FEL Wave-front and Intensity Measurements at the BL beamlines at FLASH

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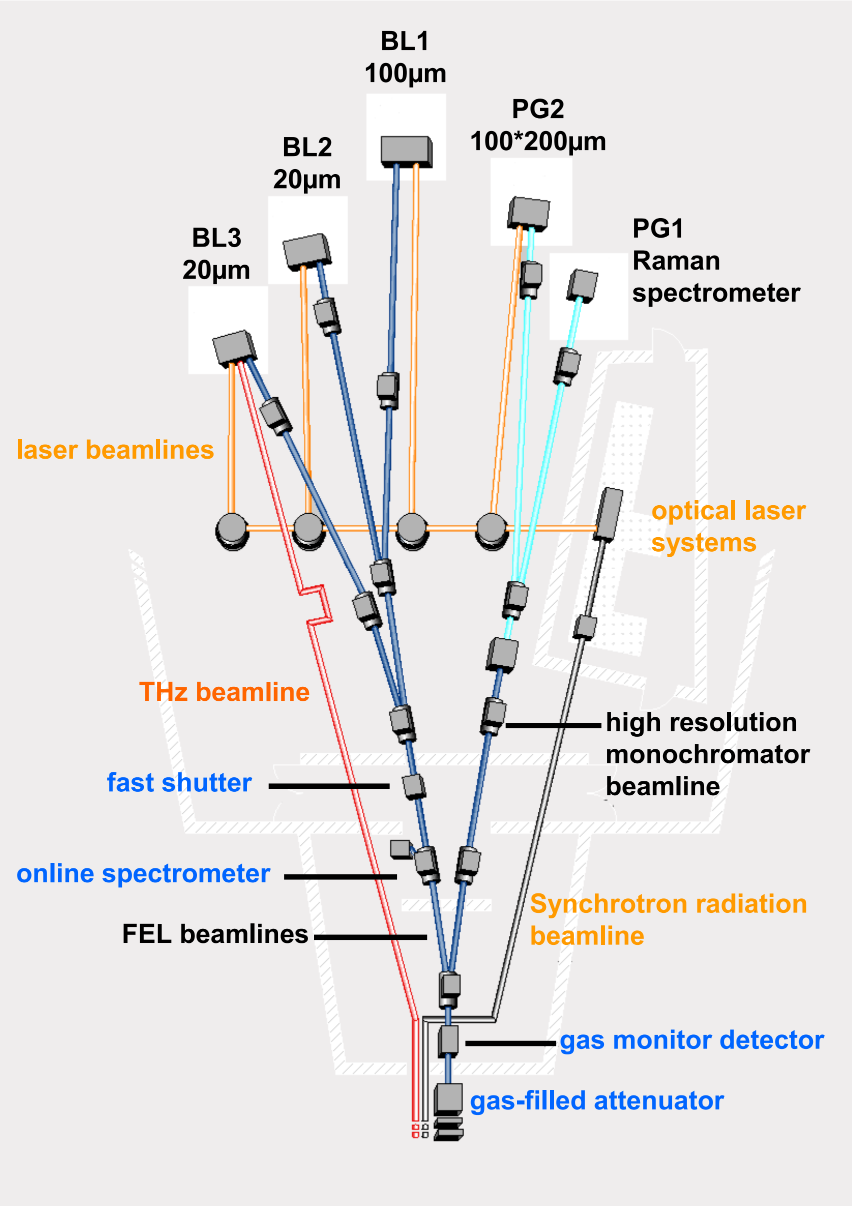
Outline

1. **Beamline commissioning**
   A first implementation as well as long-term observations of diagnostic tools and optics can be facilitated.
   - **Mirror alignment of BL1 and BL2**
   - **Effects of filters and gas attentuator on FEL wavefront**
   - **Future of WFS measurements.**

2. **Problematic beam intensity diffraction patterns observed at the beamlines, first noticed by PMMA measurements.**

3. **Possible sources of the interference pattern problem.**

Experimental hall Flash conditions



VUV and soft x-ray regime
- 50 nm -6.5 nm
- spectral shot to shot fluctuations
- higher harmonics up to the 7th
- particle-free UHV

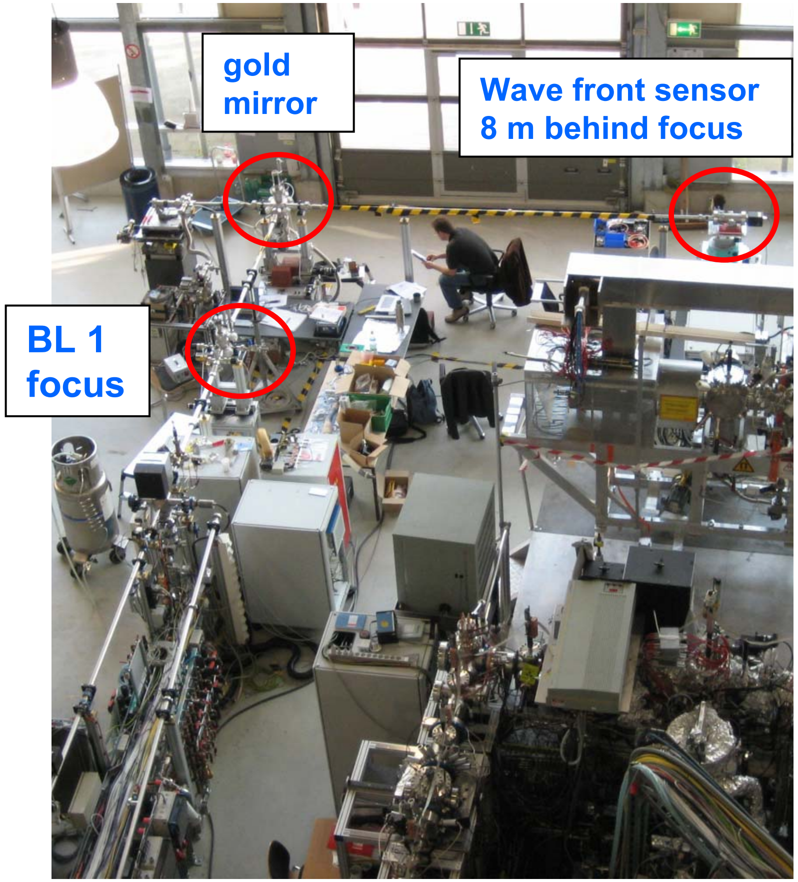
High intensity levels
- ~10 - 50 µJ
- intensity fluctuations of two orders of magnitude

