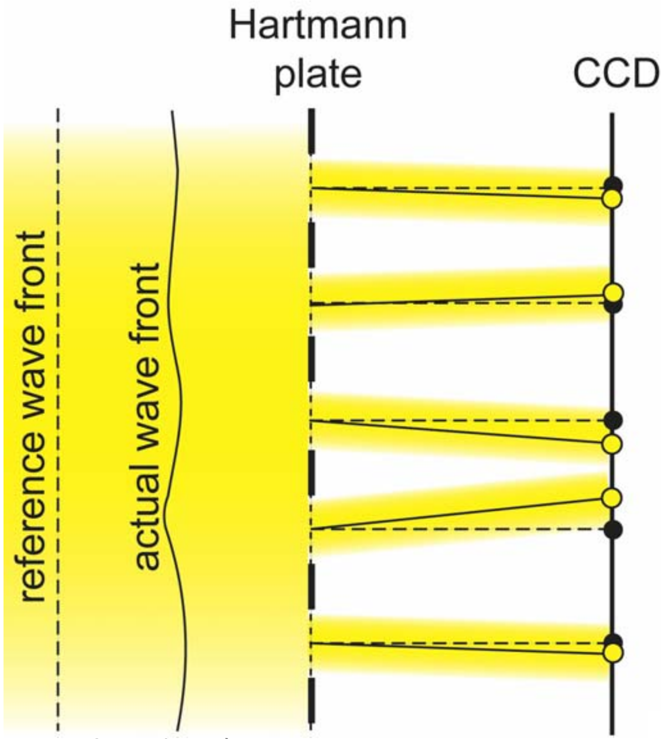
> 2. FEL characteristics

- 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

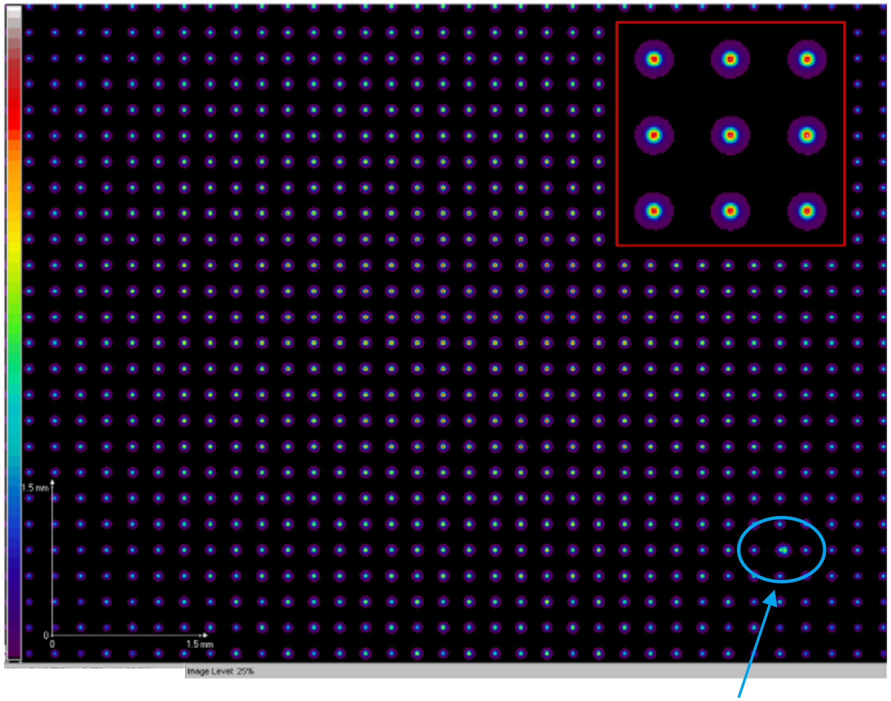
- Focus size and position can be determined online for single shots, if the main experiment is transparent for the FEL beam.

