A Fast Switching Mirror to precisely direct Photon Beams

Martin Sachwitz
A Fast Switching Mirror to precisely direct Photon Beams
3D Ionization Profile Monitor
Hamburg, 29th January 2015

HELMHOLTZ ASSOCIATION

DESY

Silicon Mirrors at FLASH I

- In the experimental hall, the laser beam can be directed towards five different test sites by massive silicon mirrors which are mounted into vacuum vessels.
- The movement of the vessels is carried out perpendicular to the beam by linear drives.
- the mirror itself is mounted into a vessel with an angle of three degrees to the incoming beam.
- With the vessel moved out of the beam the laser goes through it into the beam line straight ahead without being deflected, with the vessel moved into the beam it is deflected into the diverging beam line.

Idea of a Fast Switching Mirror

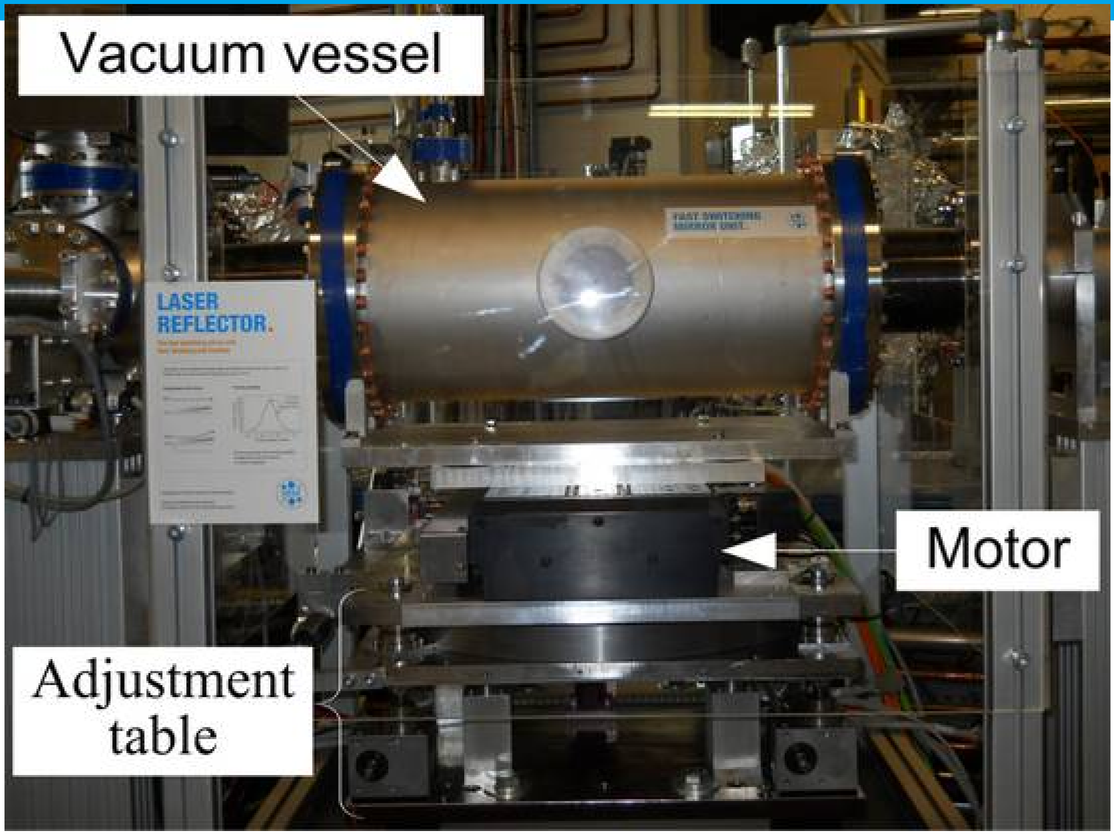
> One of these vessels can be operated in permanent switching mode, allowing a simultaneous use of the laser beam at two different test facilities.

> Since the laser beam at FLASH is pulsed with a frequency of 10 Hz, the motion has to be synchronized to the beam pulses (trains).

> The ideal switching frequency would be 5 Hz, with one train passing through and one being deflected respectively.

