4th International Workshop on Metrology for X-ray Optics, Mirror Design and Fabrication

A beam shaping active optics system for FERMI@Elettra FEL

FERMI @elettra

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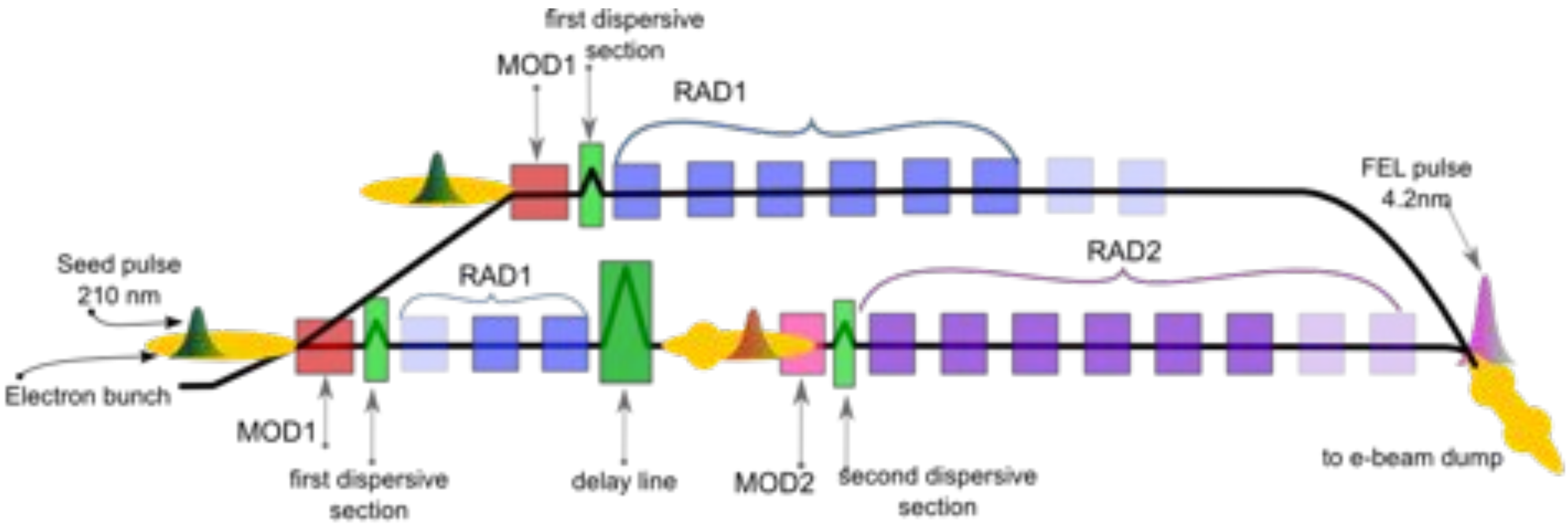
FERMI@Elettra