Wave front sensor principle

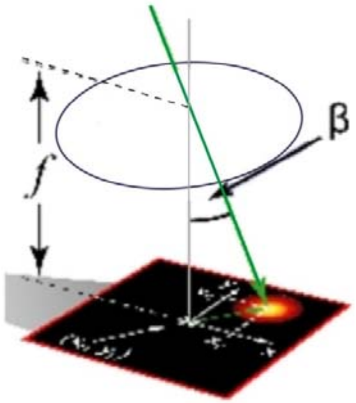


Courtesy of Pascal Mercère,SOLEIL

Reference spot pattern

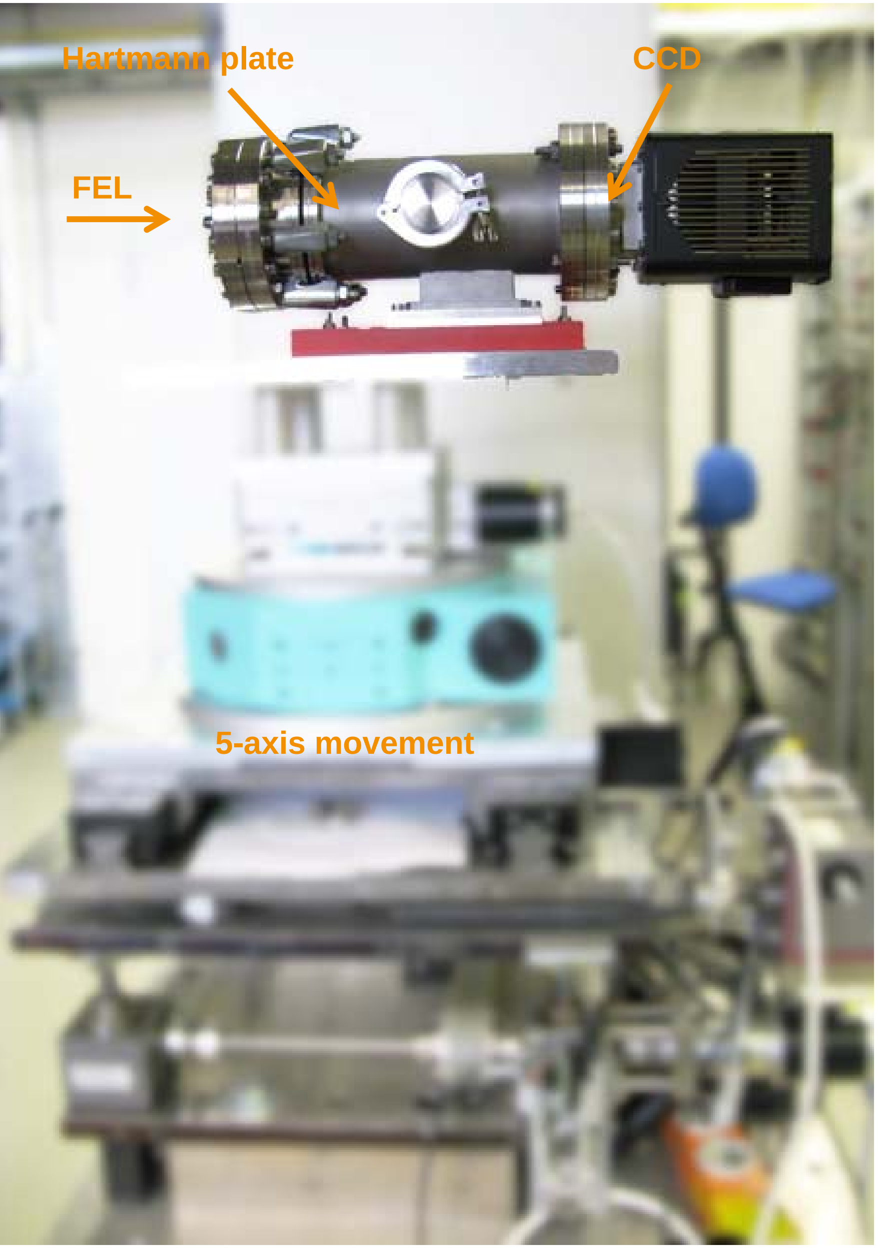


The actual beam is compared to a reference wave (perfect spherical wave)



Intensity and phase information of beam in single shot measurement:
- local intensity: amplitude of each spot
- local slope, WF phase: position of each spot

The wave front sensor

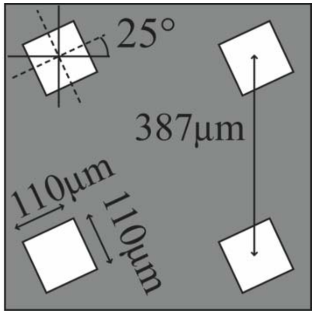


Wave front sensor: (10 – 40 nm)

Hartmann plate: ~ 80µm Ni plate
51 x 51 quadratic holes
tilted by 25° to prevent
interference of adjacent holes
CCD: field of view: 19.5mm x 19.5mm
1340 x 1300 pixel, 20µm pixel size
Plate – CCD Chip: 252mm

Repeatability (wave front rms): $\lambda_{13.4nm}/100$

Soft- and hardware by Imagine Optic (HASO 3.0)



Compact Hartmann sensor (first version)

Wave front sensor (6 – 30nm)