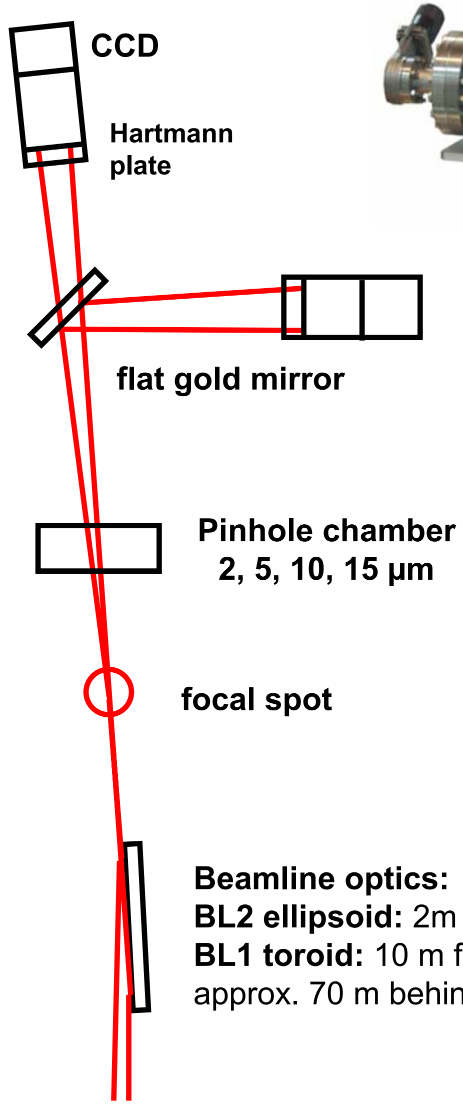
Pulse durations of 10 - 50 fs

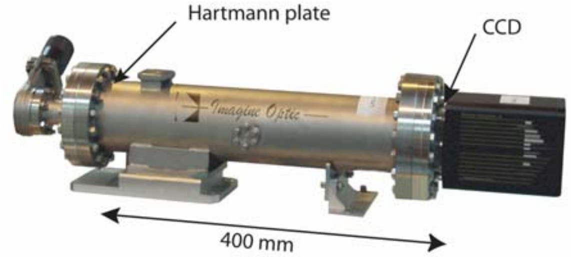
Variable time structures
- 2 or 5Hz bunch train repetition
- 1- 300 bunches in train
- 1-800 bunches with 10Hz in the near future

Wavefront sensor setup at FLASH beamline

Beamline BL 1

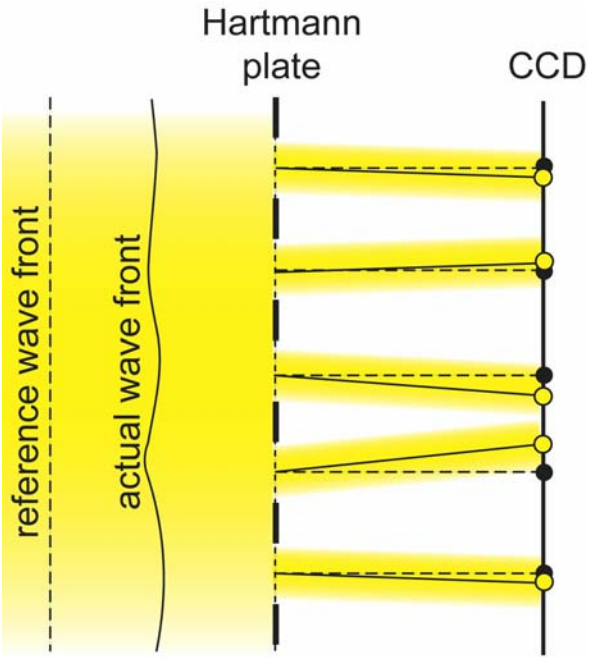




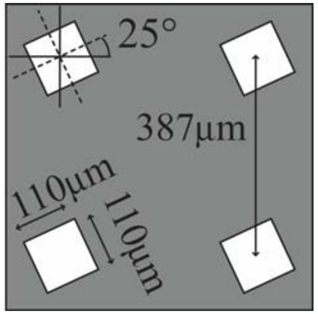


Beamline optics:
BL2 ellipsoid: 2m focal length
BL1 toroid: 10 m focal length
approx. 70 m behind FEL source

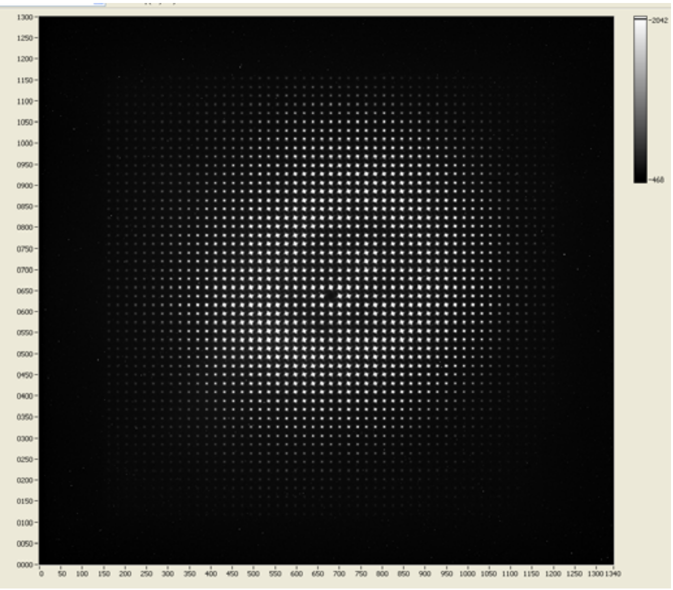
The Hartmann sensor principle



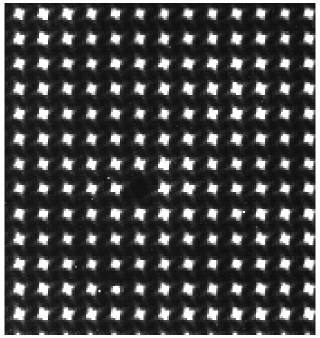
Wave front sensor
soft- and hardware by Imagine Optic
CCD: field of view = 19.5 x 19.5 mm
1340 x 1300 pixels
Hartmann plate: 51 x 51 quadratic holes tilted by 25° to prevent interference of adjacent holes