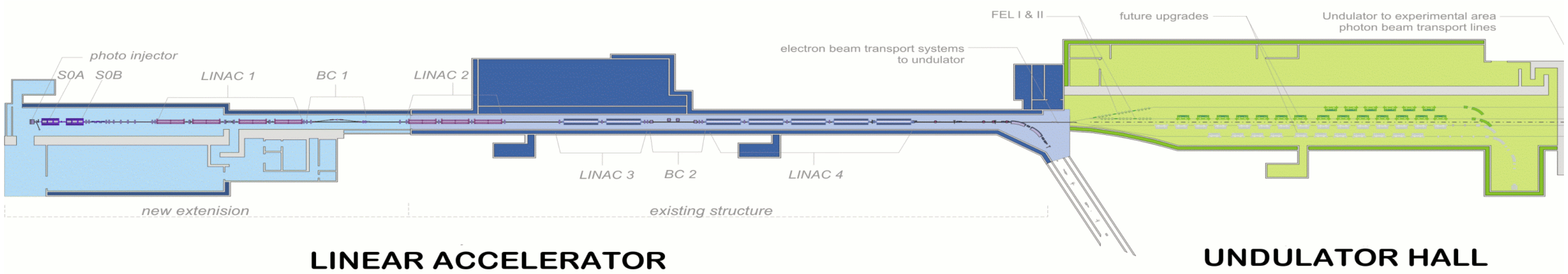
FEL 1 and FEL2

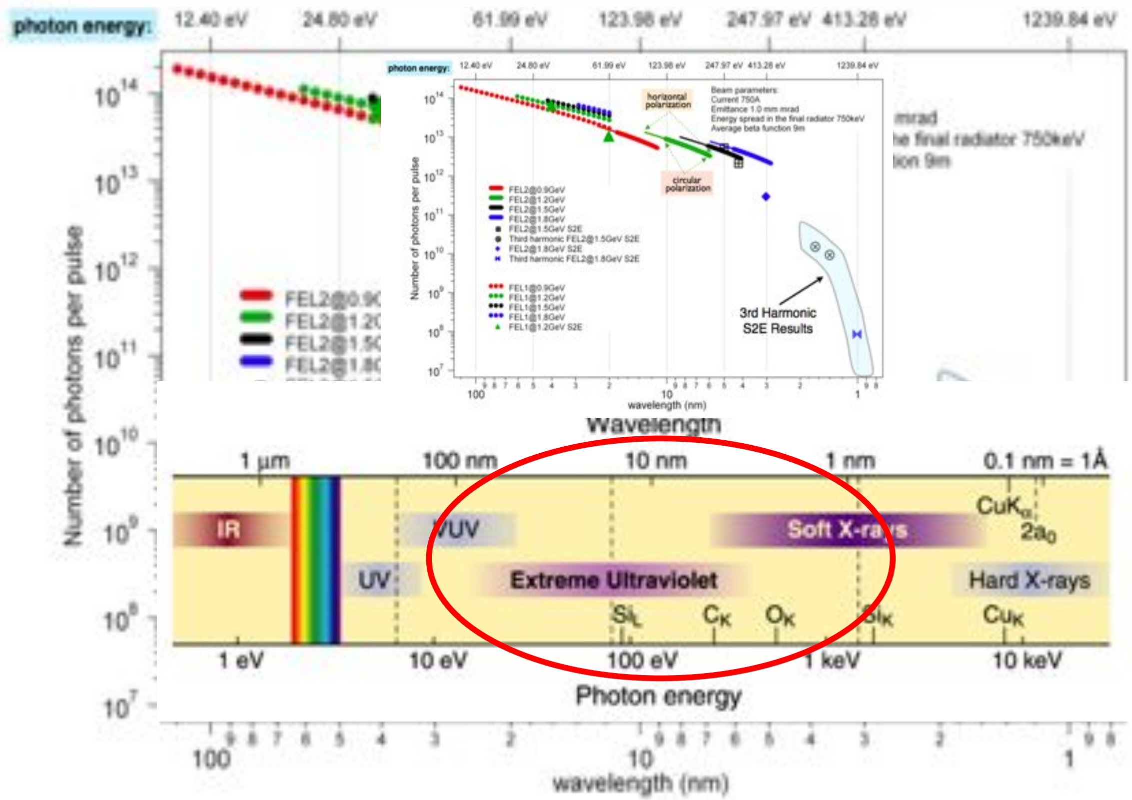
FEL-1, based on a single stage High Gain Harmonic Generation (HGHG) scheme initialized by a UV laser, covers the spectral range from ~100 nm down to 20nm



FEL-2, is based on a double cascade of HGHG in order to be able to reach the wavelength range from 20 nm to ~4 nm