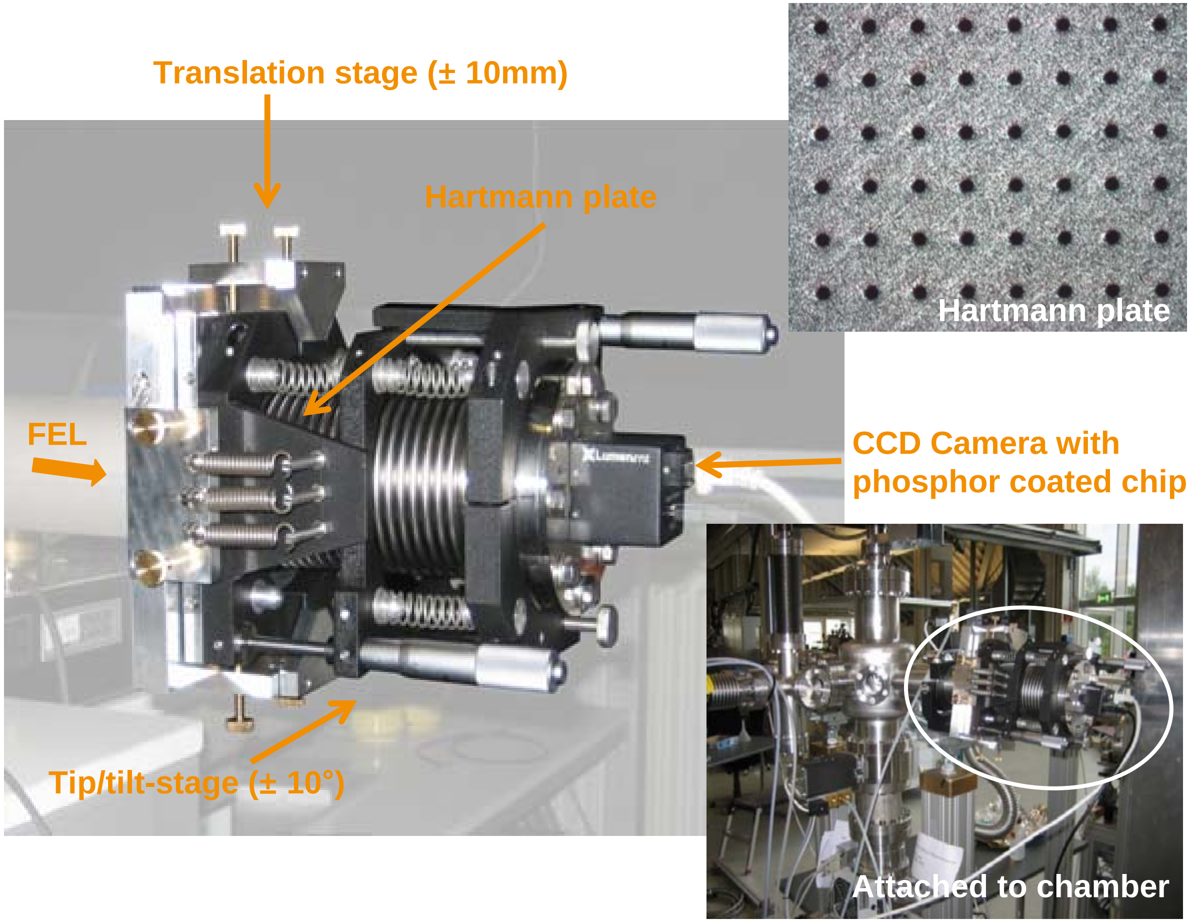
Hartmann plate:
-7µm tantalum foil with circular laser-drilled holes in a squared grid (pitch 320µm, diameter 65µm)
-20µm Ni foil with electroformed holes in a squared grid (pitch 250µm, diameter 75µm)

CCD (LM165 12bit):
field of view: 8.25mm x 6.6mm
1279 x 1023 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 (improved 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