camera image



camera image zoom

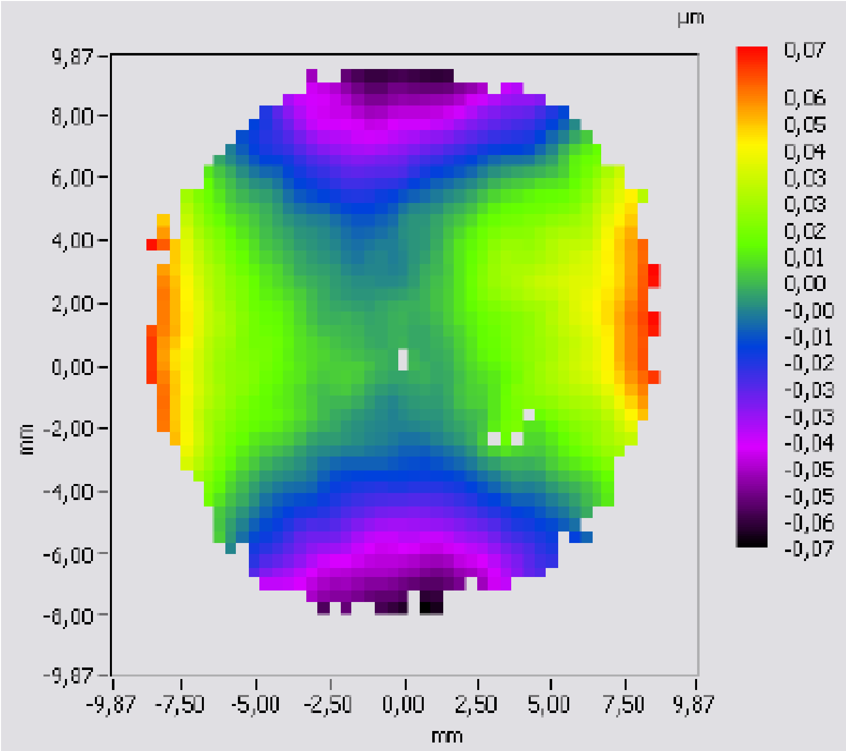


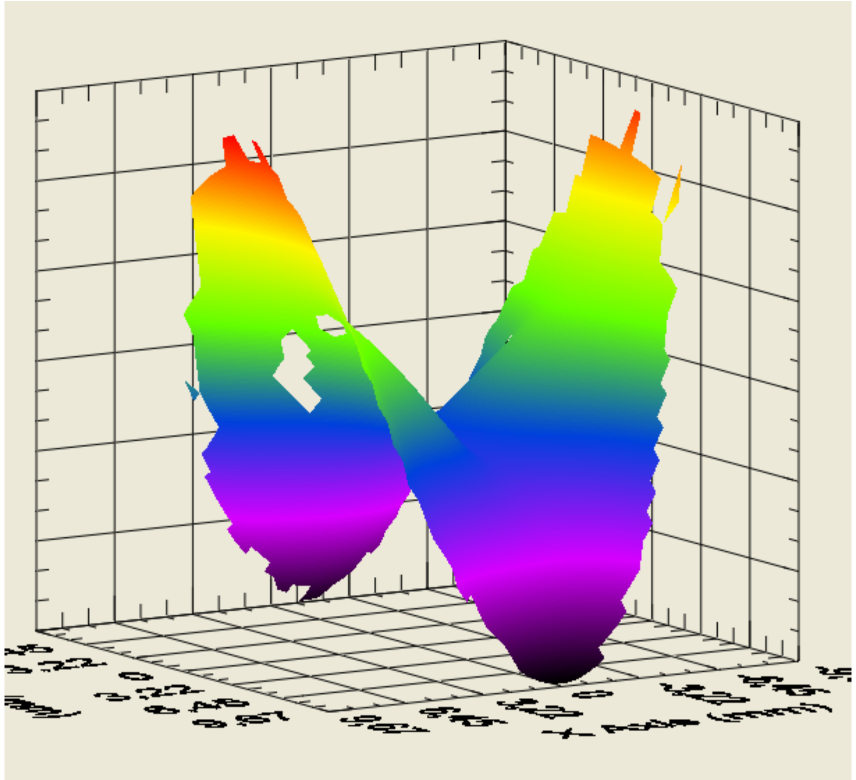
The actual beam is compared to a perfect spherical wave

Courtesy Pascal Mercère, SOLEIL

Typical misaligned wavefront

Beamline BL2 before alignment





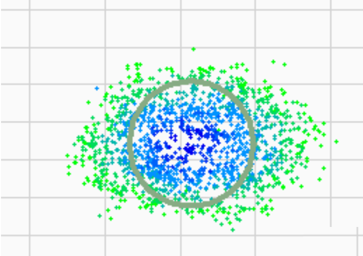
Rotation: 0 Yaw: 0

PV: 110 nm rms: 22 nm@ 27 nm → λ/1

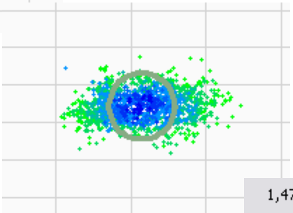
Radius (2σ) : 42.3µm

Ray tracing modeling for BL2:
FWHM: 20 µm → radius (2σ): 16µm

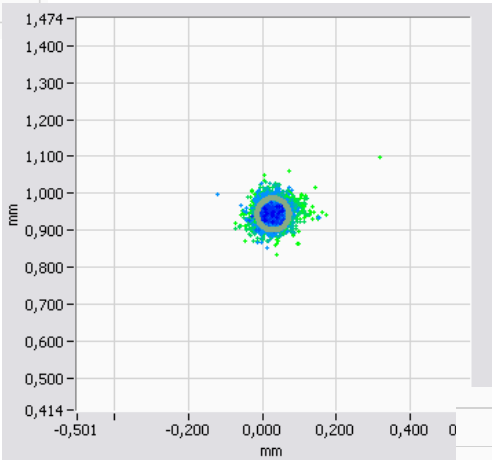
Before adjusting ellipsoidal mirror of BL2