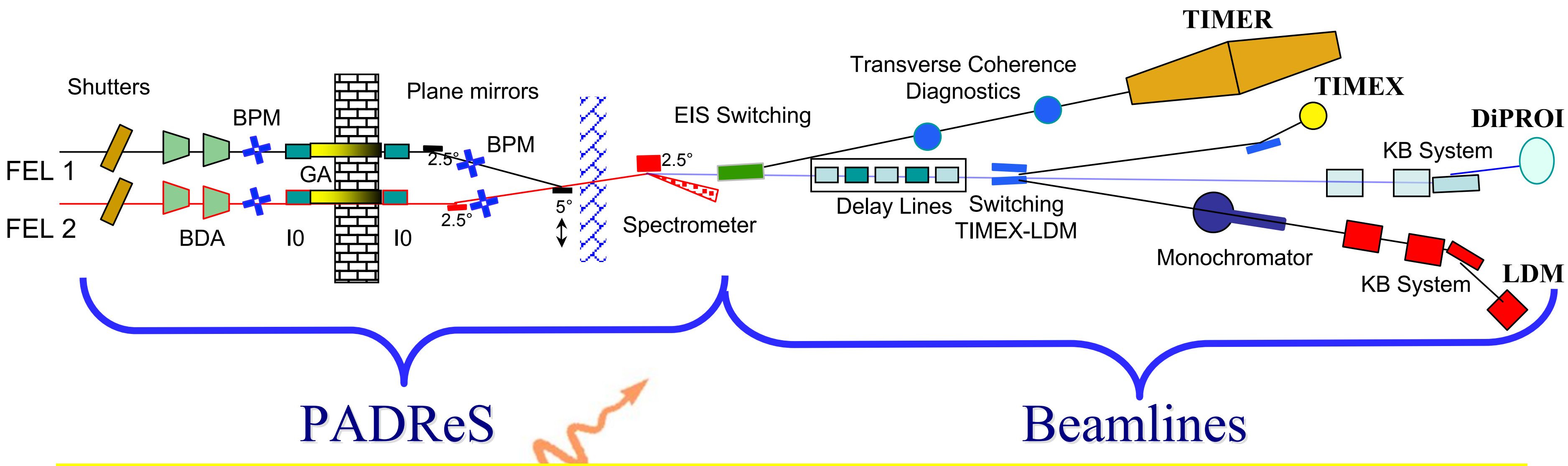
FERMI@Elettra output





Parameter	FEL 1	FEL 2
Wavelength (nm)	100-20	20-4
Pulse length rms (fs)	30-100	<100
Bandwidht rms (meV)	~20-40	~20-40
Polarization	variable	variable
Peak Power (GW)	1-5	~1
Photons per pulse	$\sim 4\cdot 10^{14}$ (100 nm)	$\sim 10^{13}$ (10 nm)
Source Size FWHM (µm)	290	140
Divergence rms (µrad)	50@40 nm	15@10 nm
Repetition Rate (Hz)	10-50	50

Experimental hall



LDM: Low Density Matter

ref.C. Callegari, F. Parmigiani, S. Svenson, K. Prince, S. Stranges, J. M. Dyke, T. Möller, F. Stienkemeier…

DIPROI: DIffraction and PROjection Imaging

ref. M. Kiskinova, F. Capotondi, B. Kaulich, H. Chapman, J. Hajdu, A. Nelson…

EIS: Elastic and Inelastic Scattering

-TIMER: TIME-Resolved spectroscopy of mesoscopic dynamics in condensed matter

-TIMEX: ultrafast TIme-resolved studies of Matter under EXtreme and metastable conditions

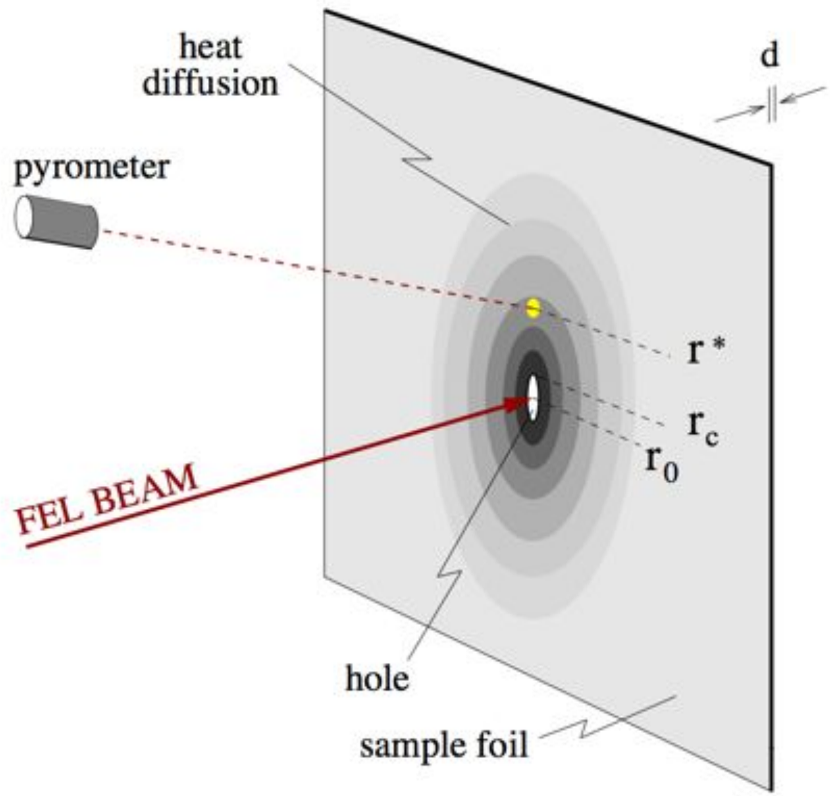
ref. C. Masciovecchio, F. Bencivenga, A. Di Cicco, E. Principi, R. Cucini…

TIMEX: ultrafast TIme-resolved studies of Matter under EXtreme and metastable conditions