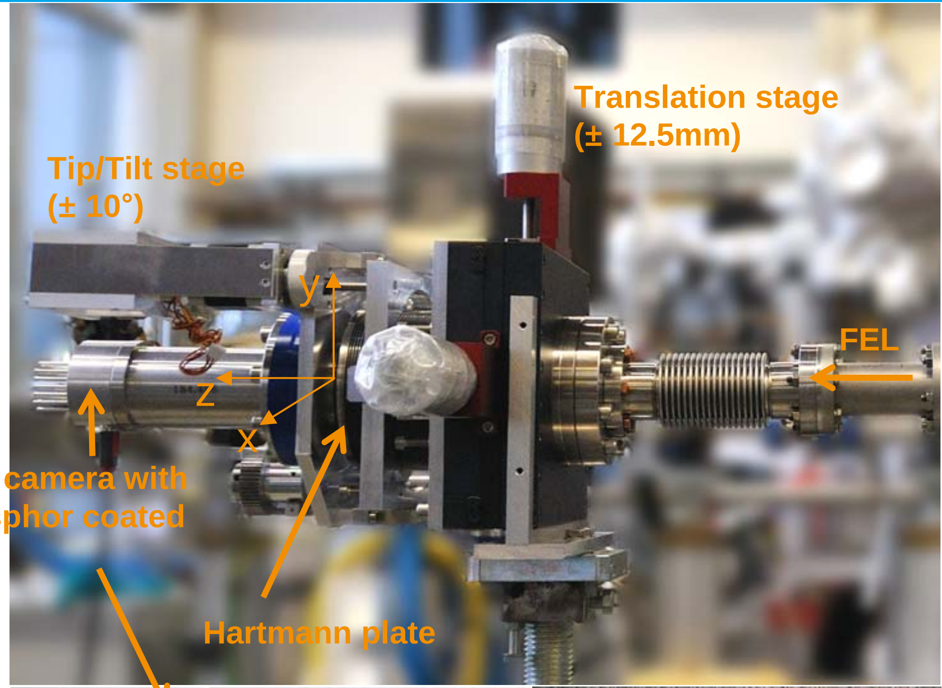
x/y and tip/tilt stages: motorized

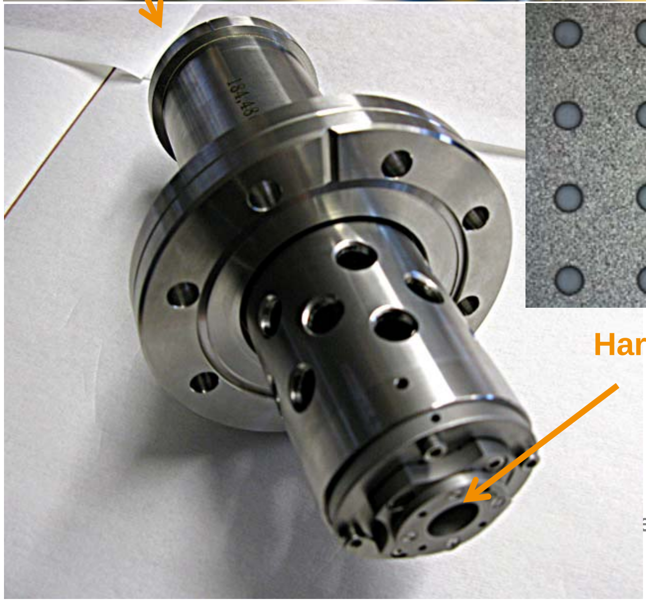
New design: higher machanical stability

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

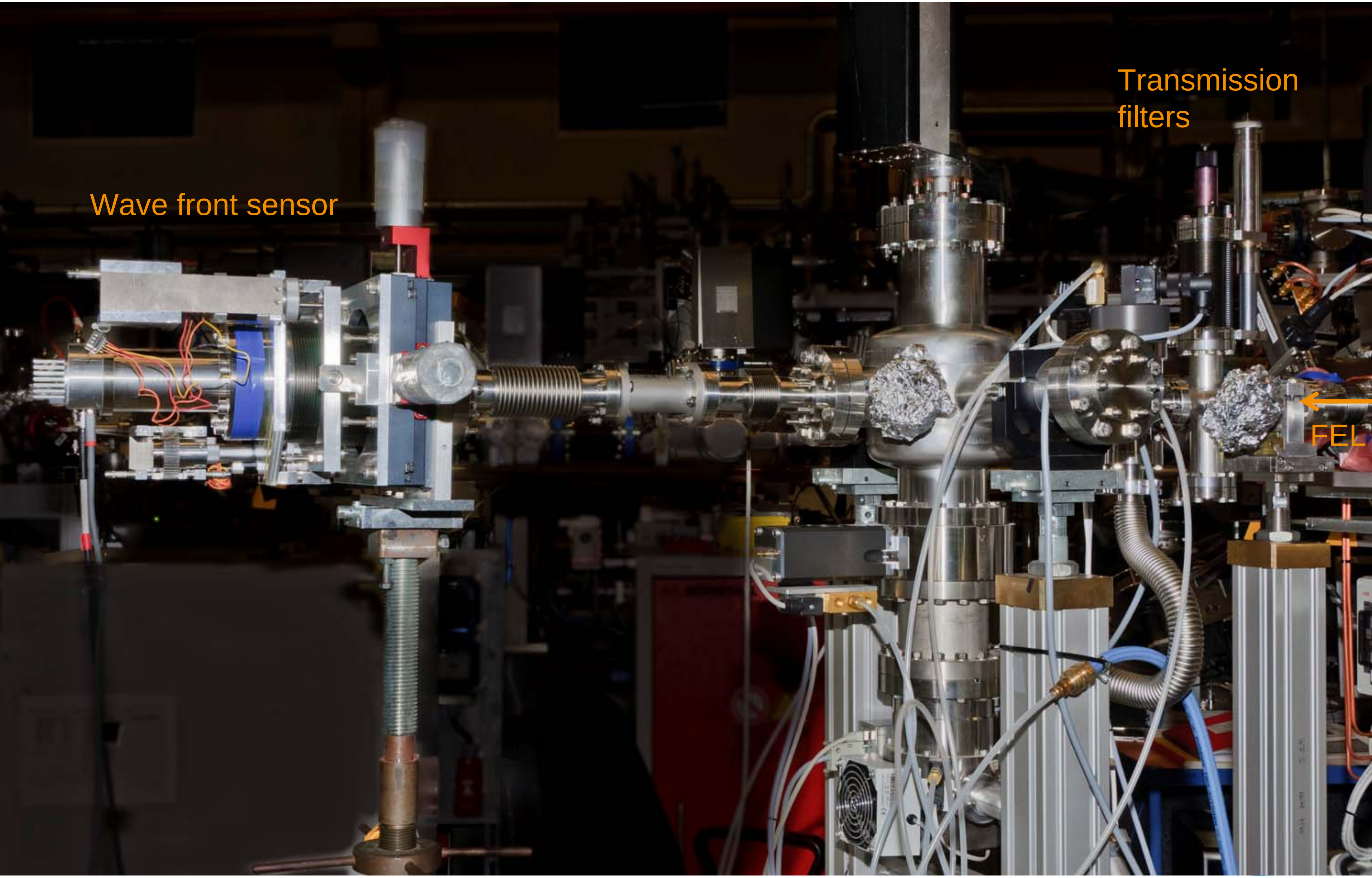
Software by LLG (MrBeam 3.5.2)