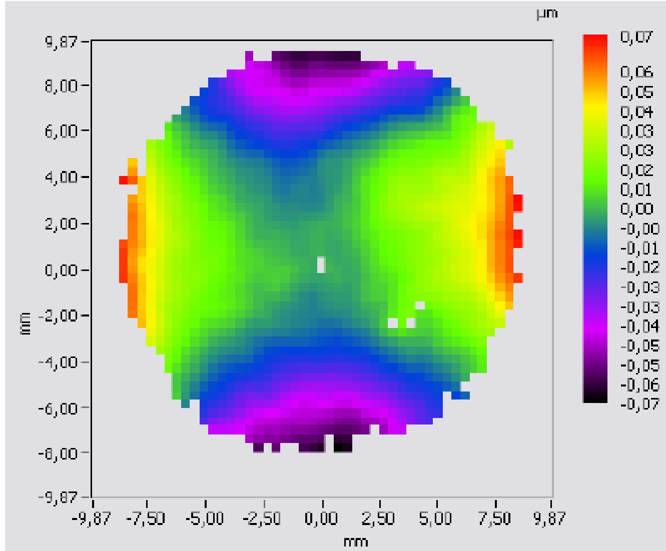
defocus 100mm
radius 164.9µm



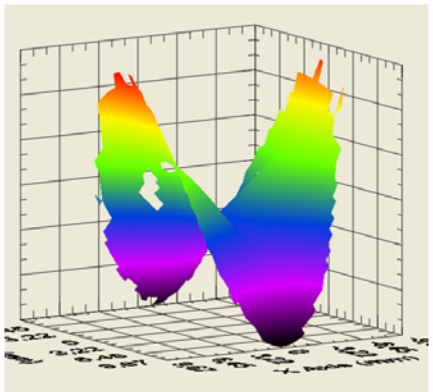
defocus 50mm
radius 87.8µm

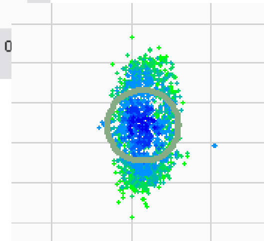


defocus 0mm
radius 42.3µm

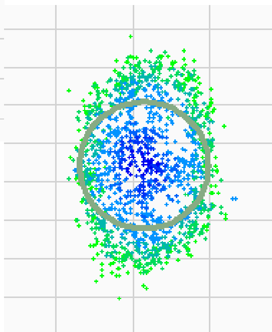


Rotation: 0 Yaw: 0
PV: 110nm rms: 22nm @ 27 nm
→ λ/1



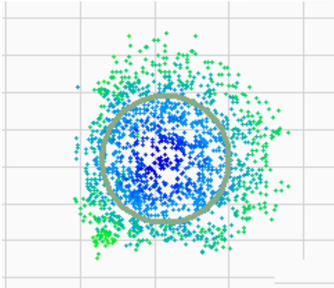


defocus -50mm
radius 88.9µm

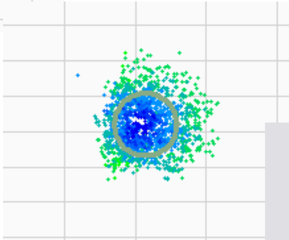


defocus -100mm
radius 166.0µm

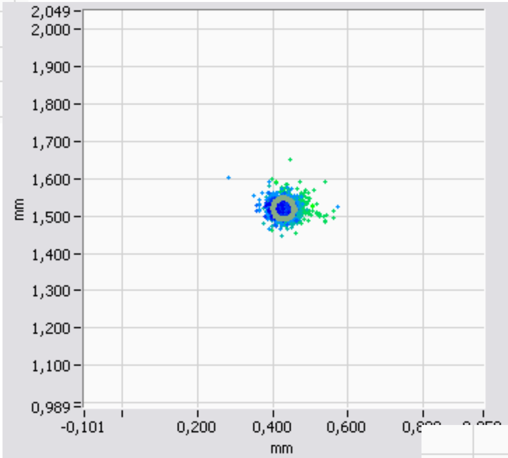
During adjustment of BL2



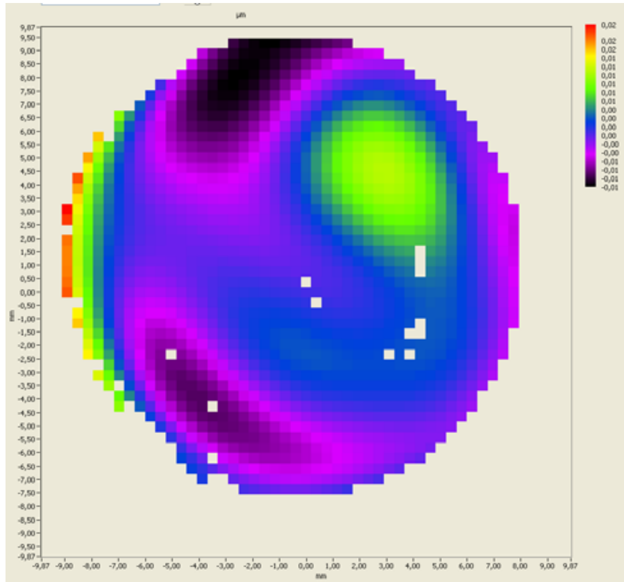
defocus 100mm
radius 170.7µm



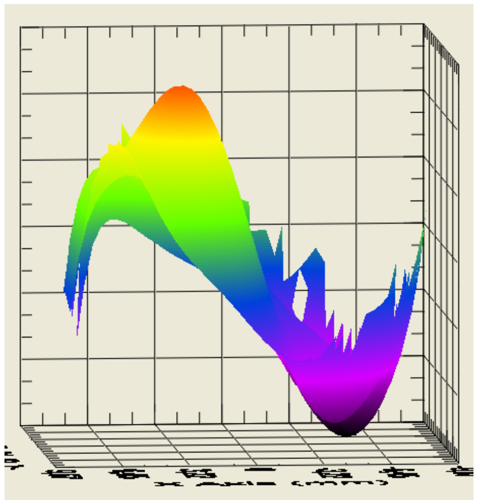
defocus 50mm
radius 88.1µm

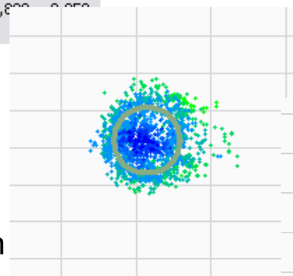


defocus 0mm
radius 27.7µm

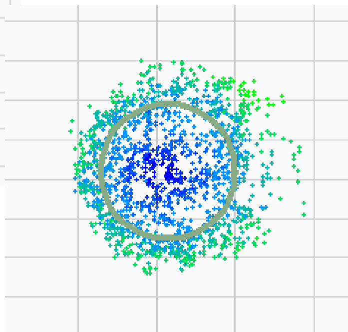


Rotation: 45000 (~1 mrad)
Yaw: 0
PV: 30nm rms: 5nm @ 27 nm
→ λ/5





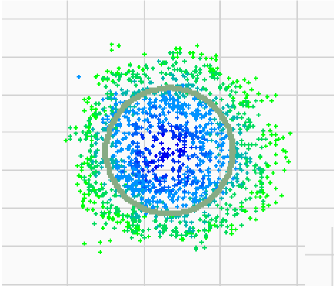
defocus -50mm
radius 88.3µm



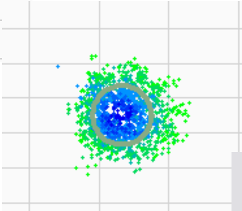
defocus -100mm
radius 170.9µm

File: 08081039.himg

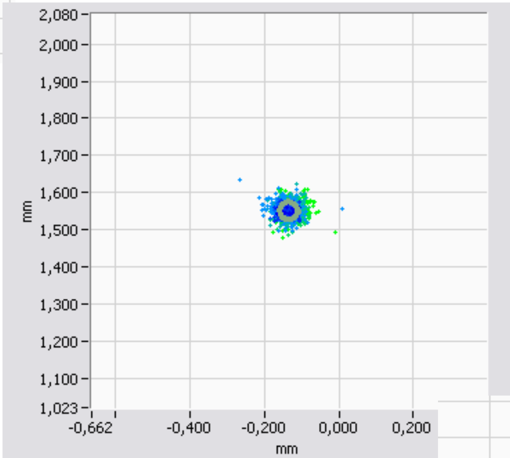
After adjustment of BL2



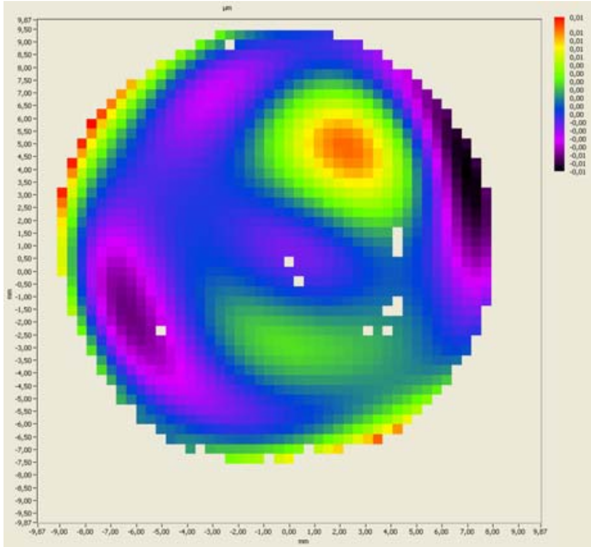
defocus 100mm
radius 165µm



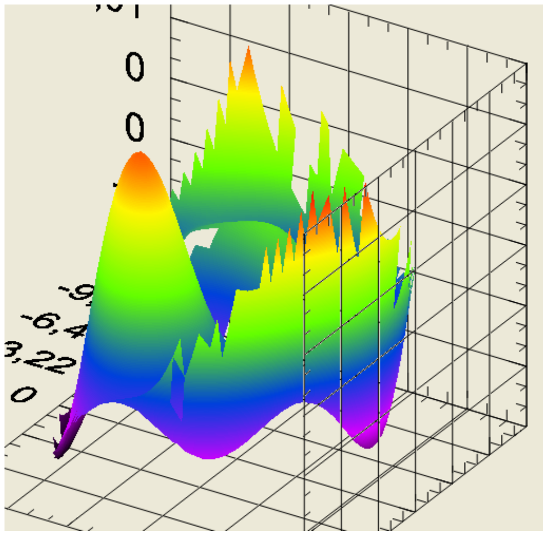