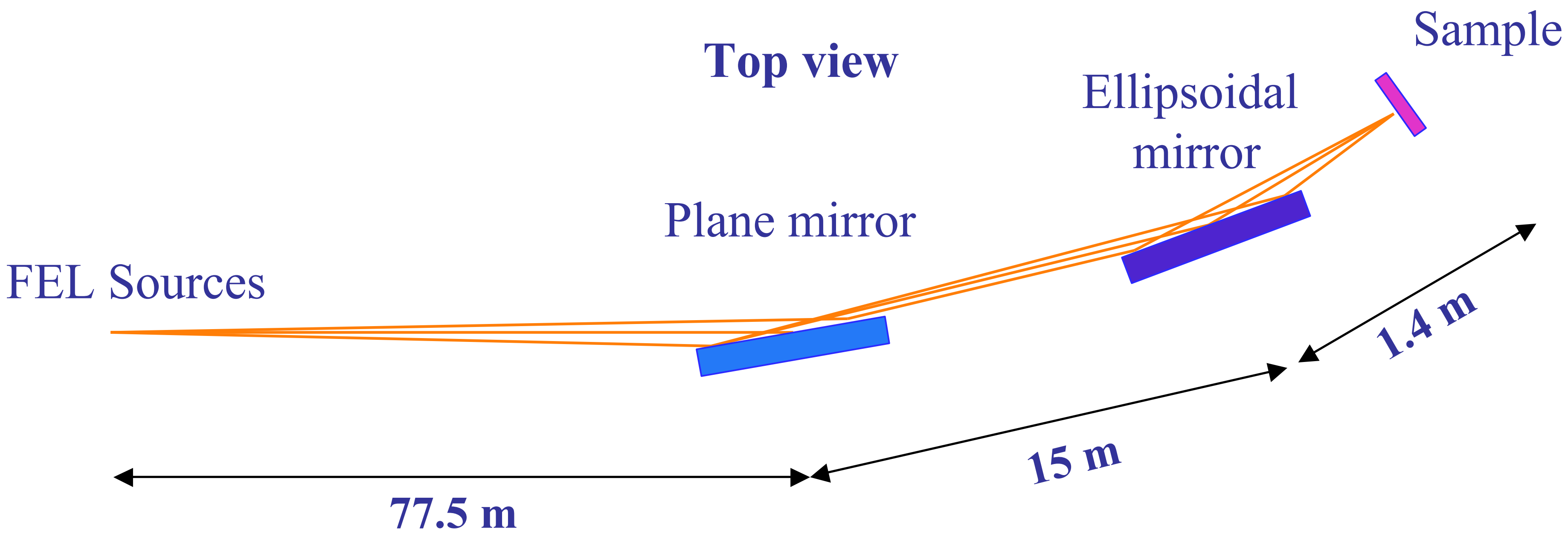
Main scientific goals:

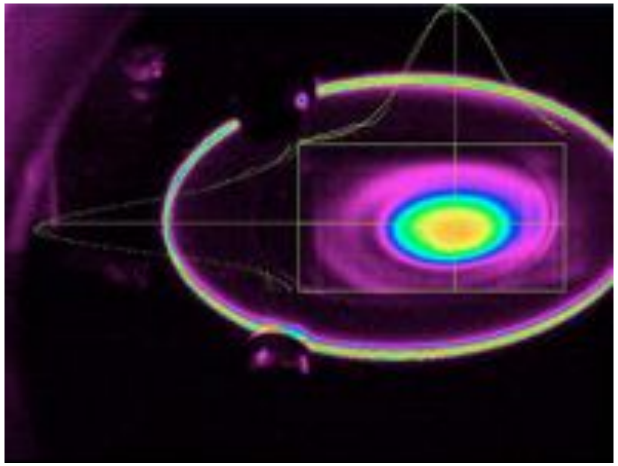
- ultrafast studies (conductance, reflectivity, trasmission, scattering) of warm dense matter (WDM)

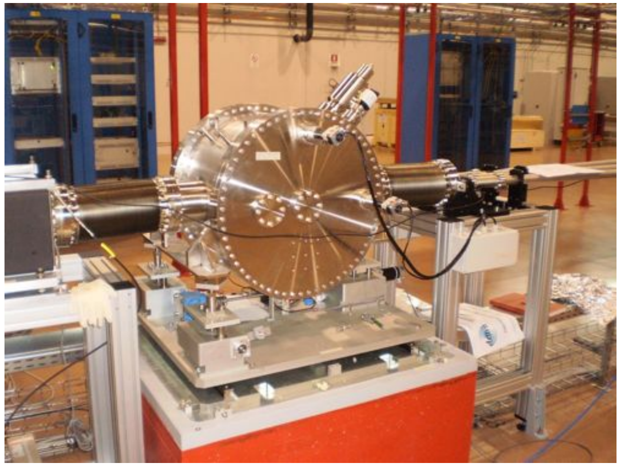
- transitions occurring in stable, metastable and excited states under extreme conditions