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





Setup at BL3

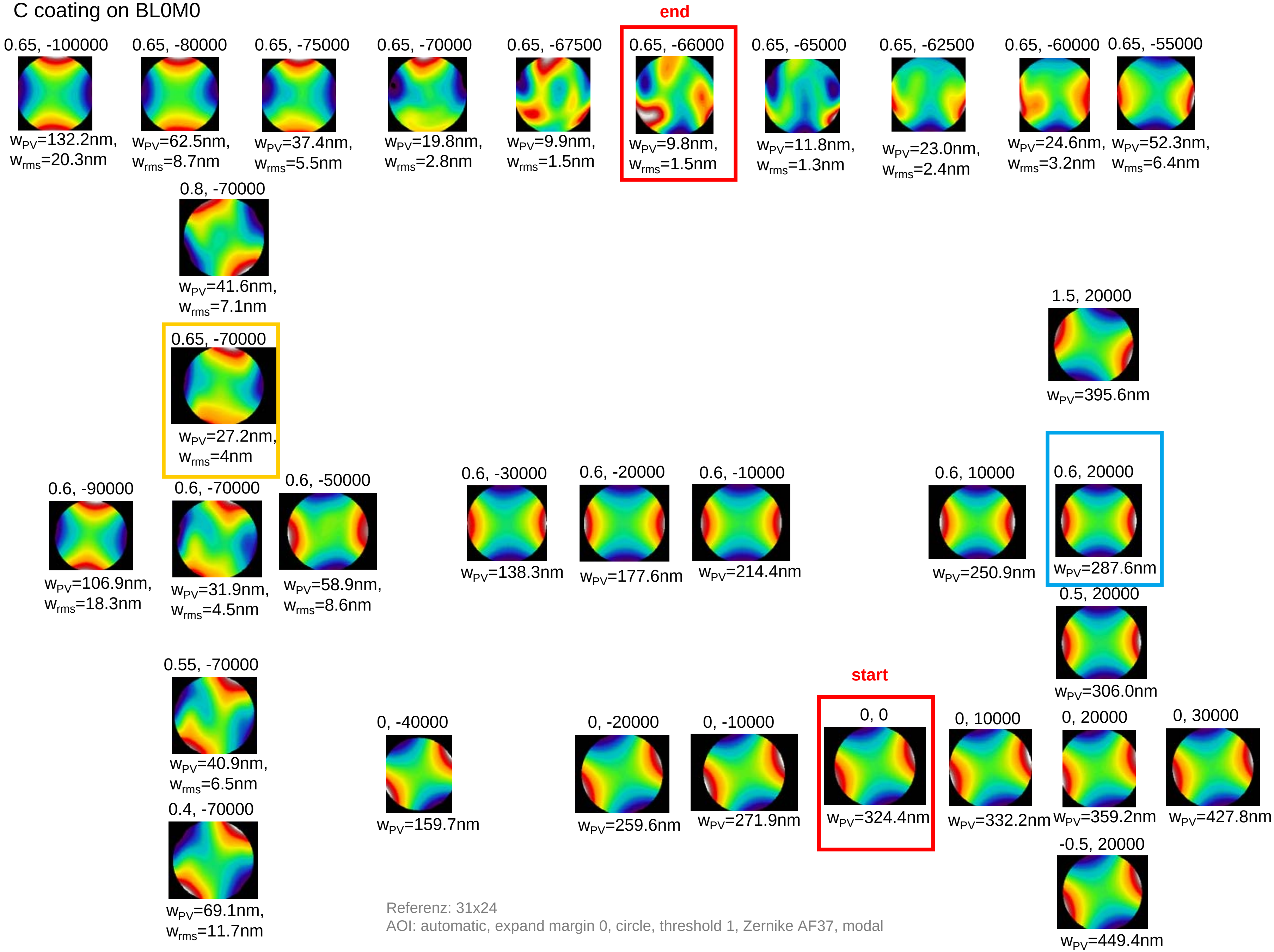


Settings

- 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

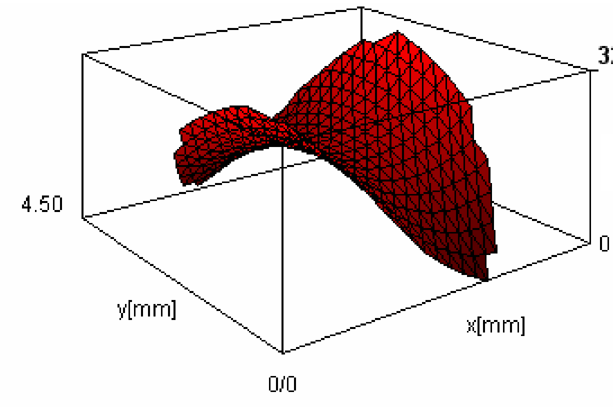
BL3M2 adjustment 29./30.1.11

C coating on BL0M0



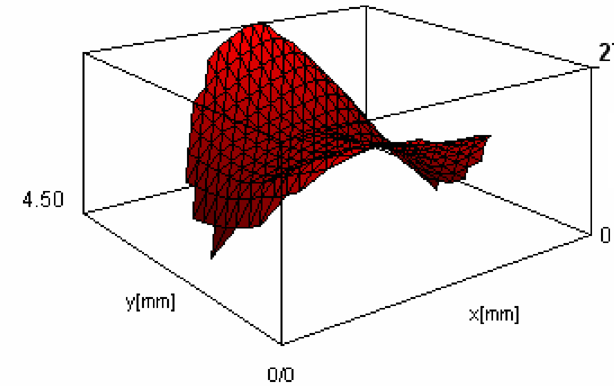
Starting conditions

During adjustment



w_{PV}: 324.431 nm