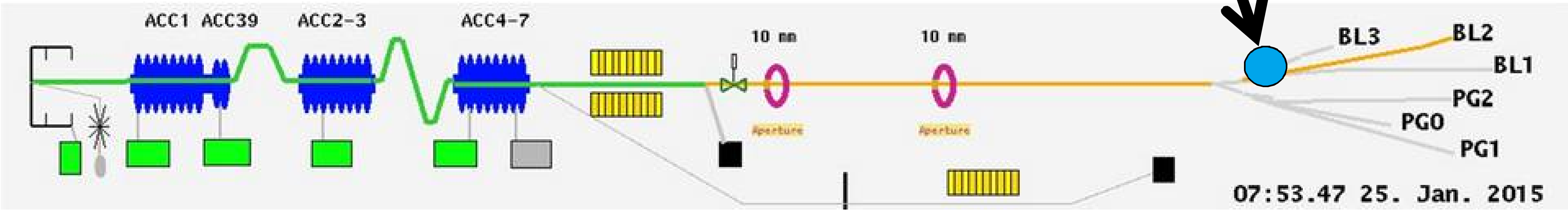
K. Tiedtke

Silicon mirrors in the photon beam line

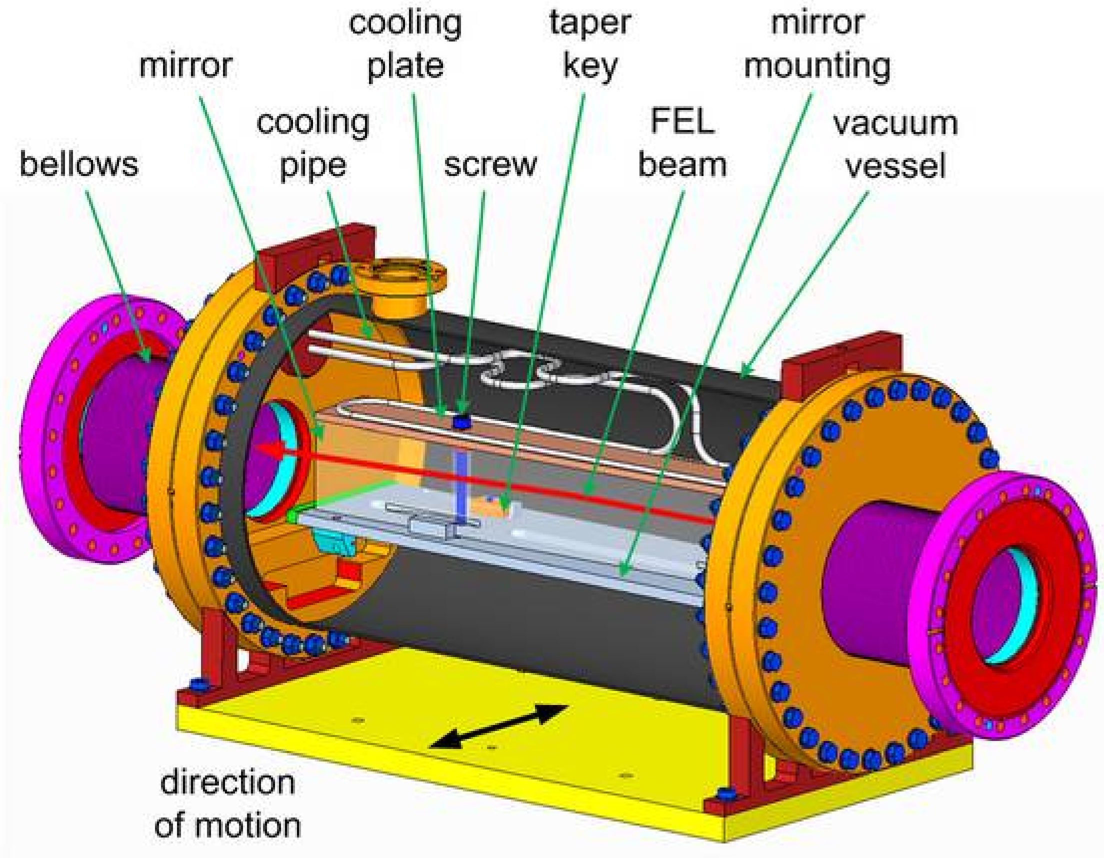


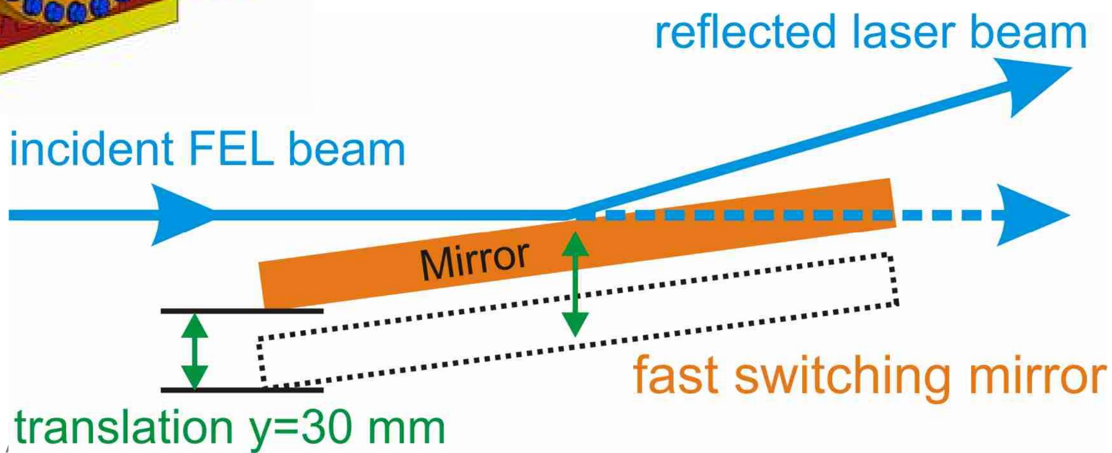
Fast Switching Mirror

FLASH I

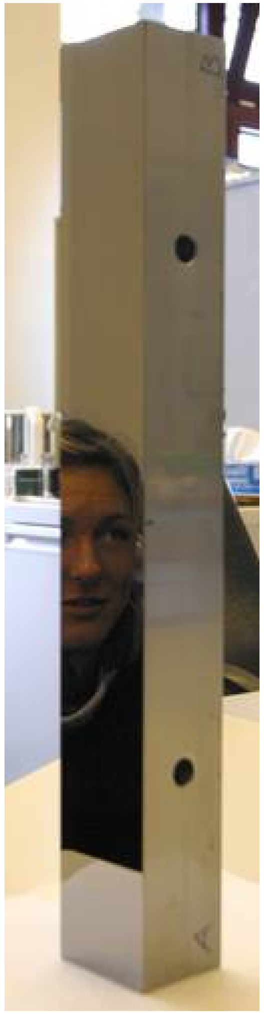


Working Principle

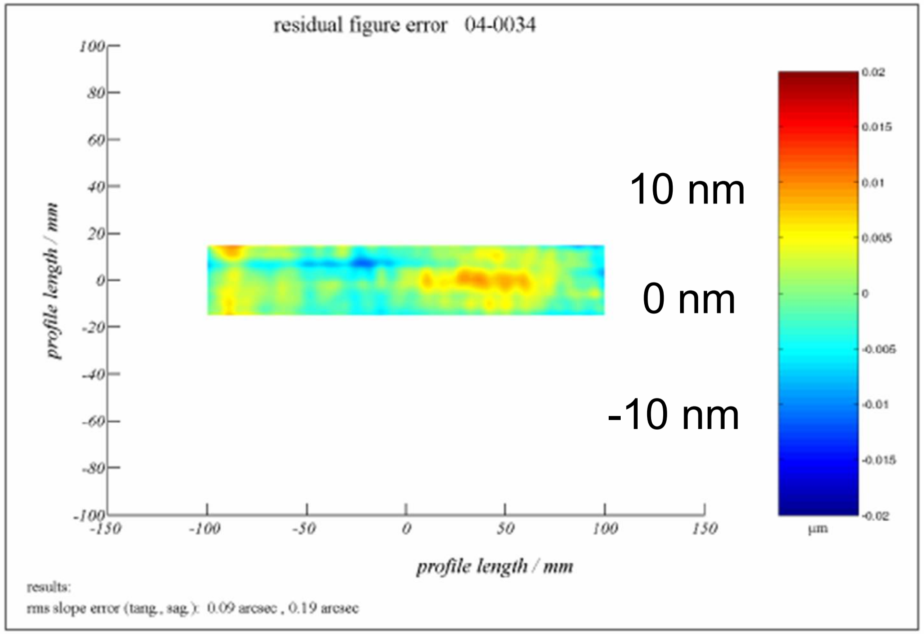




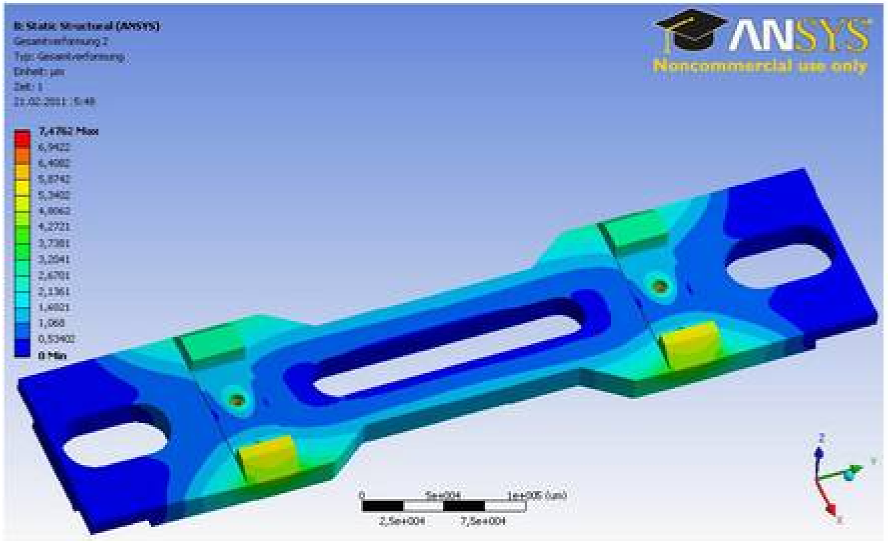
Silicon Mirror



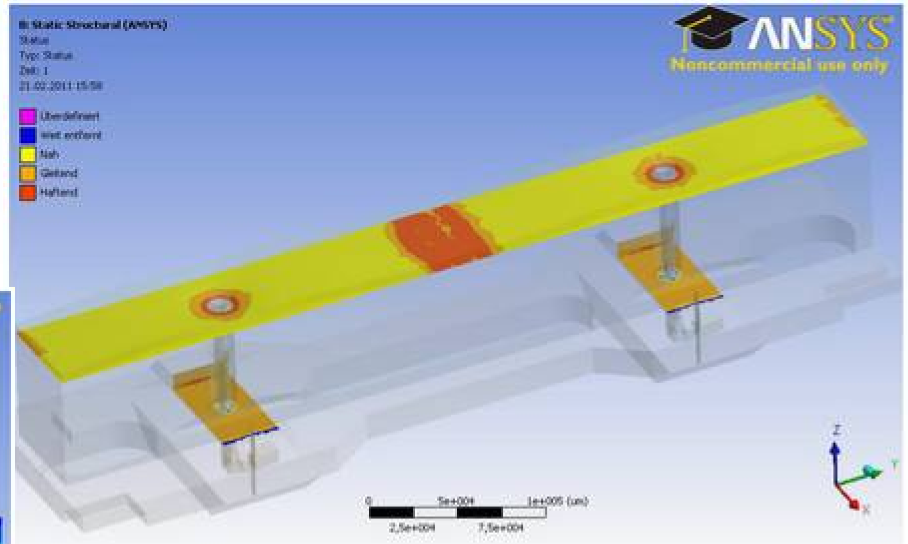
Dimensions	510 x 60 x 70 mm³ (LxWxH)
Material	Single-crystal silicon
Coating	DLC (diamond like carbon) Thickness: 45 nm
Reflectivity	> 90 %
Surface roughness	0,3 nm rms
Slope deviation, long axis	≤ 0,1 arcsec rms