Beamline design







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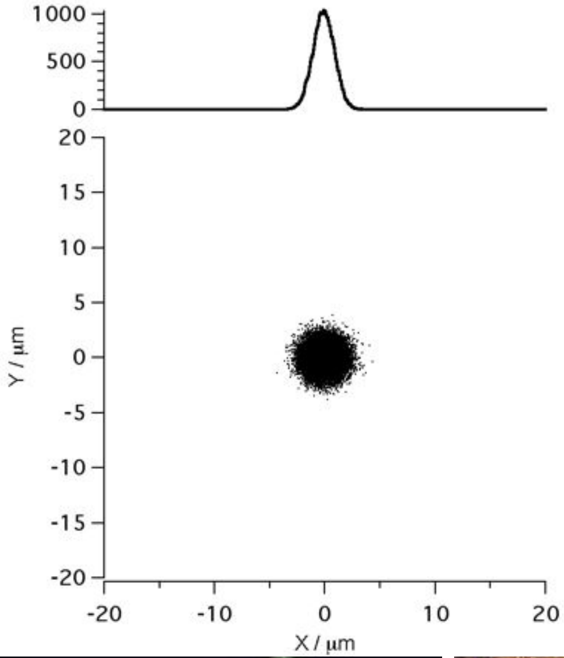
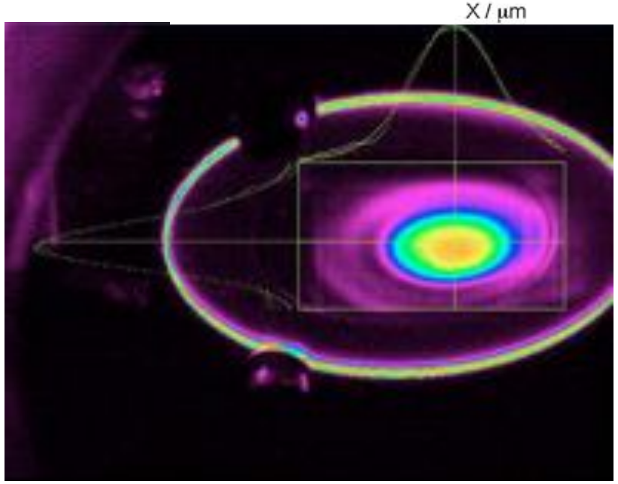
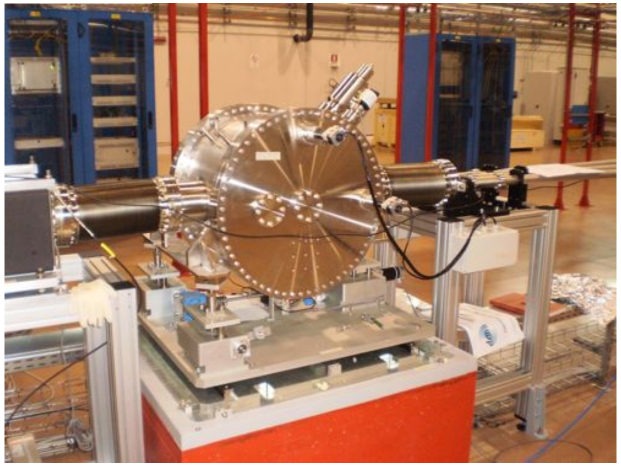


Expected a spot size ~ 3 µm

Up to 10^{17} W/cm^{2}





Beam-shaping

The natural spatial Gaussian distribution of the focused photon beam is not suitable for the TIMEX porpuses

?

Need for a versatile beam-shaping system

In the VUV/soft X-ray range the beam-shaping is possible by using reflective elements with peculiar shapes

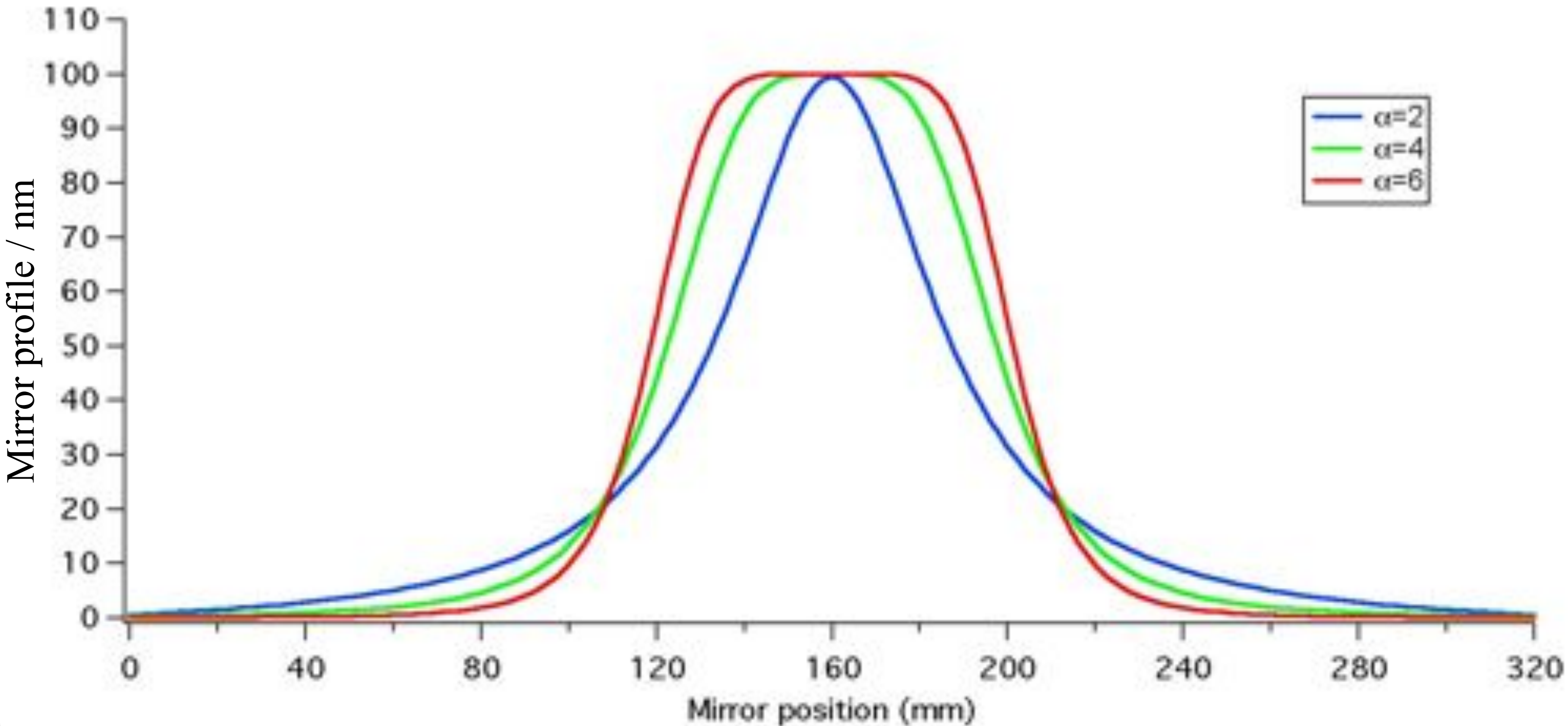
!