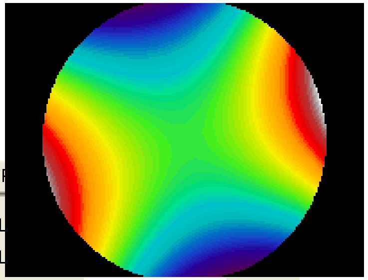
13.3nm
single bunch
2µJ

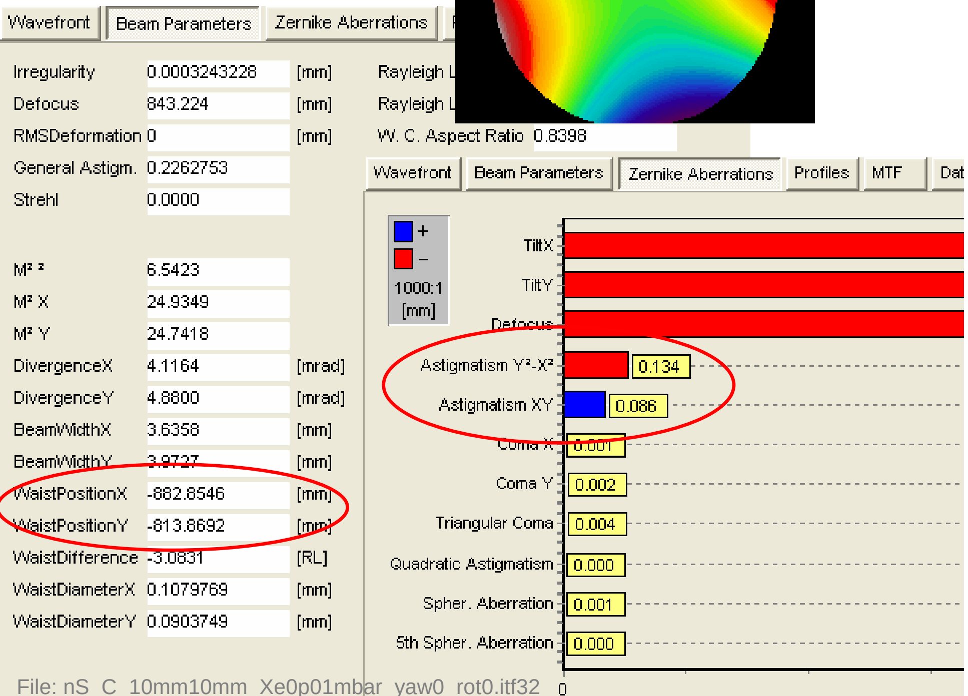


w_{PV}: 27.243 nm

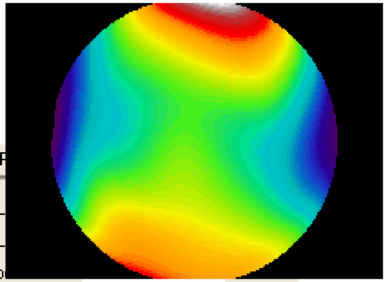
w_{rms}: 4nm @ 13nm → λ/3

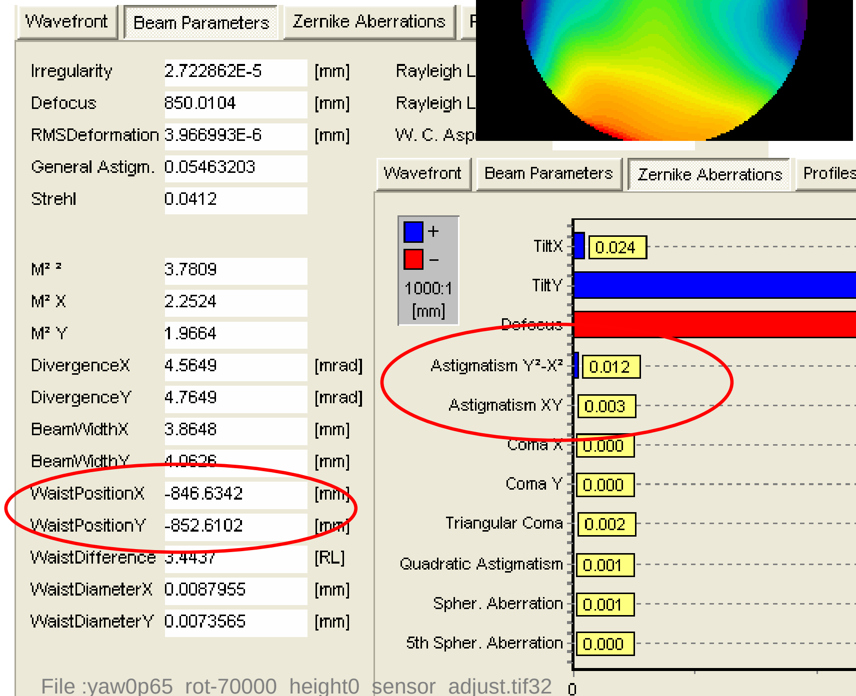
Rotation: 0 mrad
Yaw: 0 mrad





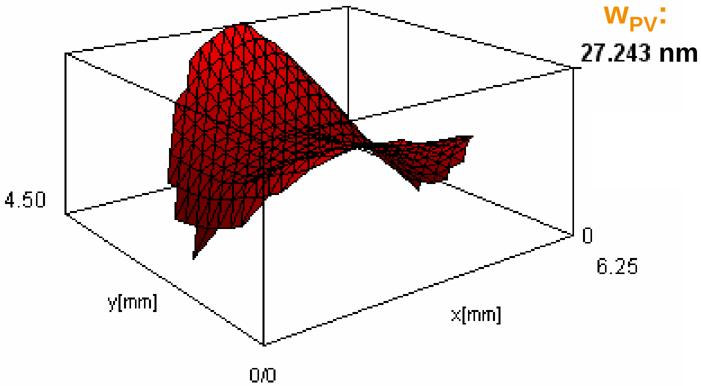
Rotation: -1mrad (-70000 steps)
Yaw: 0.65mrad