defocus 50mm
radius 84.1µm

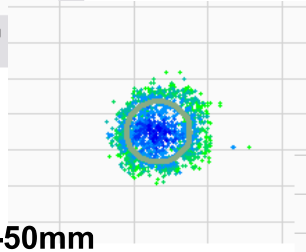


defocus 0mm
radius 24.1µm

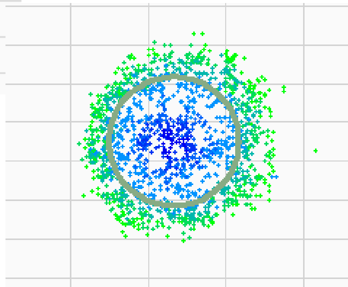


Rotation: 45000 Yaw: -0.01
PV: 18 nm rms: 3 nm @ 27 nm
→ λ/9



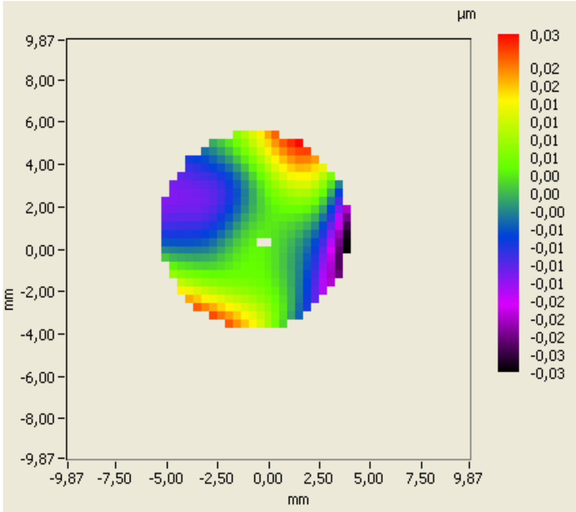


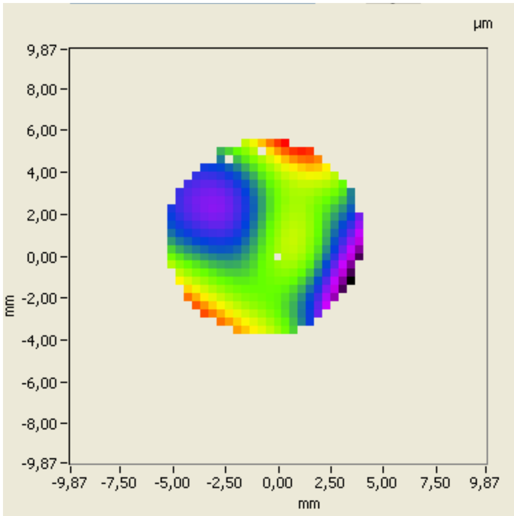
defocus -50mm
radius 85.2µm

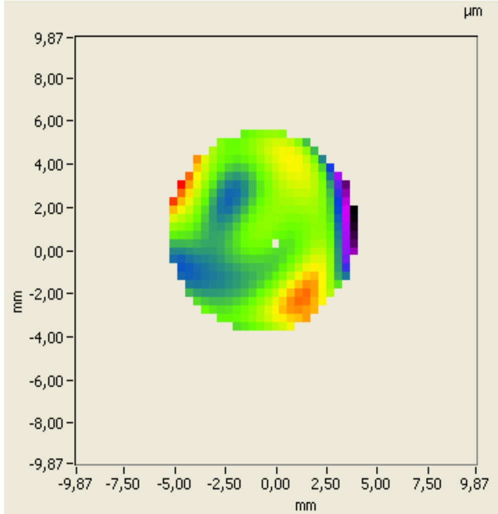


defocus -100mm
radius 166µm

Alignment of BL 1







Horizontal: 0
Rotation: 0 Yaw: 0
PV: 56 nm, rms: 10 nm @ 27 nm → λ/3

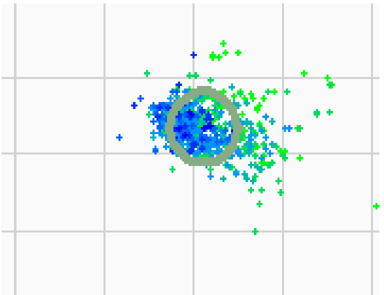
radius: 86.1µm
file 08042501.himg

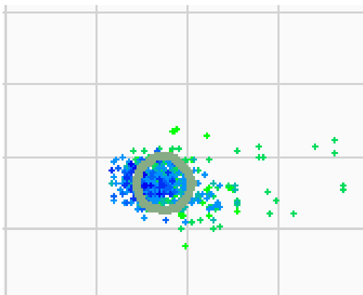
Horizontal: -1 mm
Rotation: 21000, Yaw: 0
PV: 39 nm, rms: 7 nm @ 27 nm → λ/4

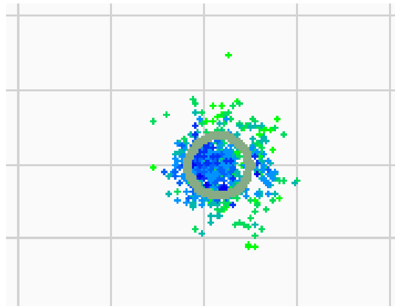
radius: 69.6µm
file 08042520.has

Horizontal: -1 mm
Rotation: 27000, Yaw: - 0.3
PV: 19 nm, rms: 3 nm @ 27 nm → λ/9

radius: 68.9µm
design value: 80µm
file 08042601.himg





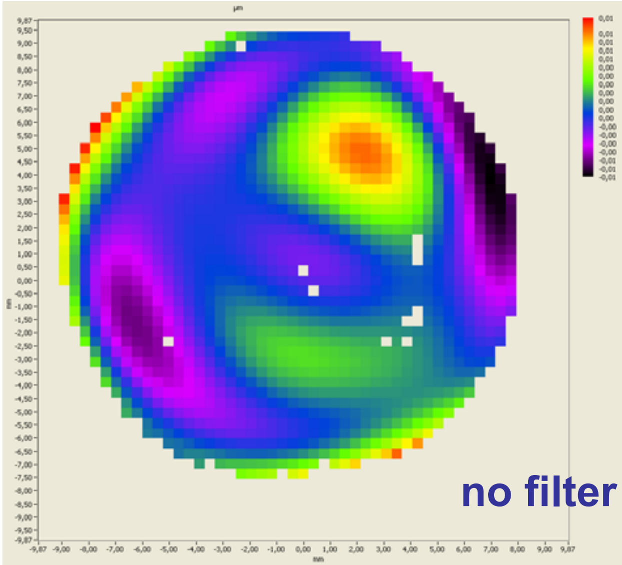


defocus -1 m

Filter and gas attenuator performance

FEL higher harmonics

- up to the 7th harmonic measured
- maximum intensity of second harmonic 1% of fundamental
- filters are required to either make use of these wavelengths or to eliminate any ill effects.