Use a bendable-plane mirror as an active optics

"Lorentzian-like" mirror's shape

$$L_\alpha(A,\gamma,x_0) = \frac{A\gamma^{\alpha-1}}{\pi\left[(x-x_0)^\alpha + \gamma^\alpha\right]}$$

A=amplitude
x_0=center of simmetry
γ=scale parameter (HWHM)
α=slope-parameter



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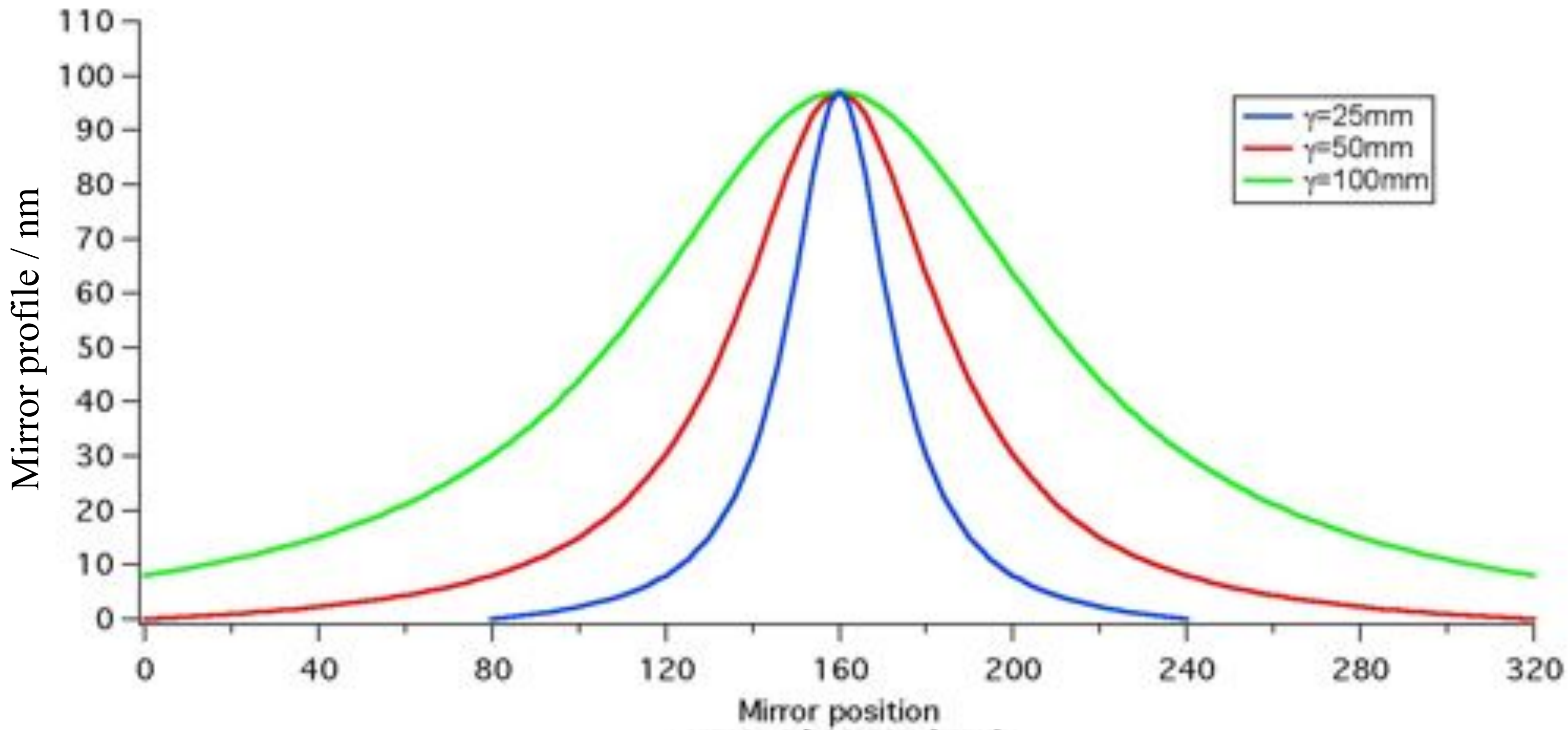