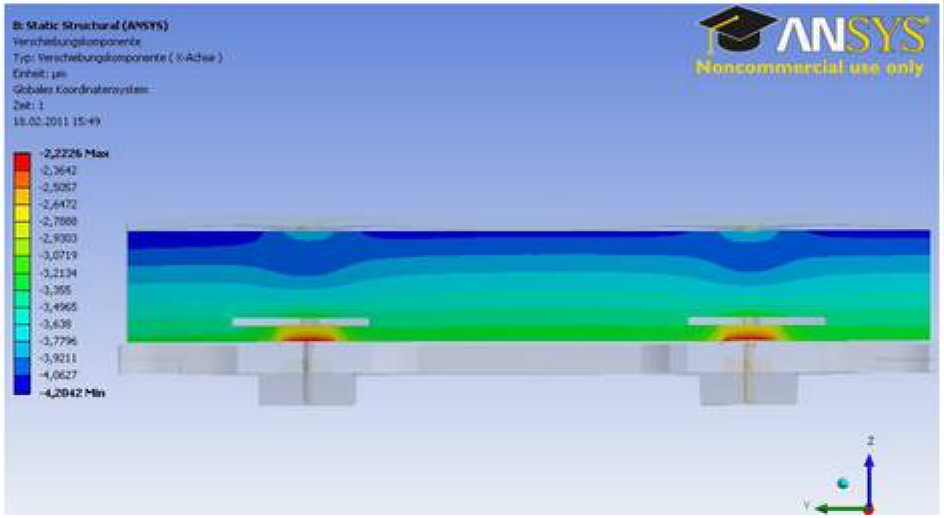


Support



FEM based design



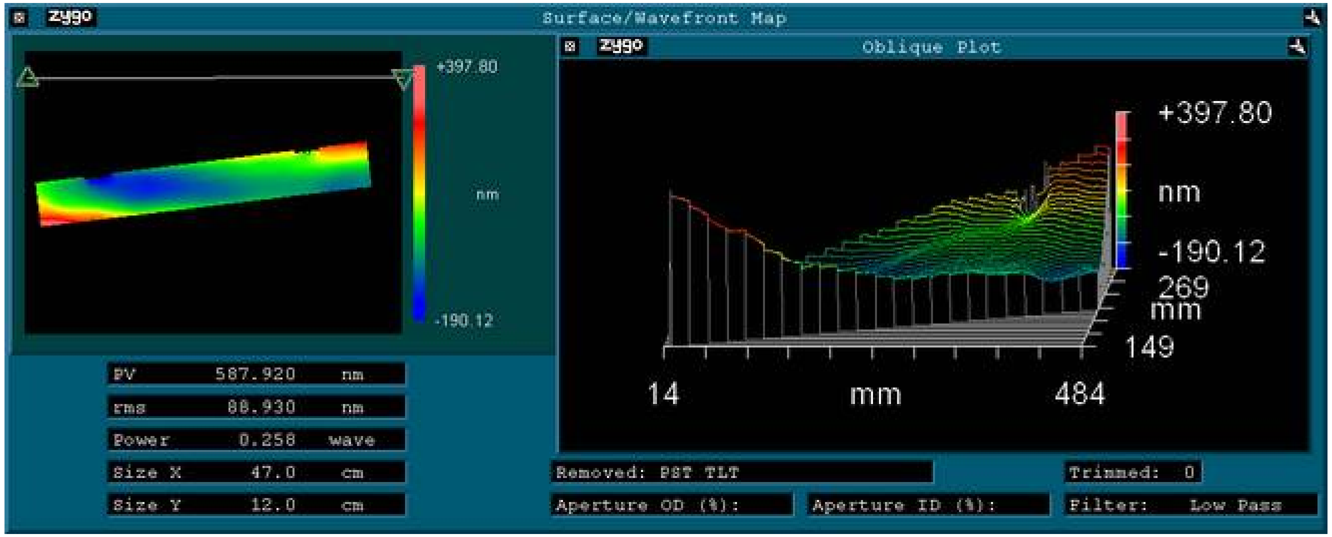


Thesis F. Perlick

Influence of Torque on Mirror Surface

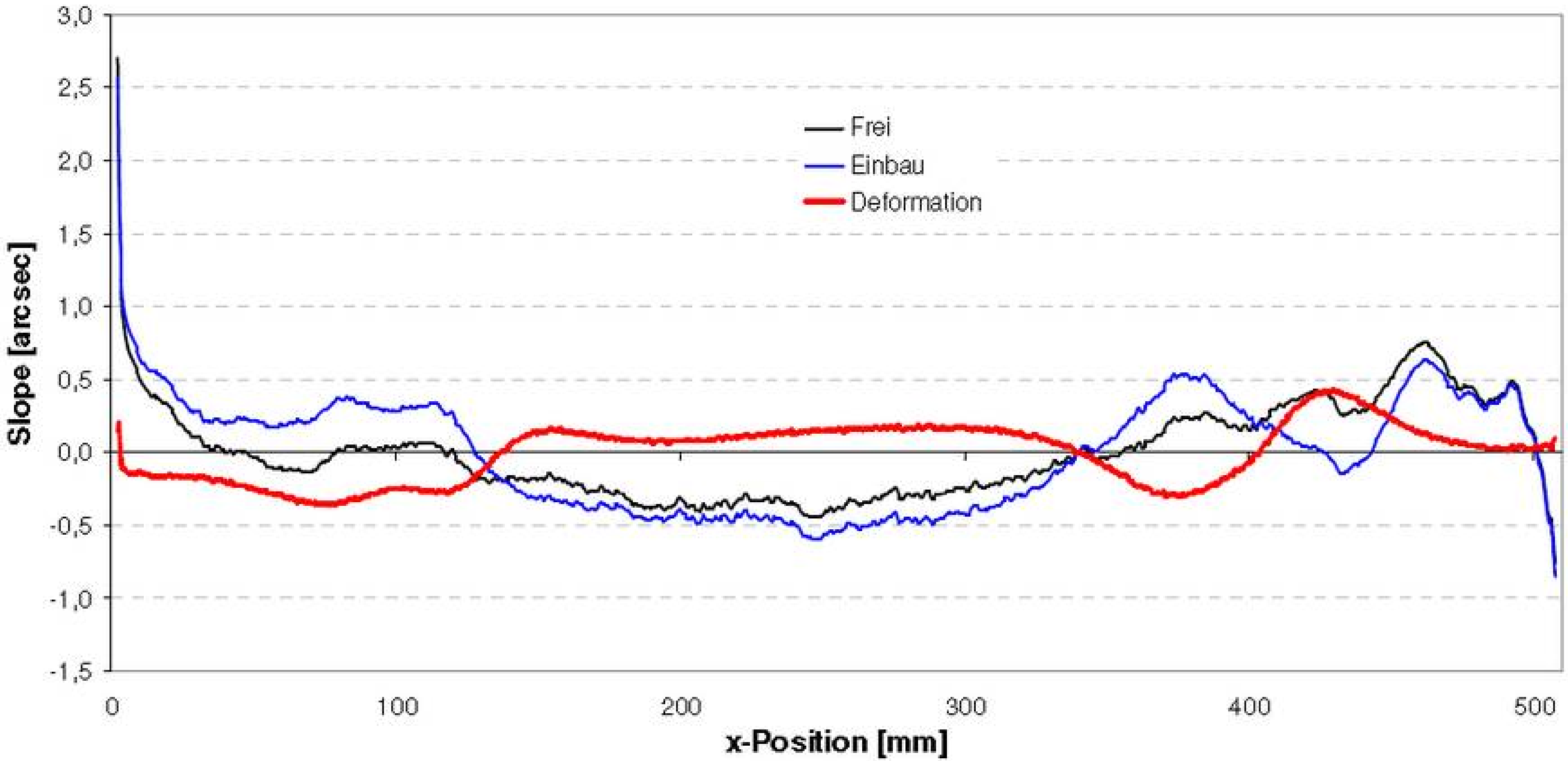
18” ZYGO Fizeau

Measurement: with 10Nm torque
0.19 arcsec rms



F. Siewert, Optical Systems Group, HZB

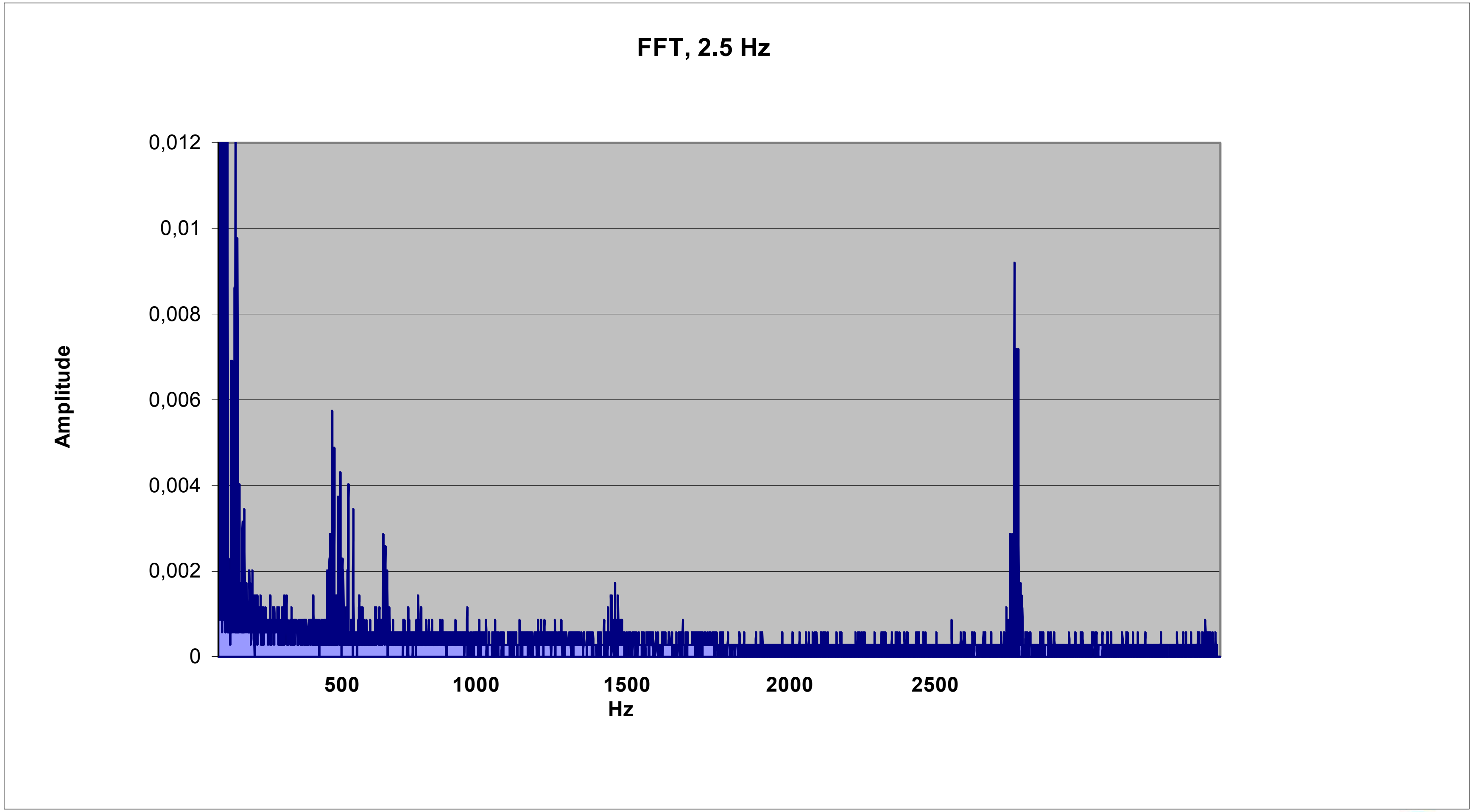
Influence of Torque on Mirror Surface (BESSY NOM)



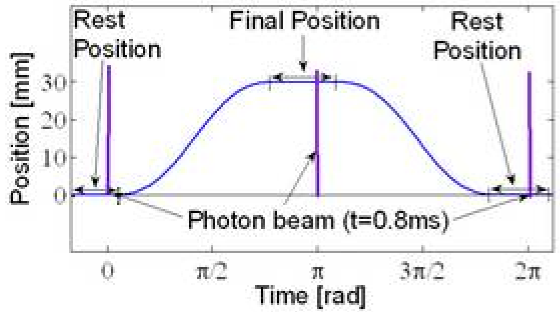
F. Siewert: “not ideal but fuctional”

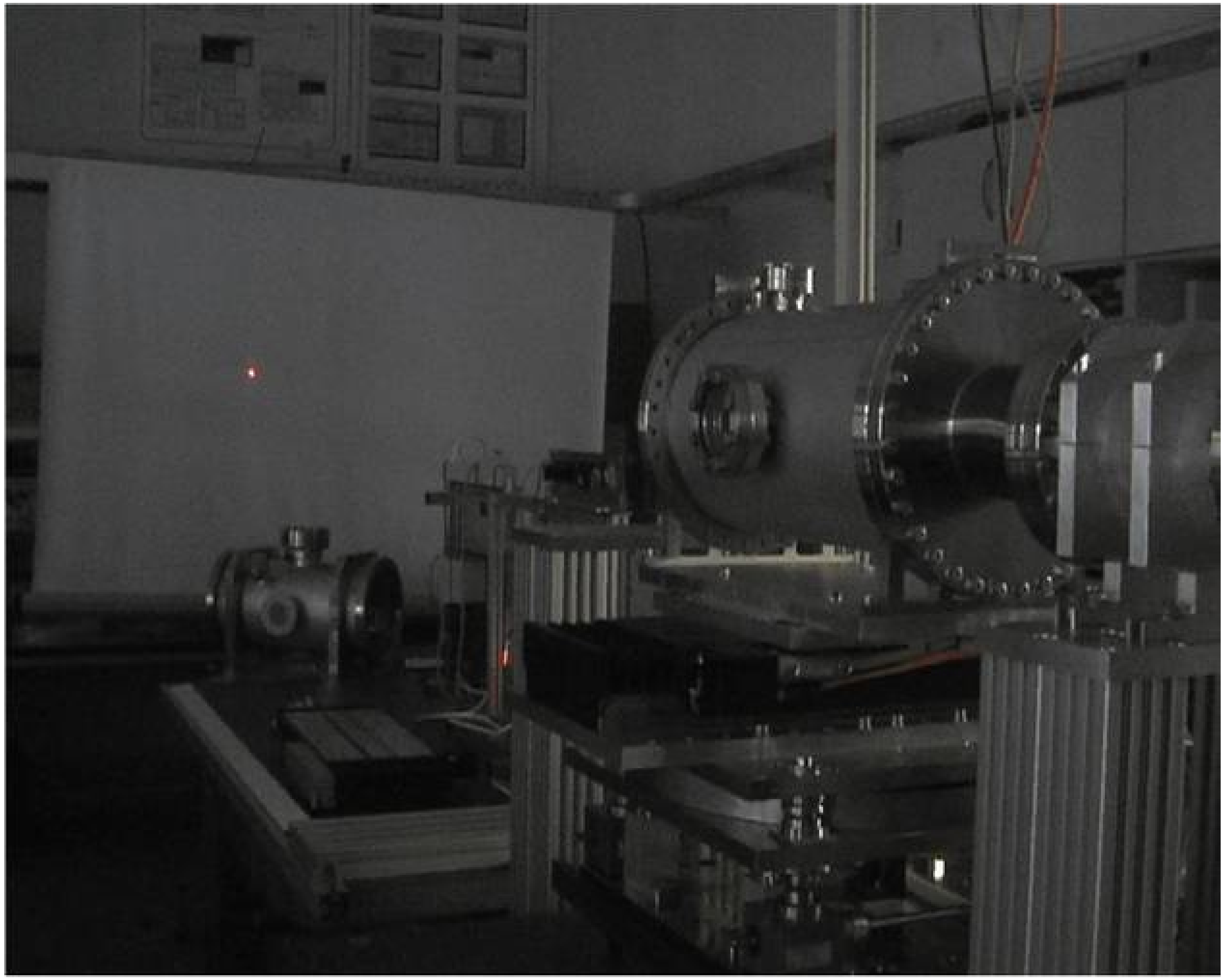
Granit girder

Resonance frequency



Silicon Mirror



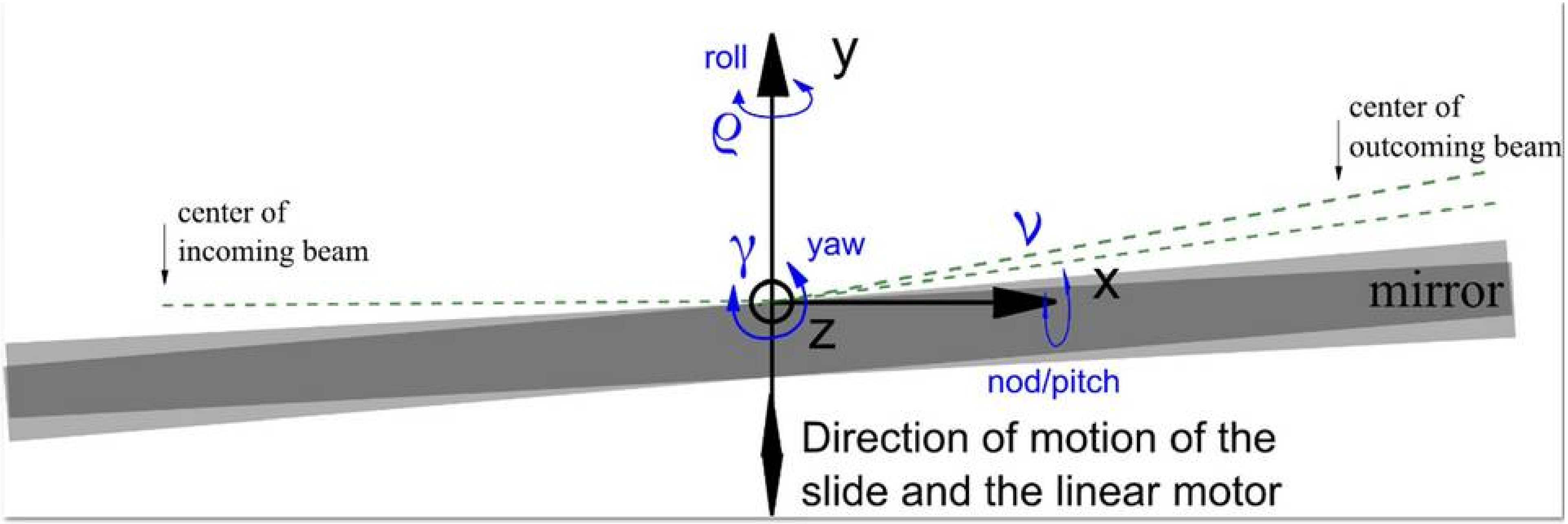


Angular and Cartesian error

Angular error	Yaw γ	Pitch ν	Roll ρ
Horizontal	2 γ	0	0
Vertical	0	2 sinα cos α ν ~0.1 ν	$\sin^2 \alpha$ ρ ~0.005ρ

Cartesian error	X	y	z
Horizontal	sin 2α Δx ~ 0	$2 \cos^2 \alpha$ Δy ~ 2 Δy	0
Vertical	0	0	0