During adjustment

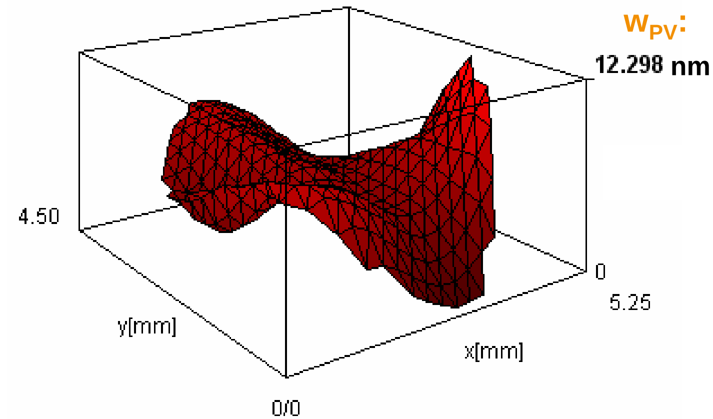
Final alignment



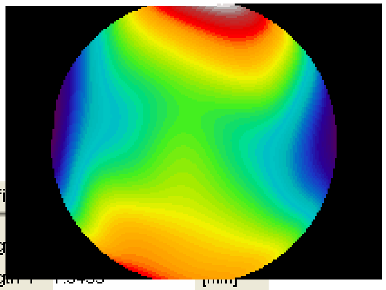
13.3nm
single bunch
2μJ

Focus position from valve flange: 528.7mm

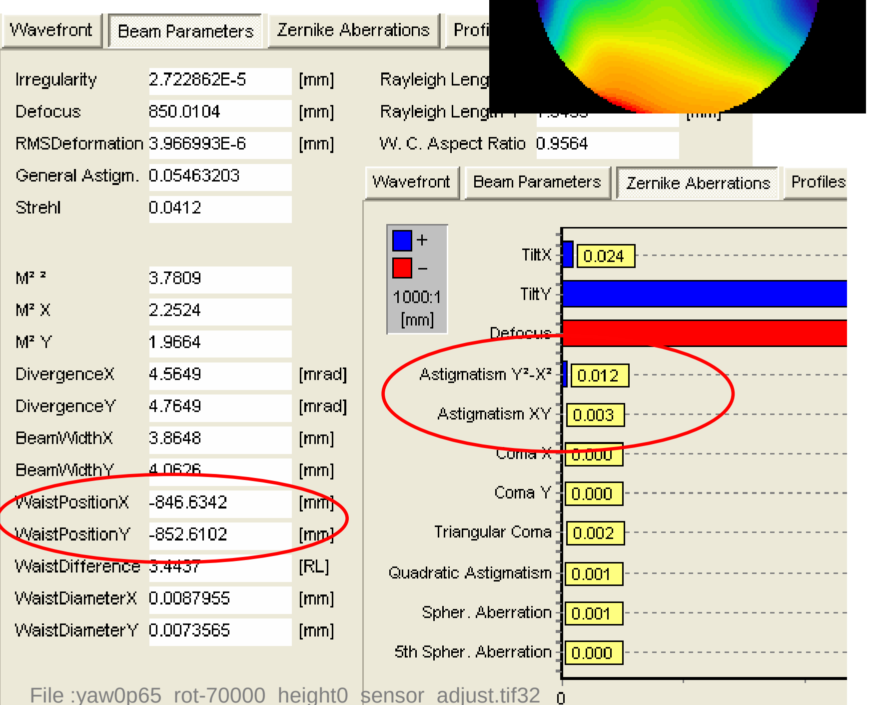
Focus size to be checked



rms: 4nm @ 13nm → λ/3

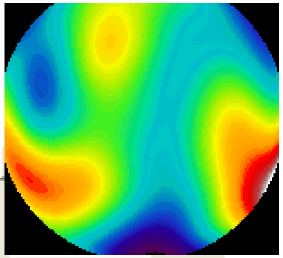


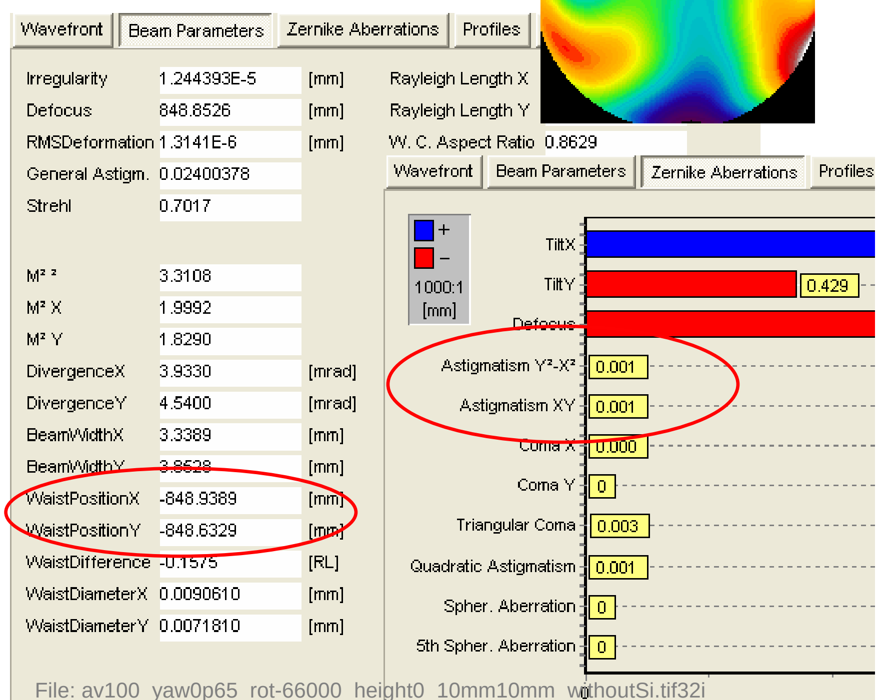
Rotation: -1mrad (-70000 steps)
Yaw: 0.65mrad