solid filters in BL2

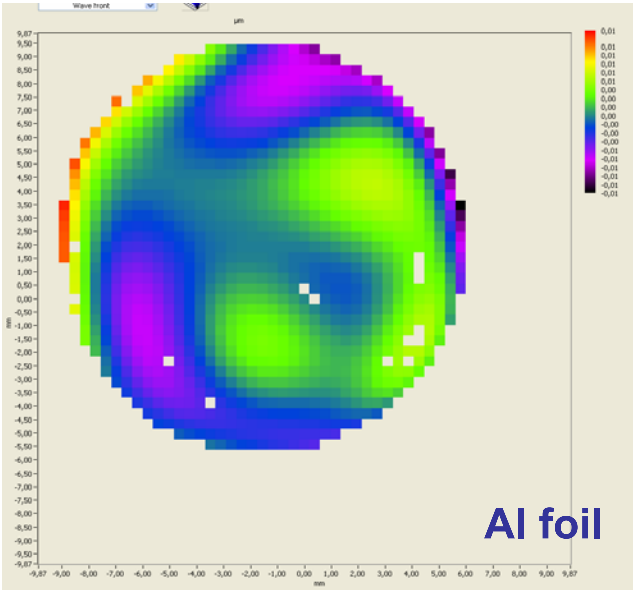
0.2 µm thick Nb foil

0.2 µm thick Si foil

0.1 µm thick Al foil

small wave front modifications @ 27 nm

shorter wavelength maybe worse

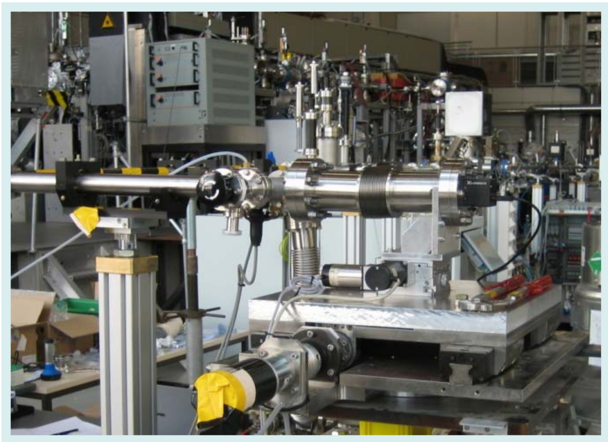


gas absorber

- N_2, Ne and Xe for various wavelengths
- at 27 nm an absorption of 94% by N_2

does <u>not</u> change the wave front significantly

Wavefront sensor of Laser Laboratorium Göttingen



Very compact design for use behind user experiments

- Laser drilled Hartmann plate
  - 7µm Al-Folie
  - YAG @ 1064nm, ~100mJ
  - 320µm hole pitch
  - Approx. 50µm hole diameter
- Camera:

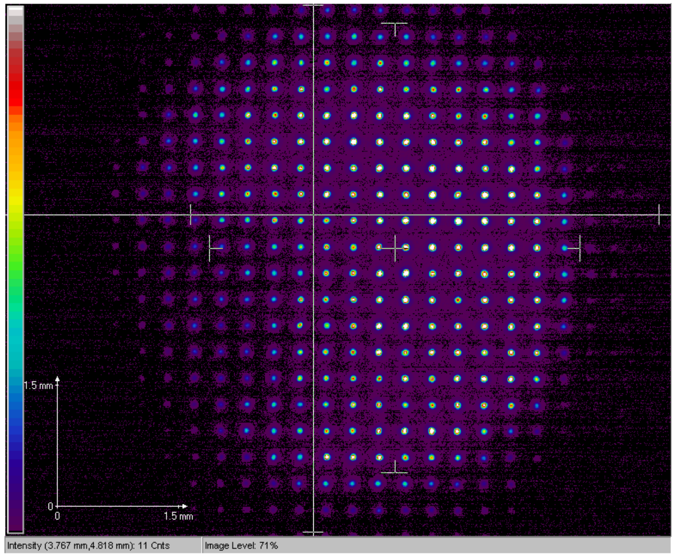
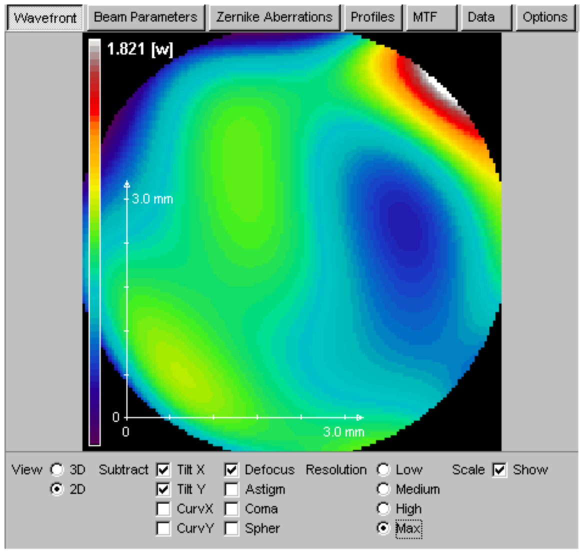
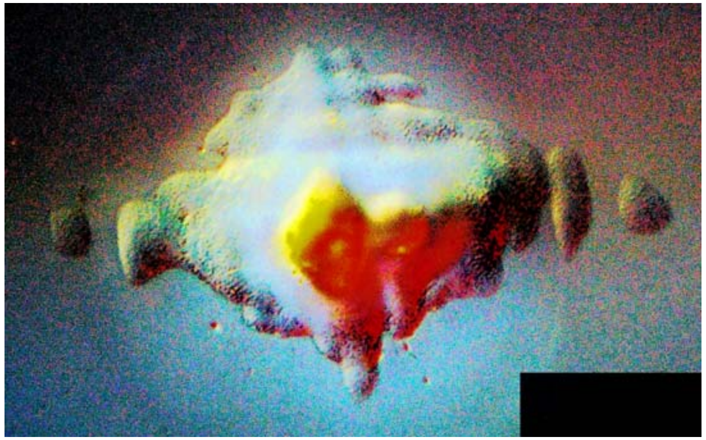