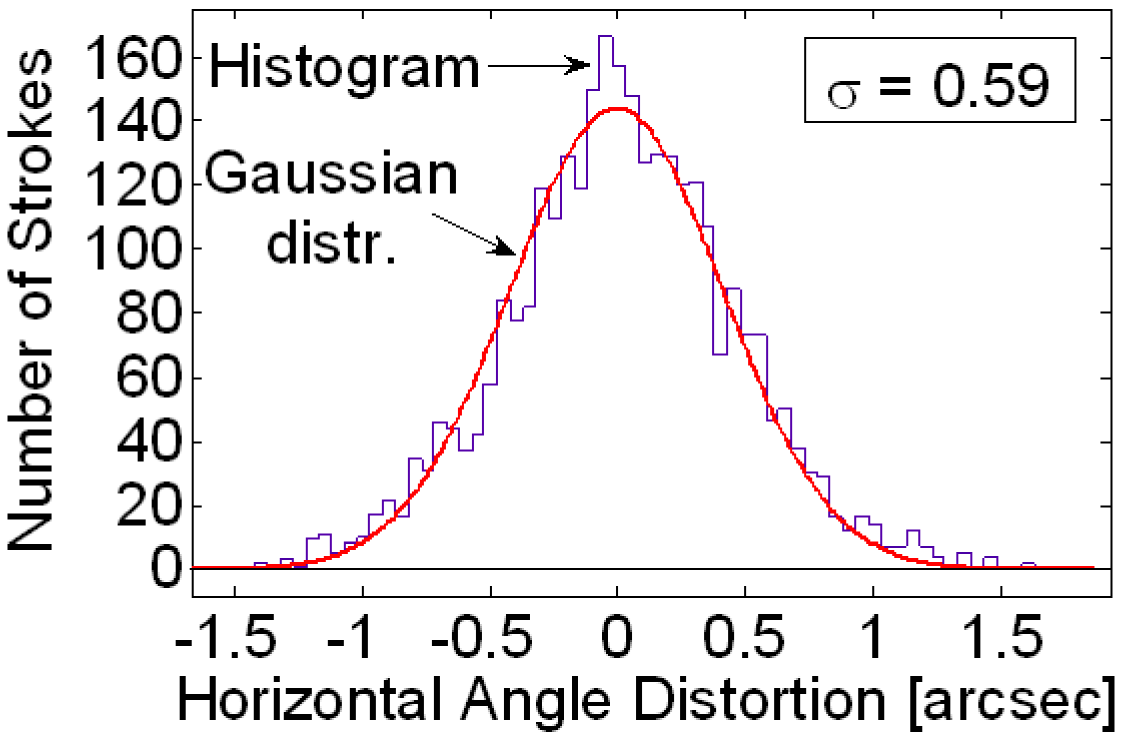
Angular error



Angular Distortion

Autocollimator

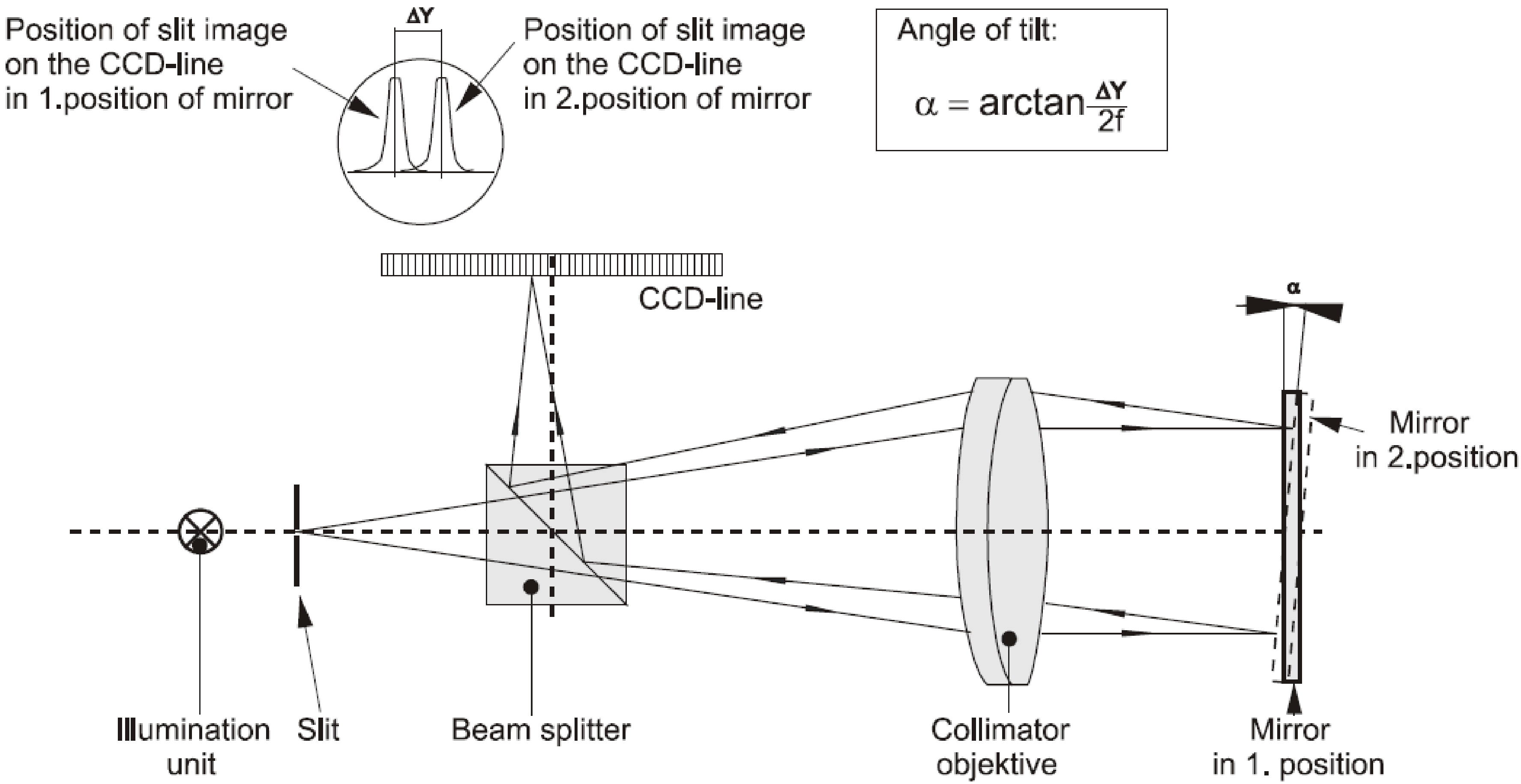
Yaw at 1 Hz



R. Sternberger

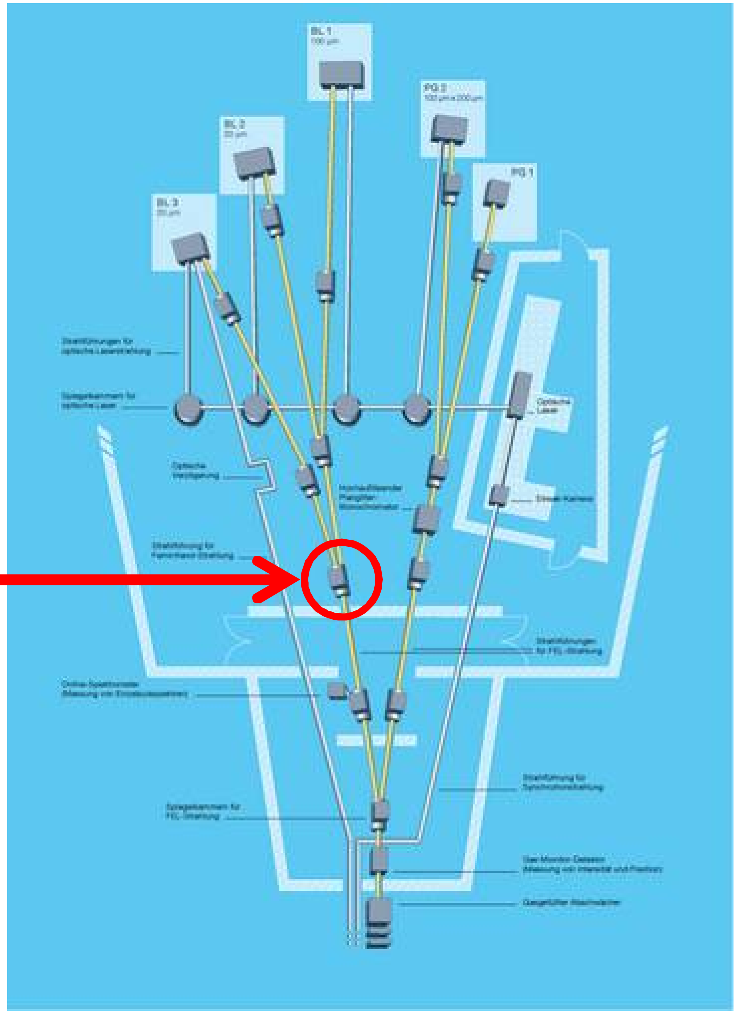
1 arcsec ~ 5 µm per Meter

Measuring Principle of Autocollimation

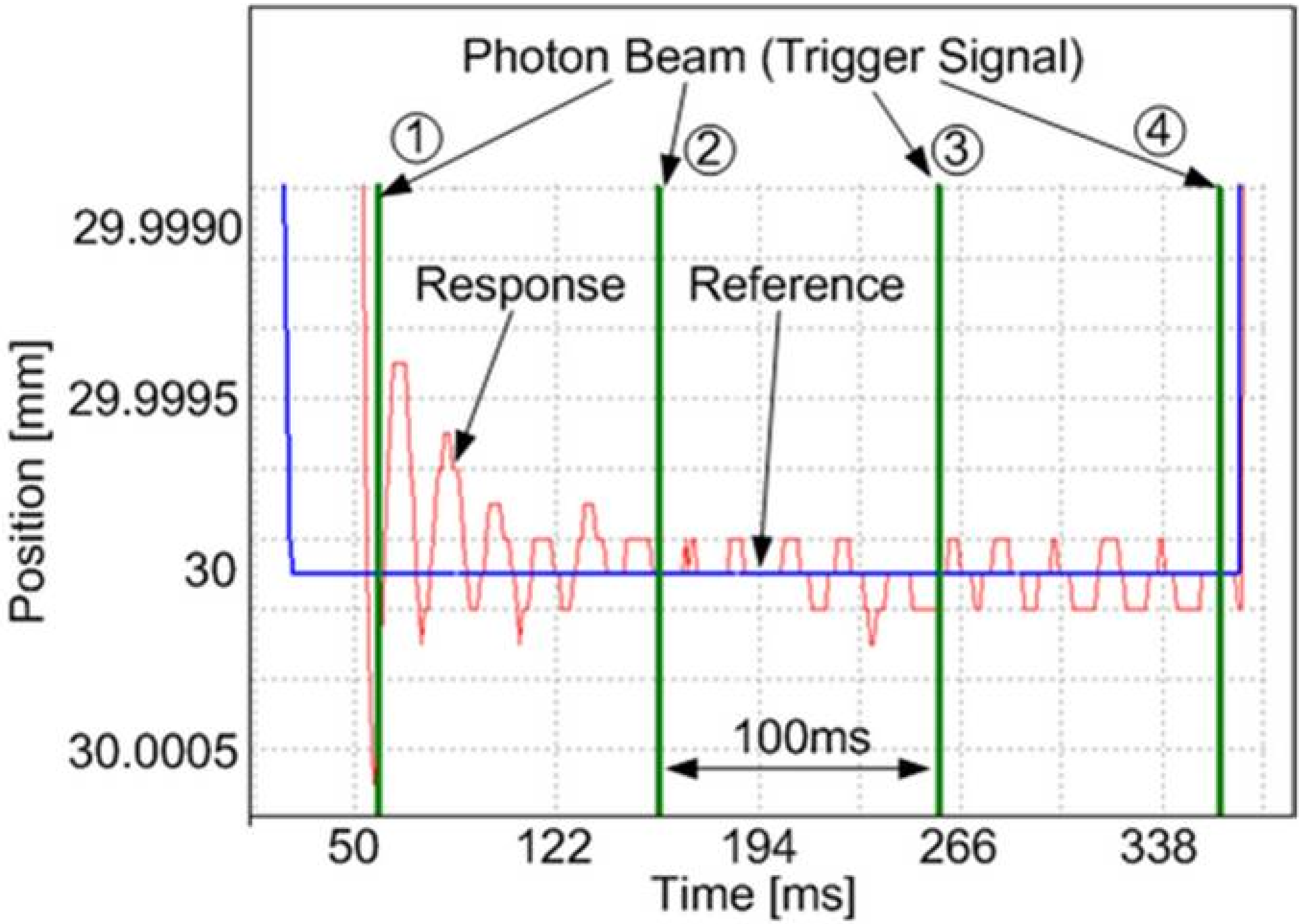


FLASH I Experimental Hall

Fast
Switching
Mirror

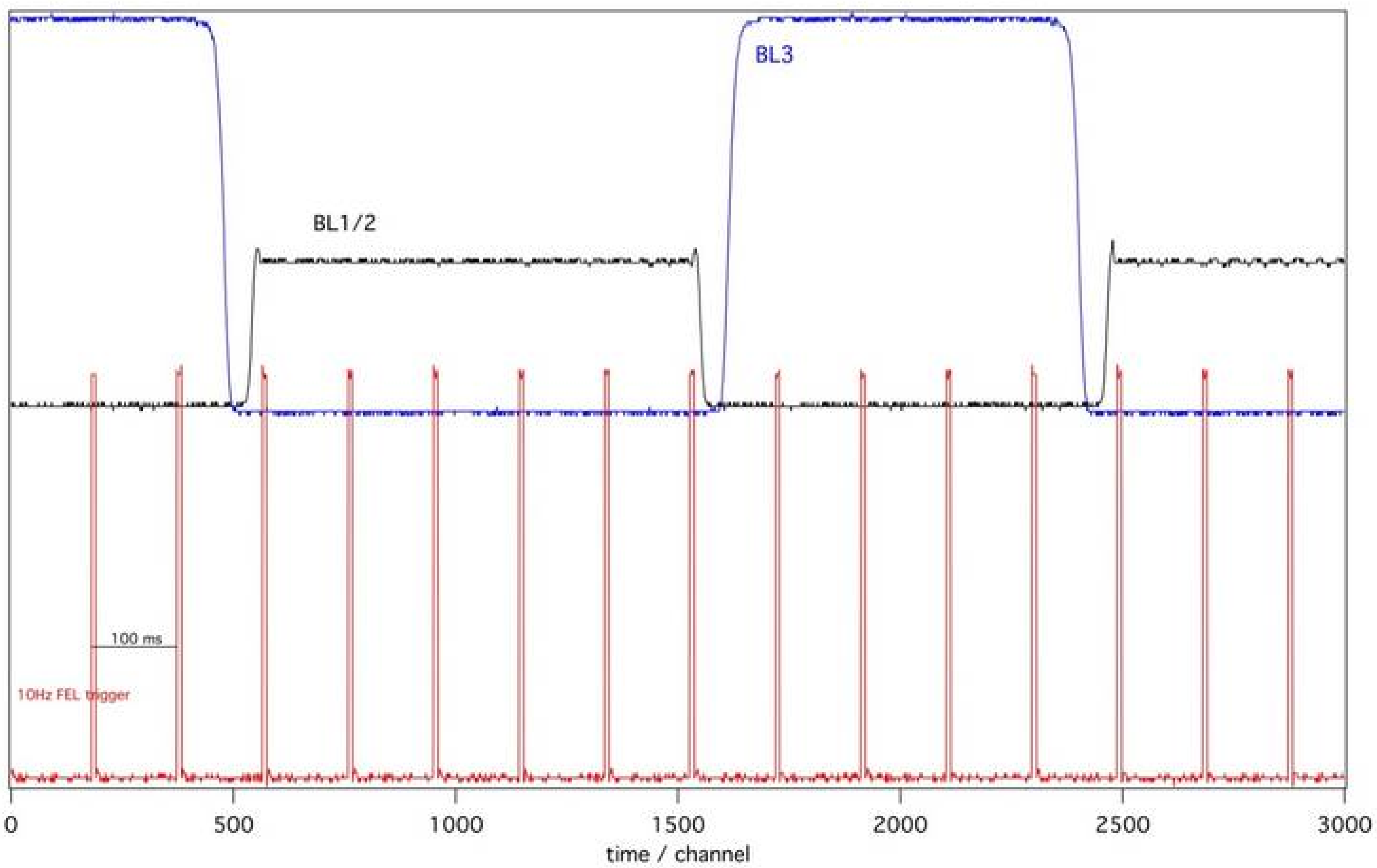


Mirror chamber at FLASH I



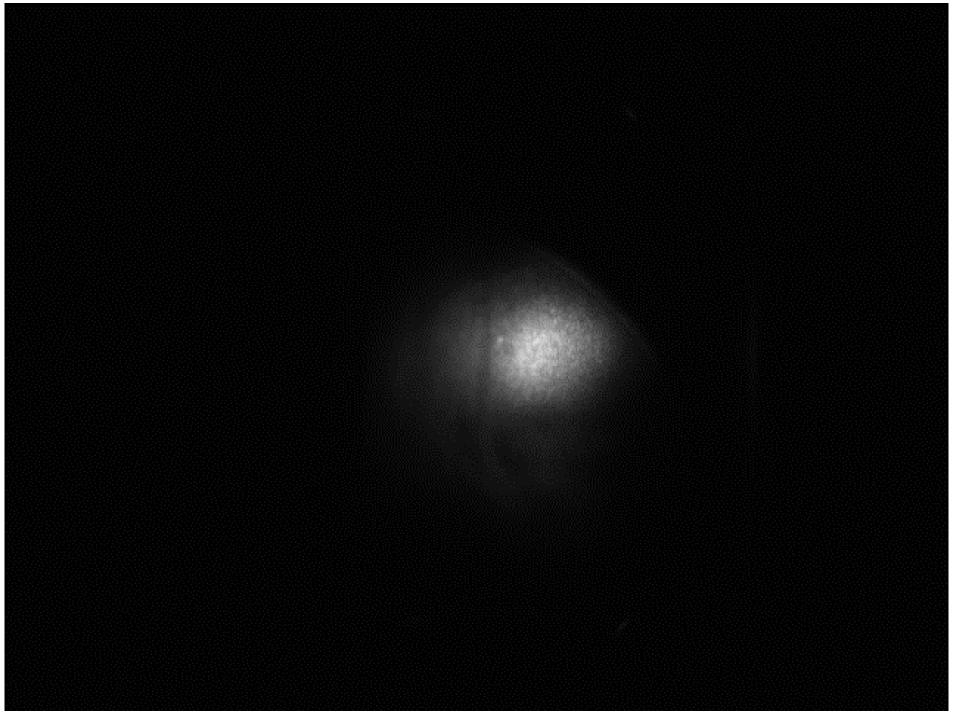
Beam Distribution between Beam Line1/2 and 3

Timing Scheme