rms: 1.3nm @ 13nm → λ/10

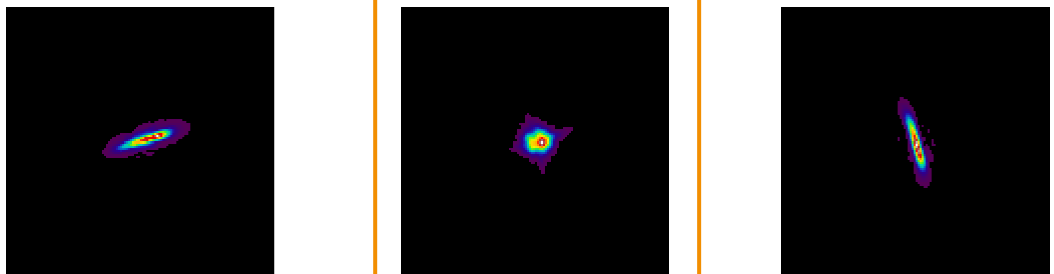
Rotation: -0.95mrad (-66000 steps)
Yaw: 0.65mrad





Simulated beam profiles

before alignment

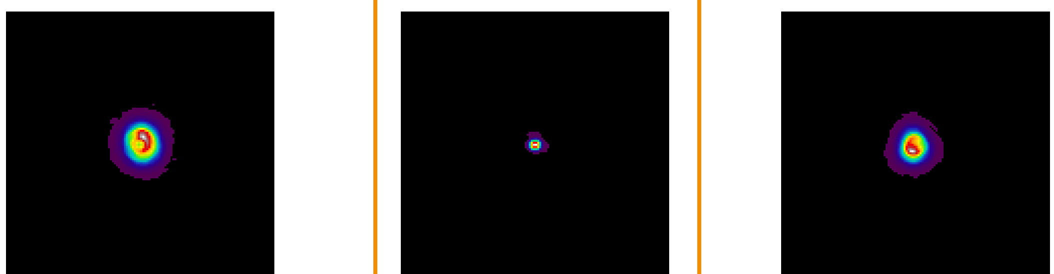


-50mm

focal plane

+50mm

after alignment



Numerical propagation via Kirchhoff-Fresnel integral

Conclusions

- The new compact Hartmann sensor proved to be a valuable diagnostic tool during the beamline commissioning 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.

Acknowledgements

Many thanks to:

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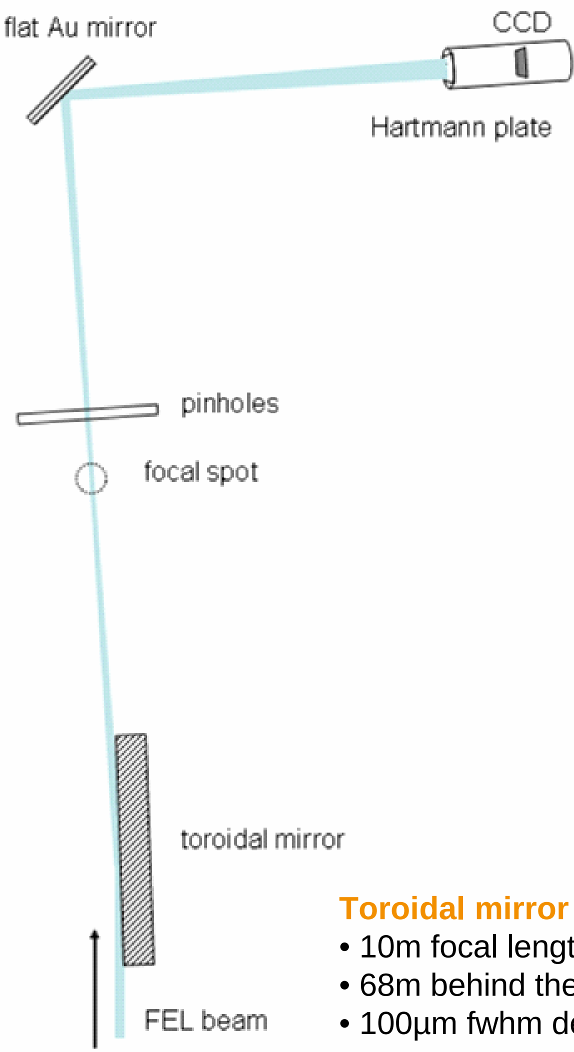
G. Brenner, P. Juranić, S. Kapitzki, H. Kühn, M. Markert, E. Plönjes-Palm, K. Tiedtke, Photon Diagnostic at FLASH

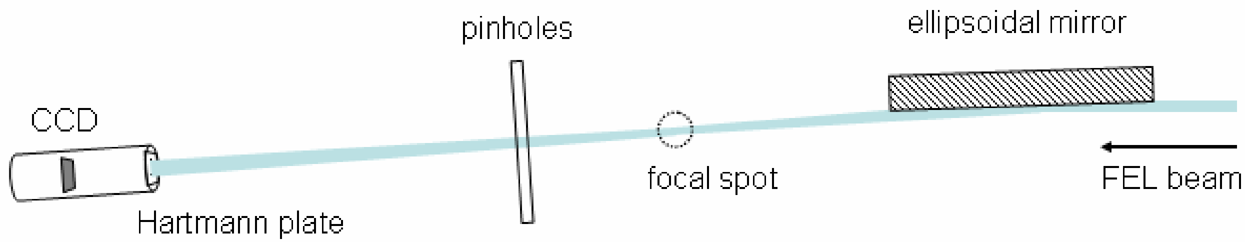
the whole FLASH team

Thank you.

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

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

L: distance plate-pinhole
d: diameter pinhole