Image on camera

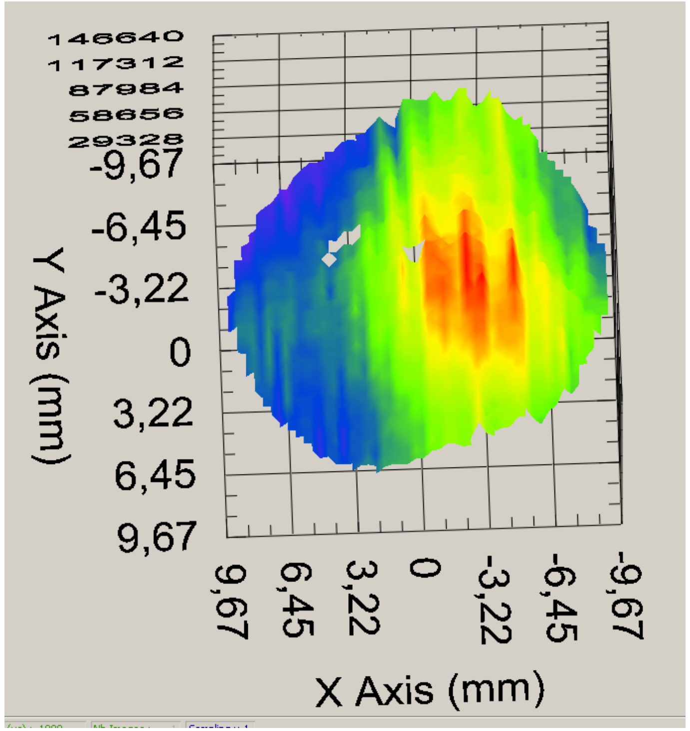


Calculated wavefront

The PMMA measurements detected the presence of interference patterns in the beam, which a closer examination of the intensity measurements taken by the WFS confirmed.