M. Kuhlmann
S. Toleikis

Timing o.k.



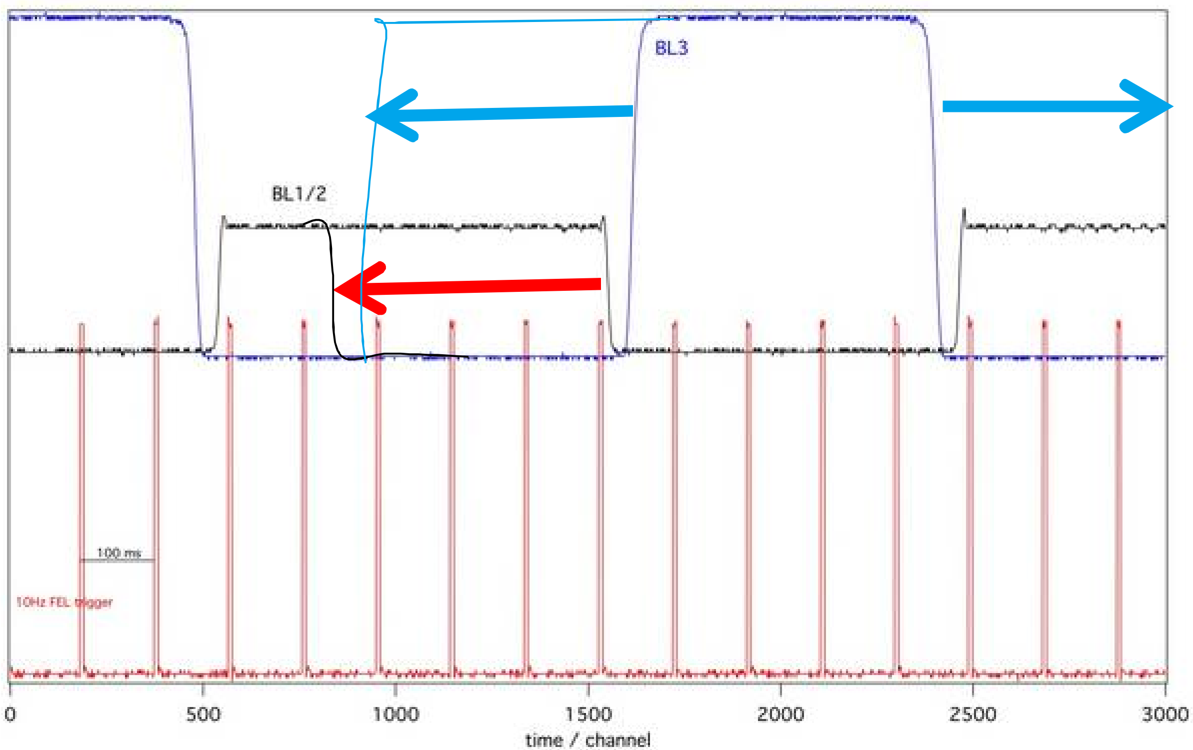
Wrong Timing

Edge of the Mirror

Chamber Frequency Limit

Due to increasing mechanical vibration and resonances

Limit of chamber frequency is about 2.5 Hz

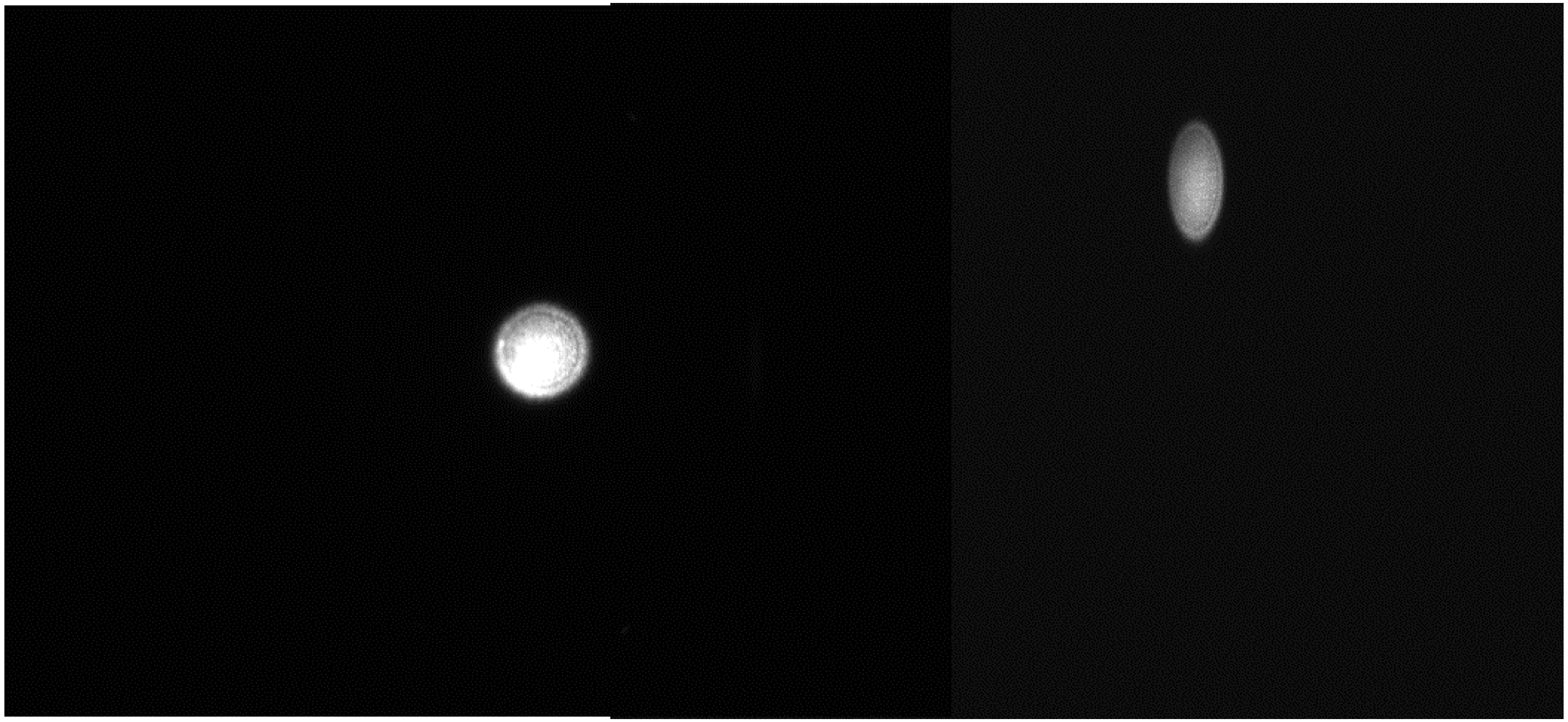


Free programmable
Pulse sequence,

Minimum 2 Pulses

R. Sternberger,
S. Grunewald

Switch BL1/2 and BL3



Using Titanium instead of Steel

Problems:

No commercially available standard flanges, all parts “home made”

Special welding (Zeuthen work shop)