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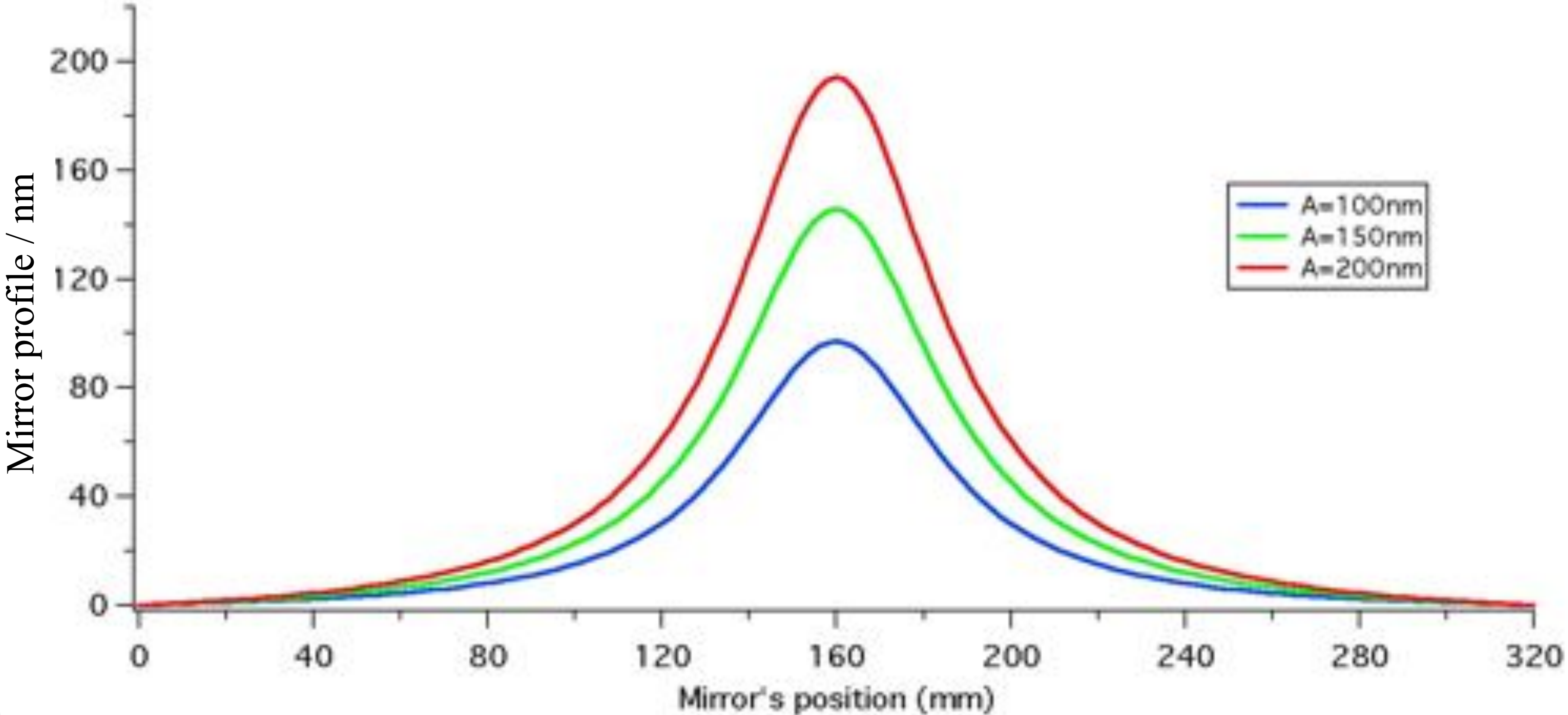
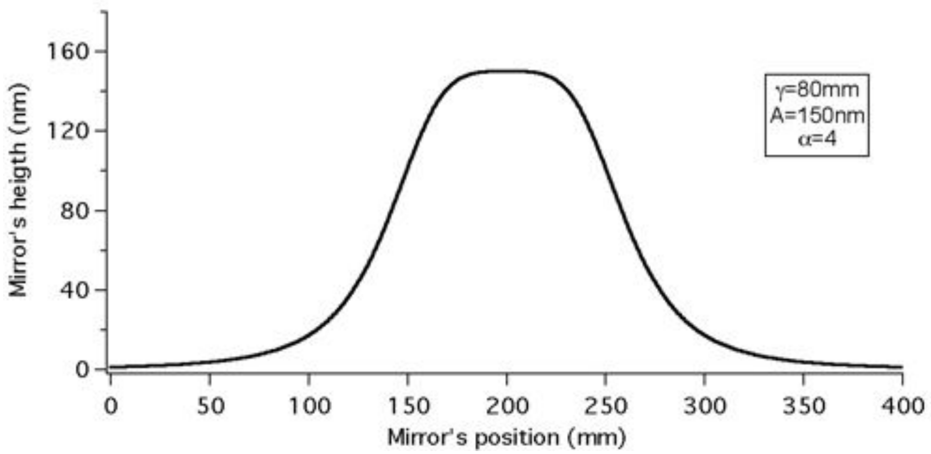
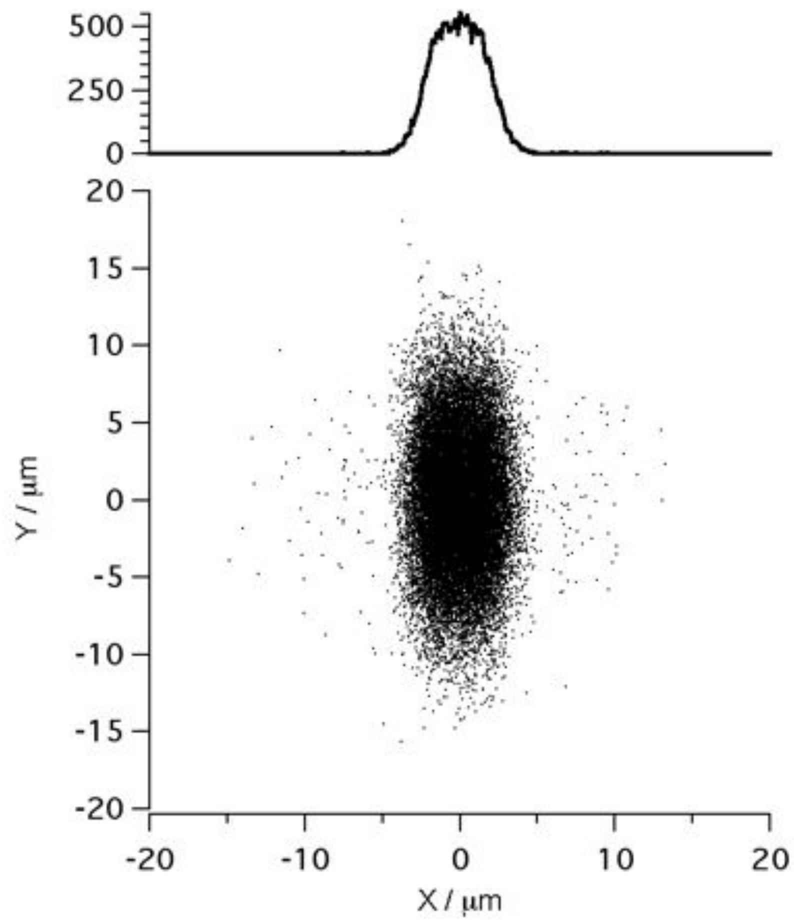