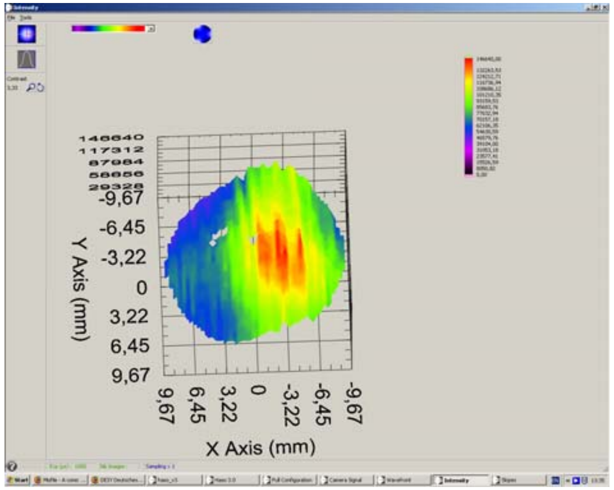


PMMA measurement

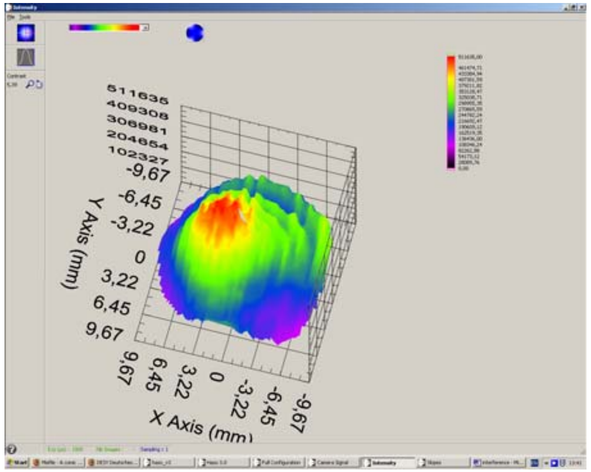


WFS intensity measurement

Interference more obvious with larger apertures

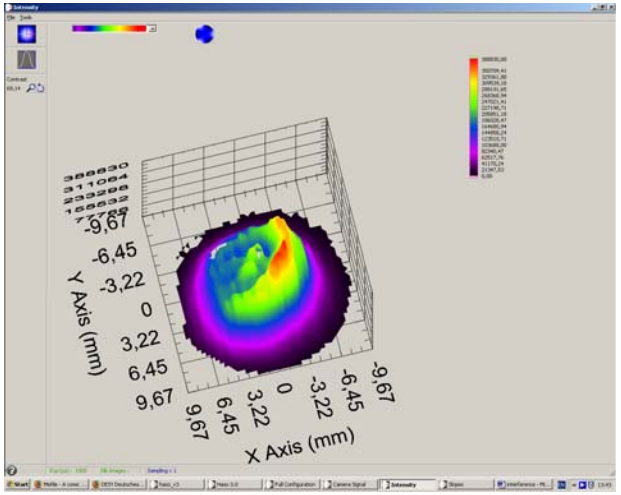


10 mm x 10 mm aparerture



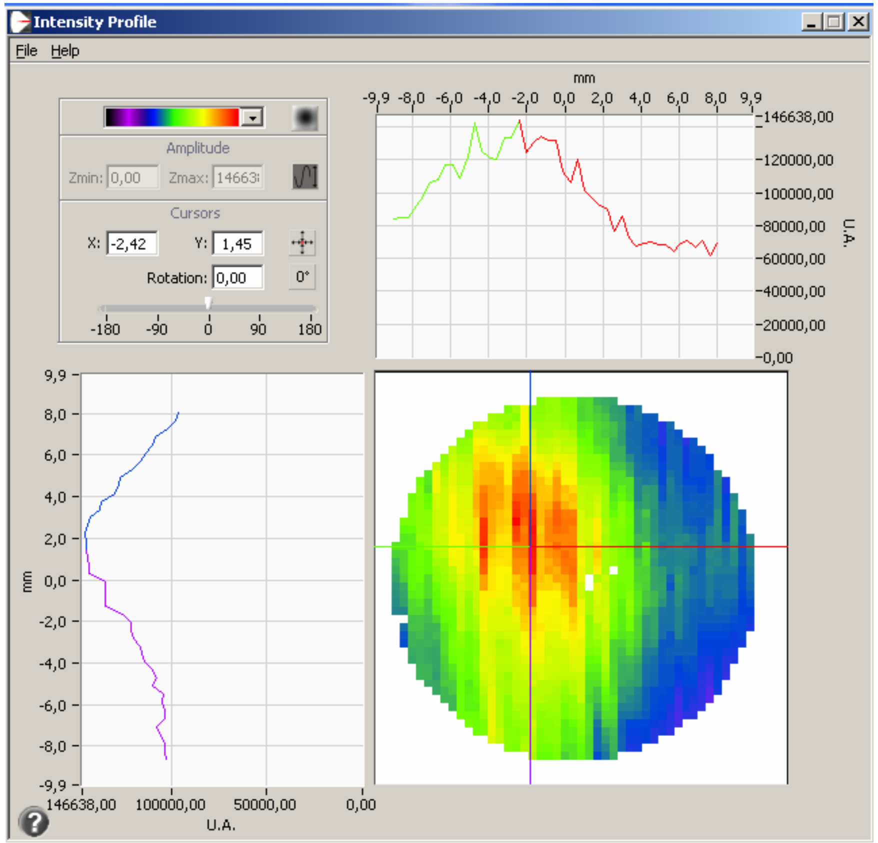
5 mm x 5 mm aparerture

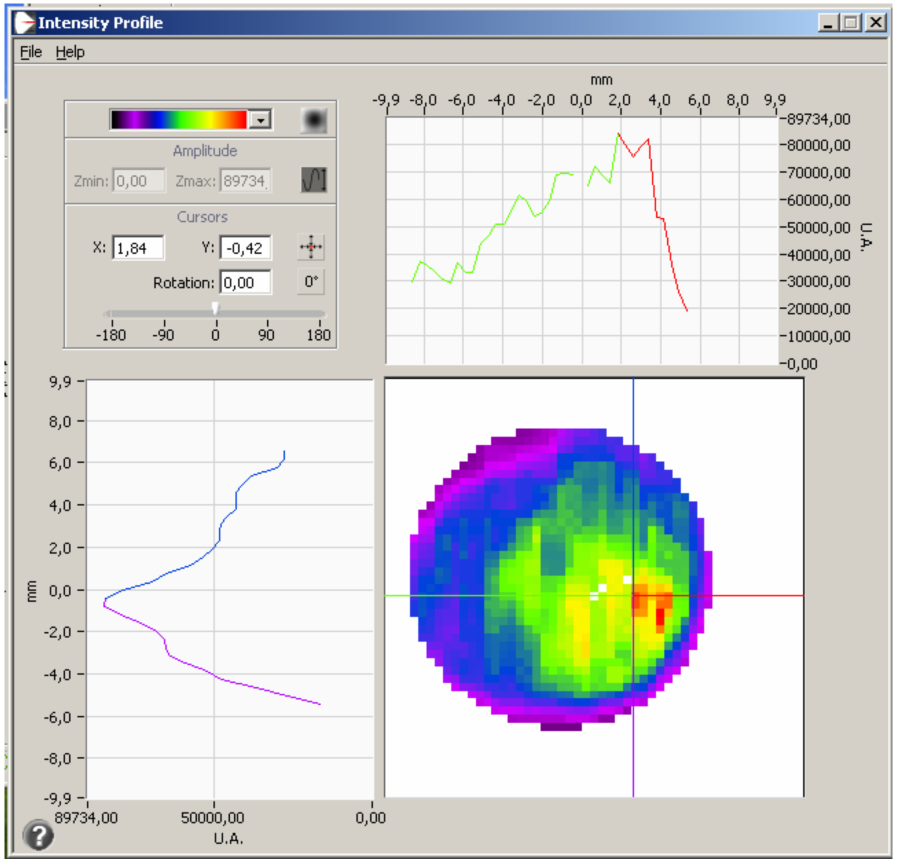
All taken at BL2, λ=26 nm



3 mm x 3 mm aparerture

Interference changes with wavelength





λ=26 nm gives about 2.1 mm distance between fringes

λ=13.5 nm gives about 1.1 mm distance between fringes

Interference on other beamlines?

•The micro-focusing experiment on BL3 also reported having seen interference patterns. Sven was in England last week, otherwise I would have asked him for some pictures of this claim.

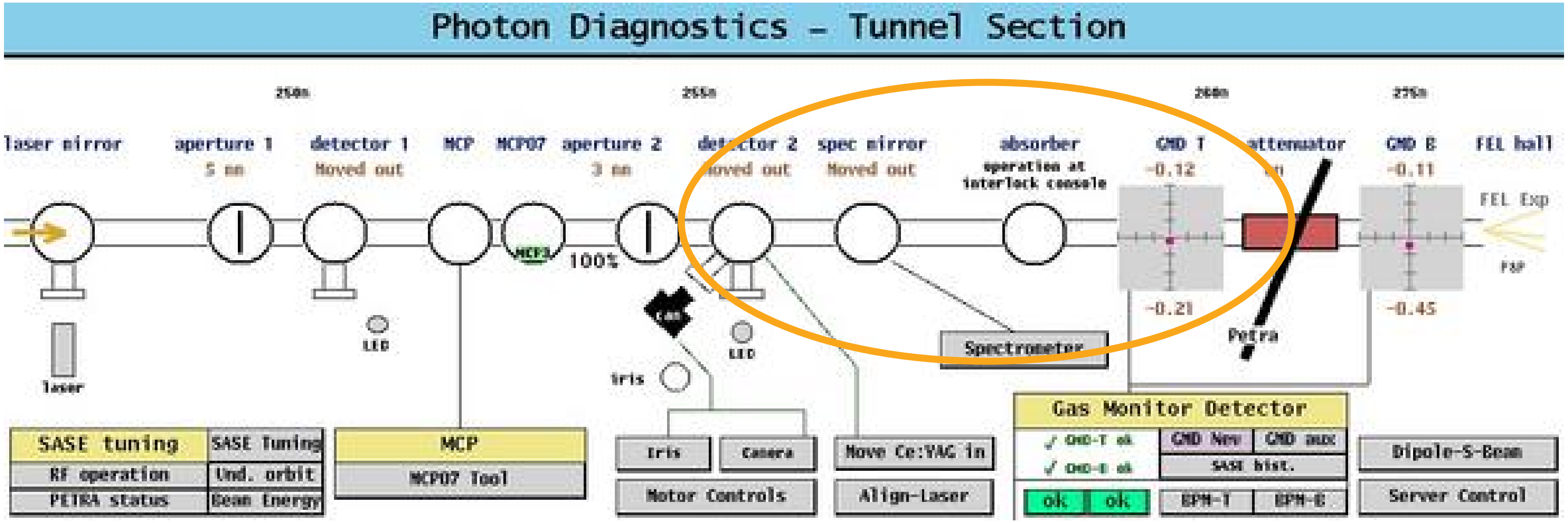
•The BL1 beamline, where we did WFS measurements only four months earlier, may show them as well. The intensity profiles from it are too poor to make out any interference.

•We assumed that the interference did not come from the last mirror at BL2, but from further upstream.

•The possibility of the light itself carrying these interference was discounted because they were very stable and seemed to always be in the same positions, or at least equally separated from shot-to-shot.

Possible source of problems

By inserting edges of mirrors and screens into the beam, we were able to find that the interference fringes of similar size to the ones we saw at 26 nm occurred in the vicinity of the spectrometer mirror. Maybe the BPM is to blame?



Actions taken

•The Beam Position Monitors (which weren't functioning anyway) were taken out. No obvious problem was noted with them, but they're still being looked at.

•We will need to take another series of intensity profile pictures of the beam with a ICCD camera to see if the problem has gone away with the BPM's.

•If the problem is still there, we will need to start taking out pieces of FLASH put in since the last upgrade one at a time until we find the problem. It's equivalent to doing exploratory surgery. We know there's a problem in the machine somewhere, but we're not sure on its exact location

•Any ideas on how to make this process less painful are welcome.

The FLASH Team

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FLASH experimental hall