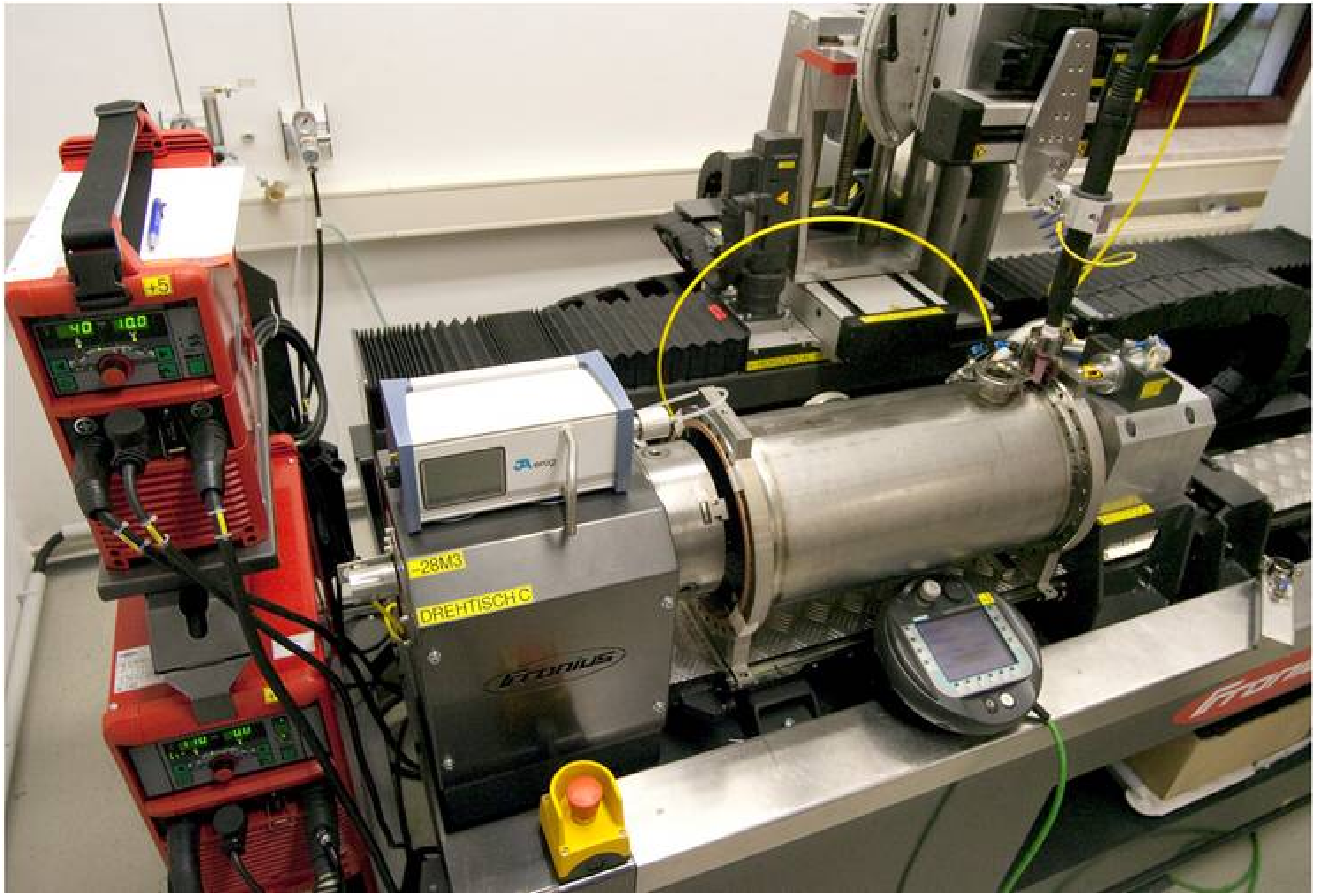
No Ti-Bellow on the market, welding between Titanium and Steel problematic (no guaranty for 10 Million strokes)

→ Compromise: Flange at bellow as thin as possible

L. Vu

Vessel material	Steel	Titanium
Mass (kg)	> 60	ca. 37
Max. switching frequency	2,5 Hz	5 Hz

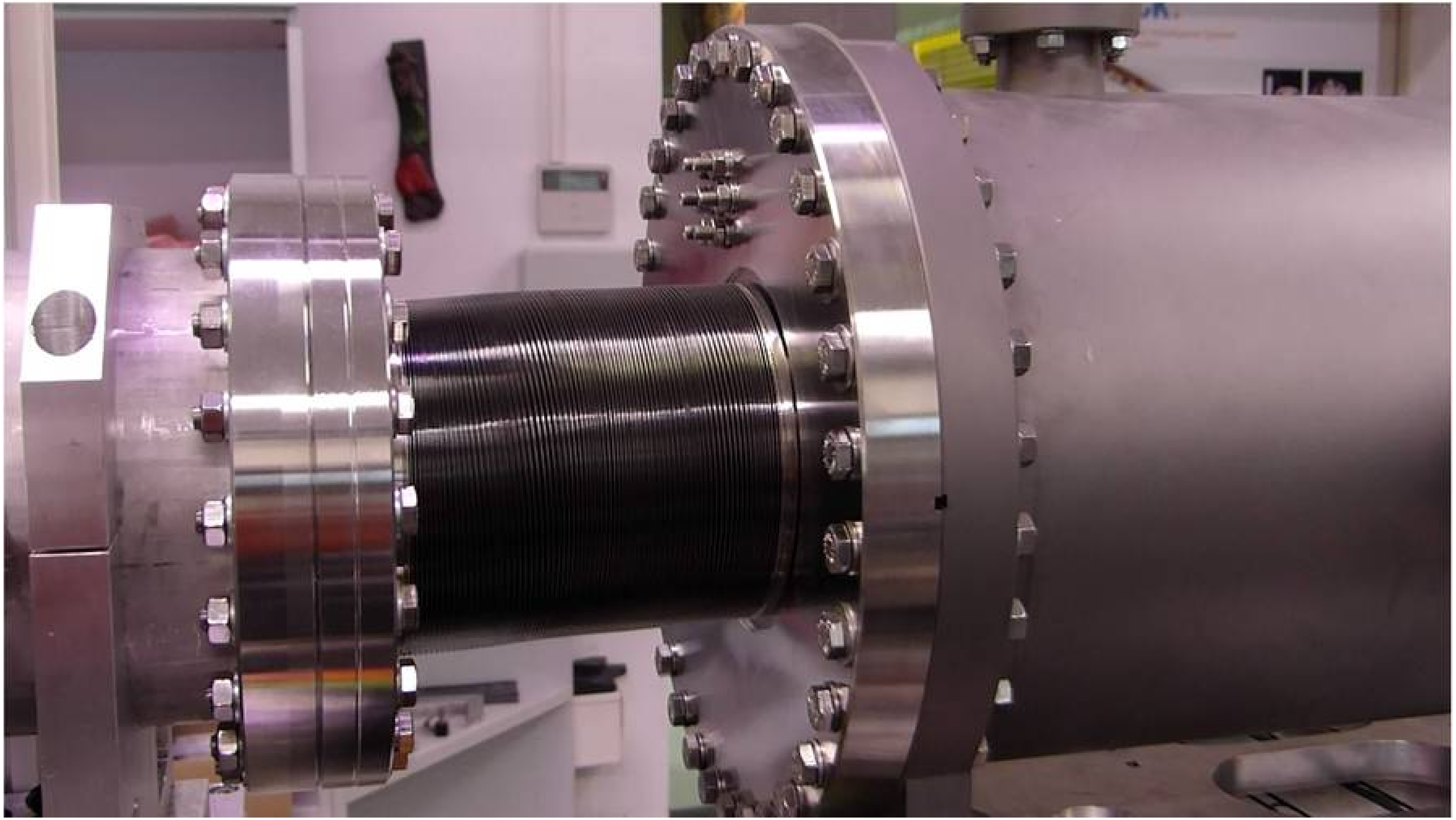
Welding



Welding Inner Parts

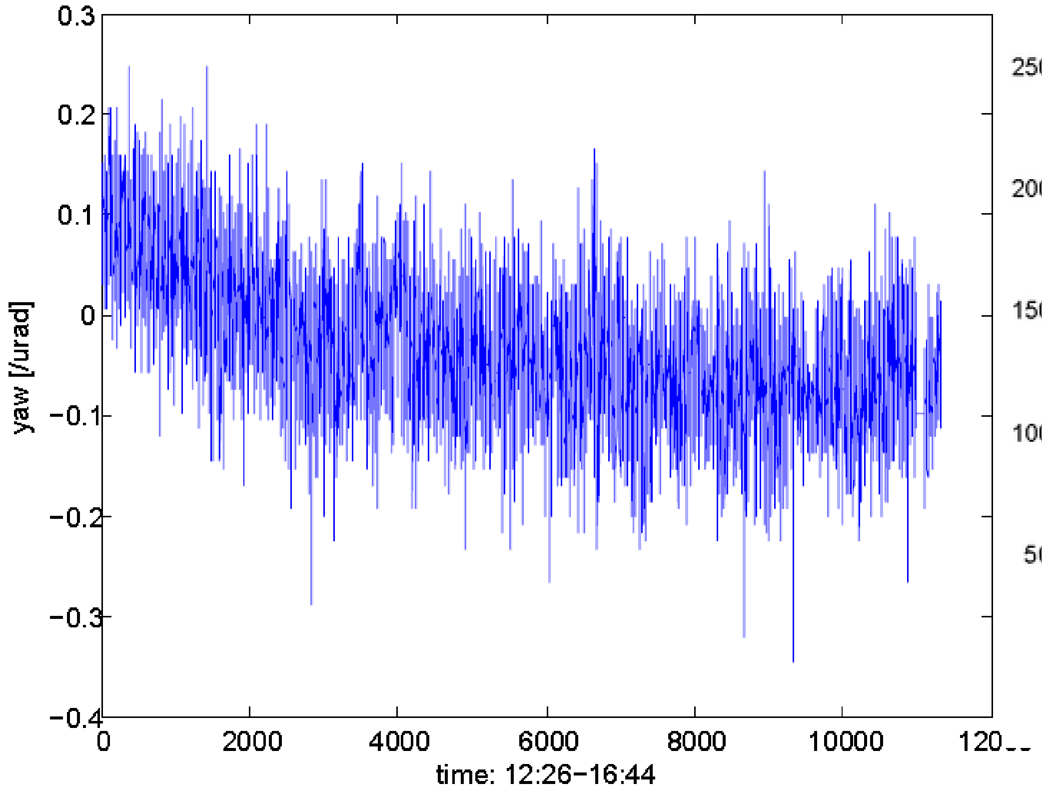
Zeuthen Workshop

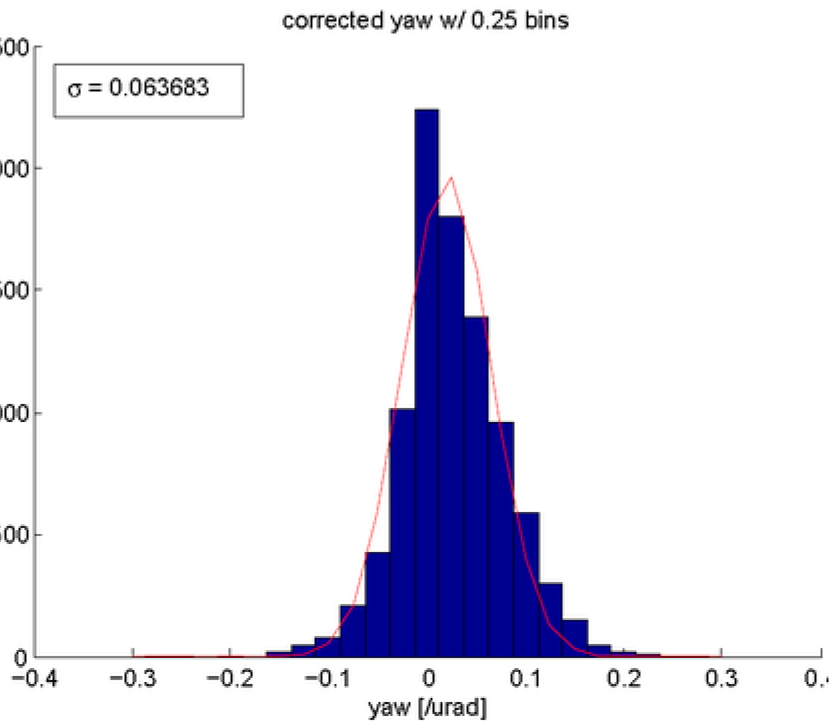
Chamber Frequency 5 Hz



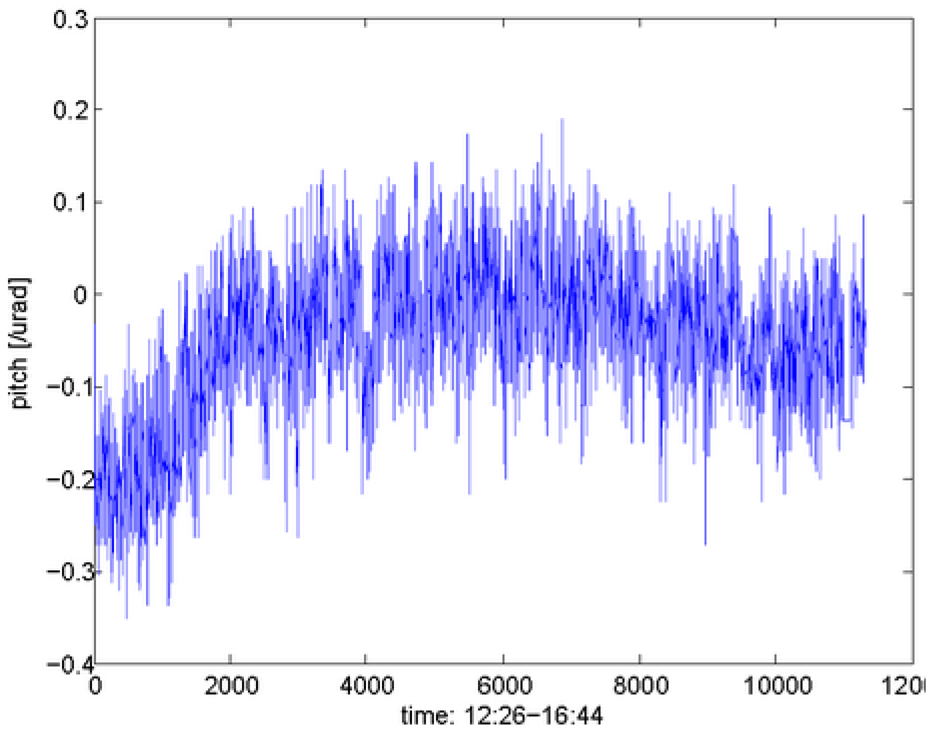
Long Time Stability Test: Yaw

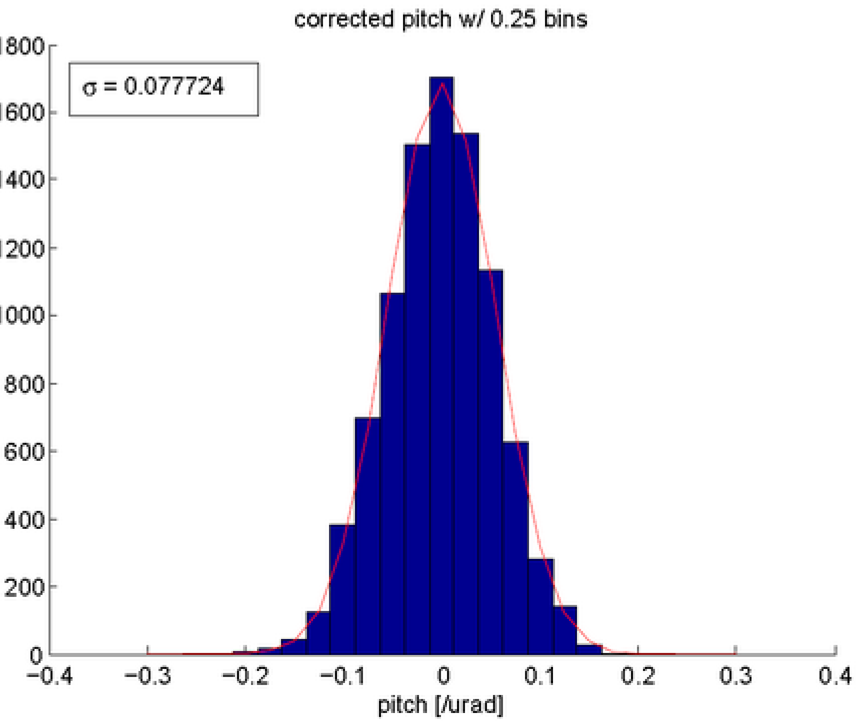
J. Good





Long Time Stability Test: Pitch





Conclusion

1. Fast Switching Mirror (steel) implemented in FLASH I

---- switching frequency up to 2.5 Hz

---- accuracy better 1 arcsec

---- free programmable photon beam distribution

between BL1/2 and BL 3 (minimum 2 pulses)

2. New Fast Switching Mirror (Titanium) foreseen for FLASH II

---- switching frequency up to 5 Hz

---- accuracy better 1 arcsec

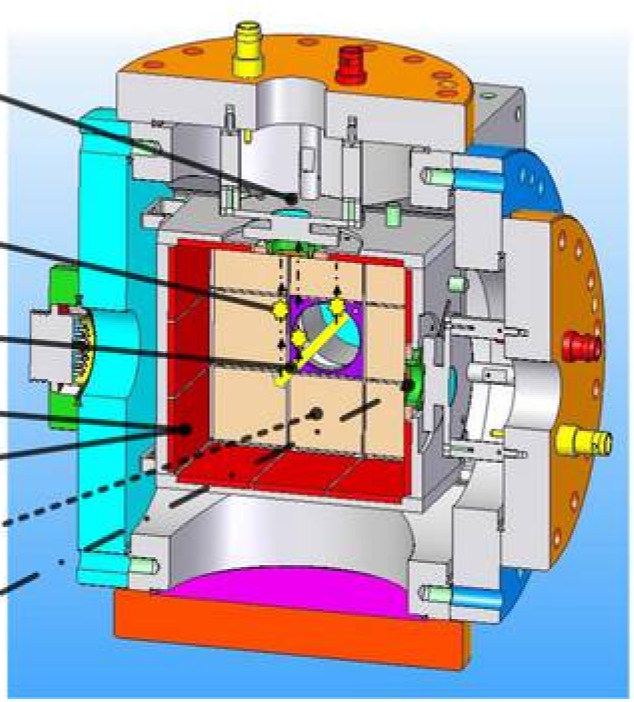
---- free programmable photon beam distribution pulse by pulse (train)

Ionization Profile Monitor

- Widely used at DESY
- A X und Y Module implemented at FLASH I (K. Tiedtke, A. Hofmann)
- Different IPMs at PETRA III (H. Schulte-Schrepping et al.)

- Common feature: each device “looks” only in one direction, e.g. X-Direction Module followed by a Y-Direction Module

Ionization Profile Monitor -----3D design



203 x 218 x 246 mm for 3D-measuring

H. Breede

H.-J. Grabusch

Principle

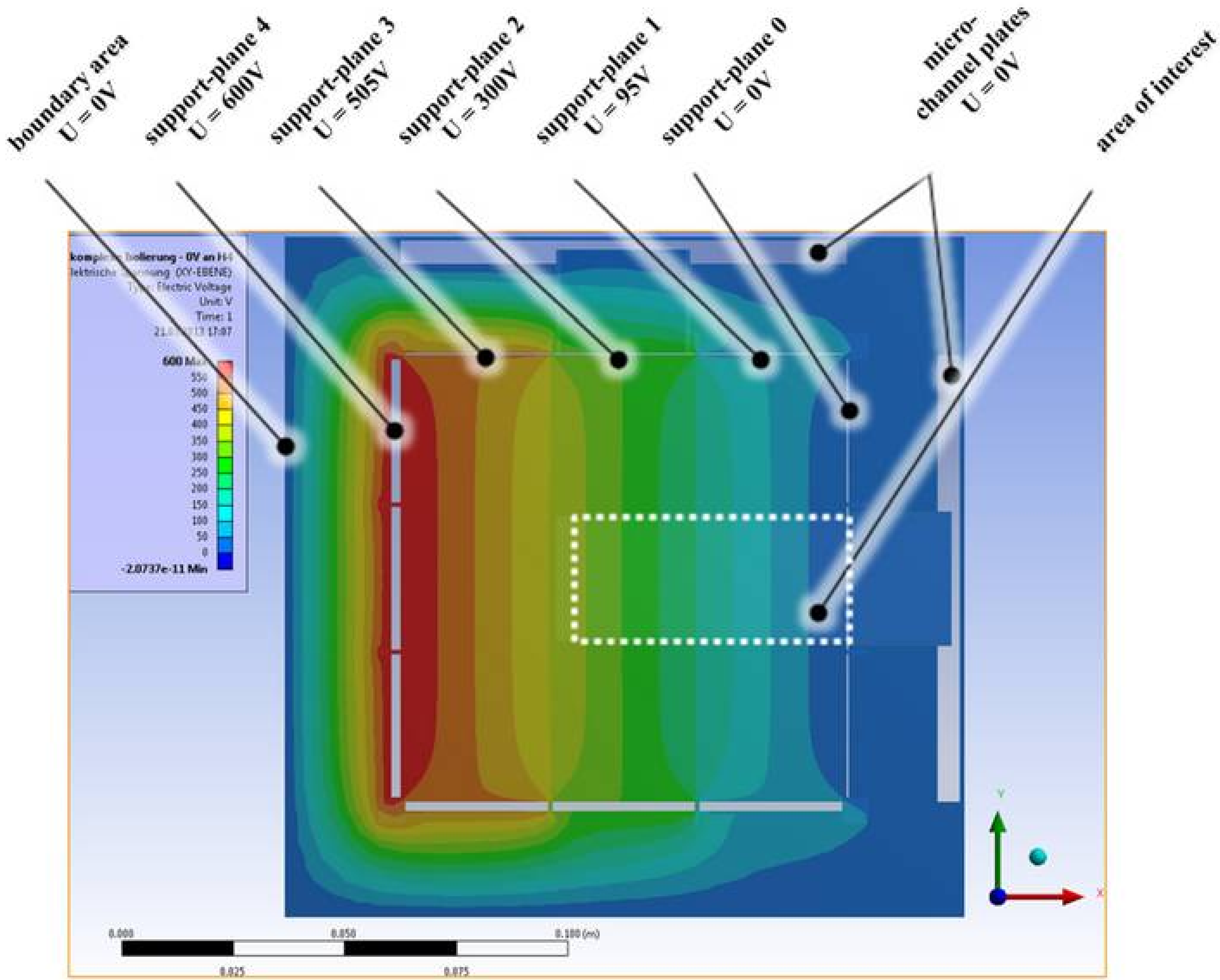
> Laser beam located in an Ultra High Vacuum (UHV) pipe with small amount of residual gases.

> Beam hits residual gases and ionize it.

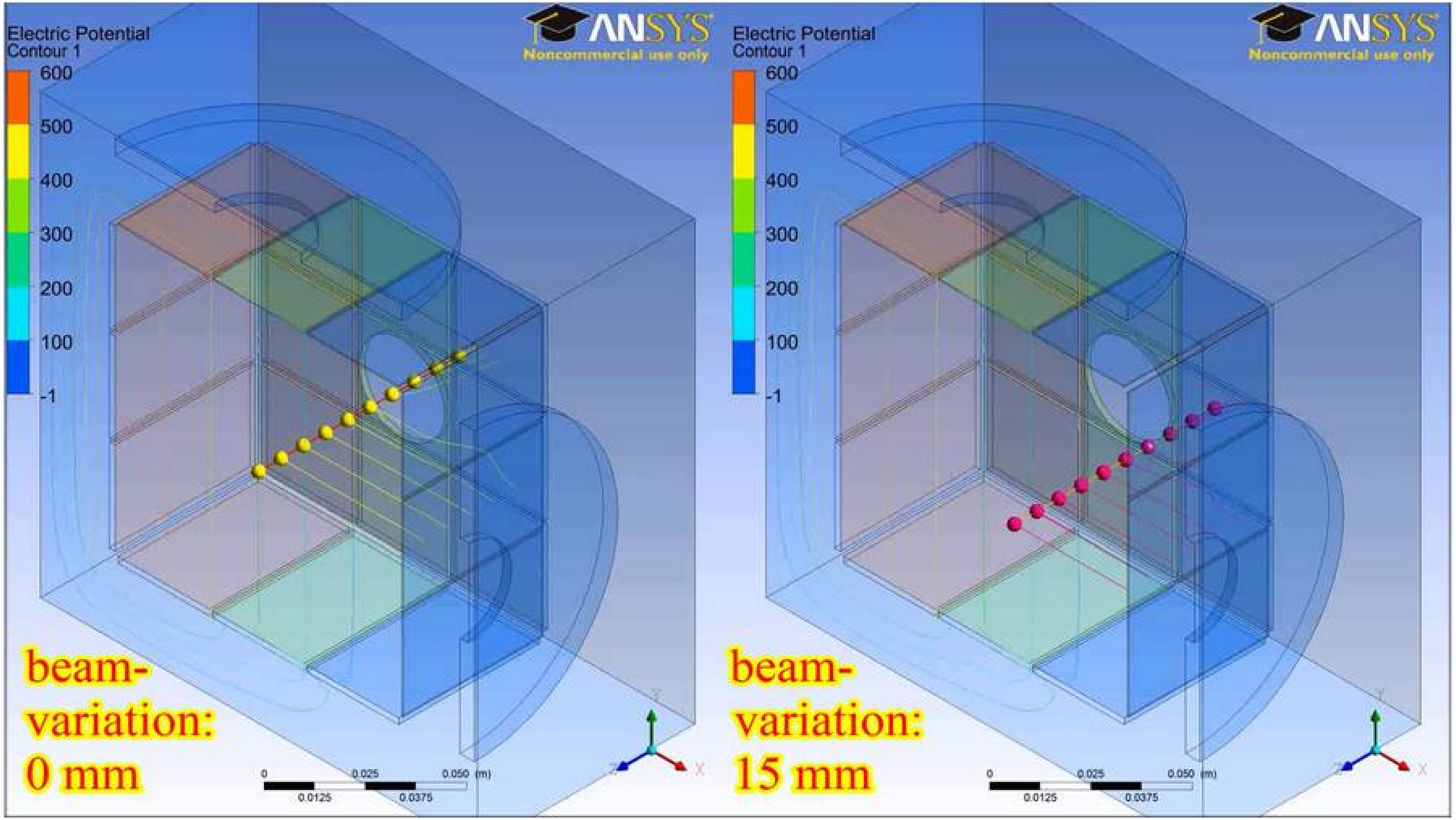
> Electrical field deflects electrons and ions in a rectilinear way toward MCP.

> The impacting particles create an avalanche of secondary electrons in the MCP and are being visualized on the phosphor-screen.

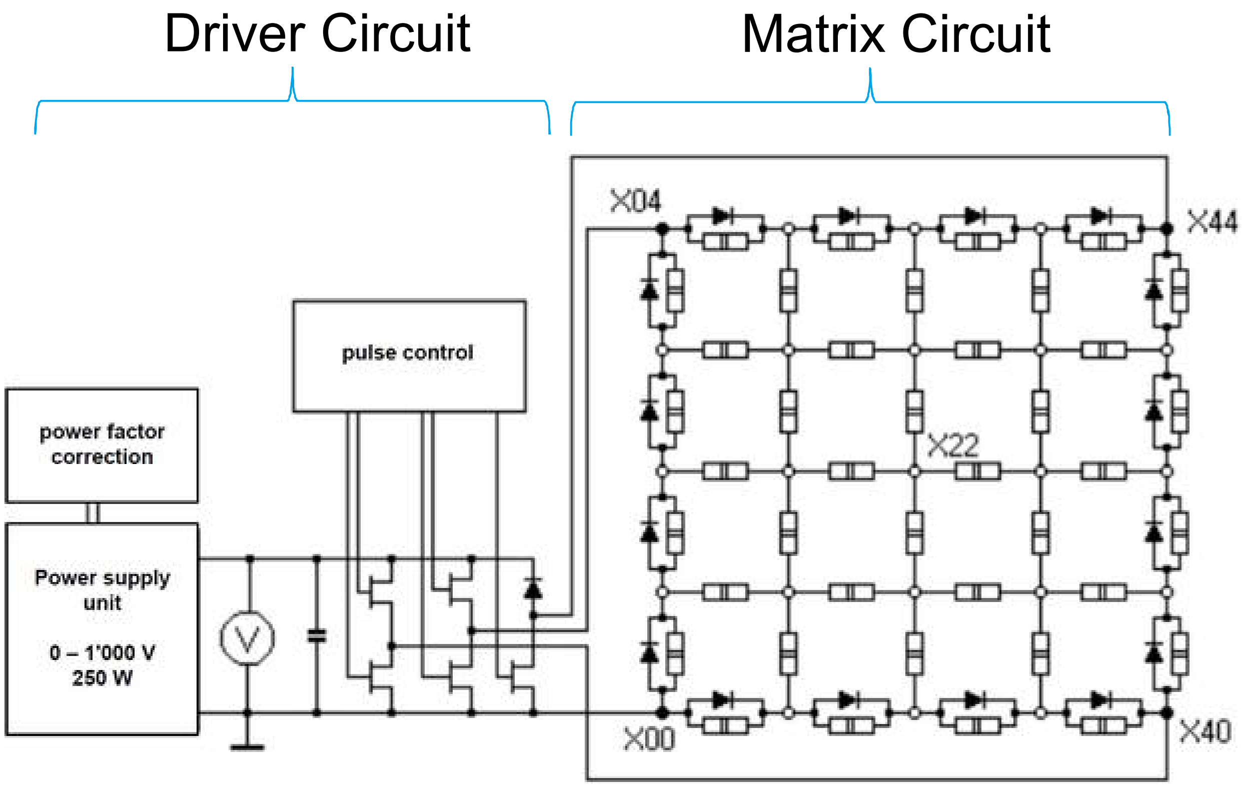
Electric Field



Movement of the Ions/ Electrons



3D-IPM simplified power supply design

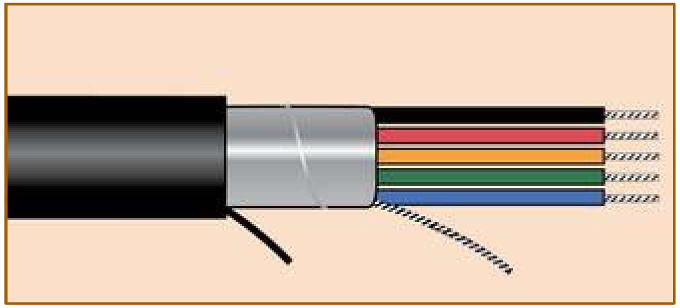


Specification

Current max	: 250 mA
Active Connectors	: 25
Vin max	: 1000V
Frequency max	: 100kHz
Accuracy	: 99%

Dian Ahmad Hapidin |Power Supply Simulation and Optimization for 3D-IPM

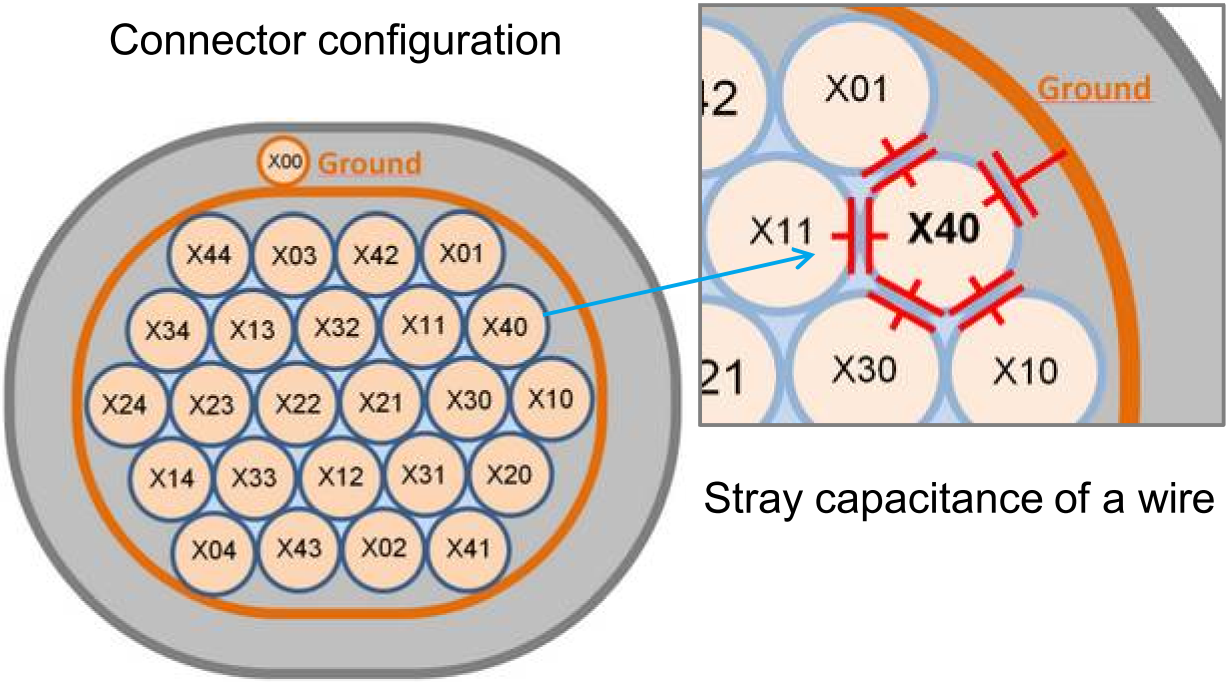
Wires parasitic components



Wire Specification

Wire type : Multi-conductor
Conductor : 16 AWG(19/29),24 bundle
Voltage max : 1000 V
Capacitance : 46 pf/ft (wire to wire)
83 pf/ft (wire to ground)
Inductance : 0.18 µH/ft

Connector configuration

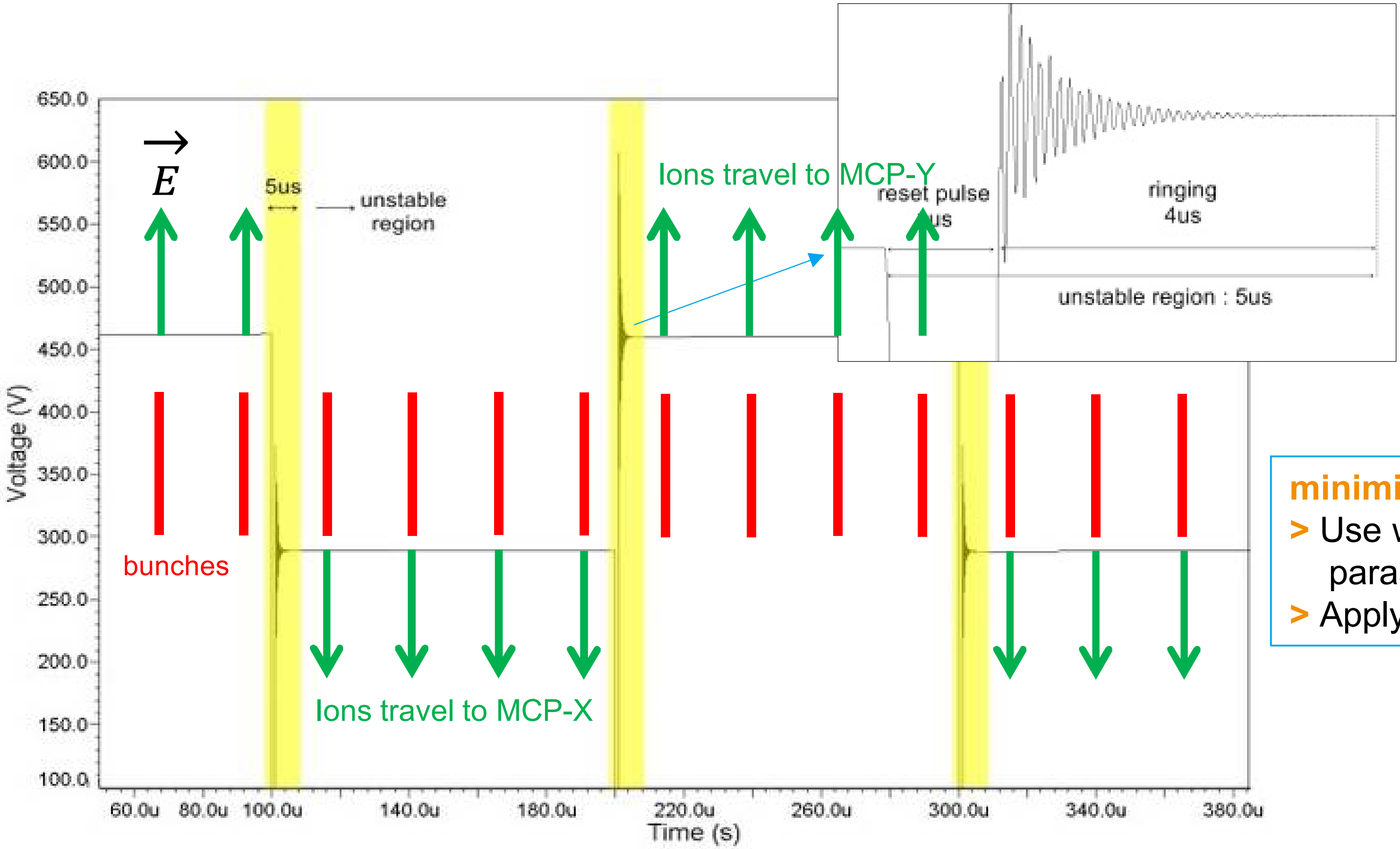


Stray capacitance of a wire

Wire parasitic components

> Stray capacitance
> Parasitic inductance
> resistance

Unstable region



minimize unstable region
> Use wire which has low parasitic components
> Applying snubber circuit

Unstable region can be ignored if buch distance > unstable region

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Next Steps

The first prototype of a 3D-IPM is currently under construction and is completed.

Next: Test in the Lab with an electron gun.

First practice tests are planned in 2015 at FLASH in DESY Hamburg site.