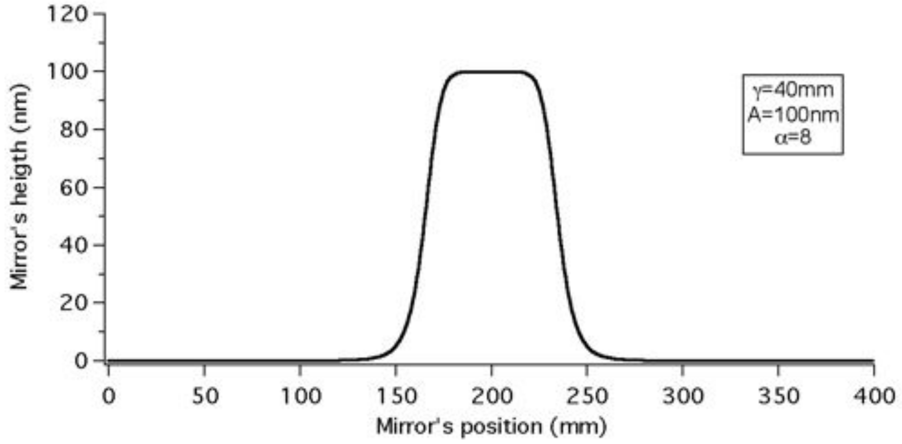
Almost **Flat-top** spot for irradiating the sample uniformly

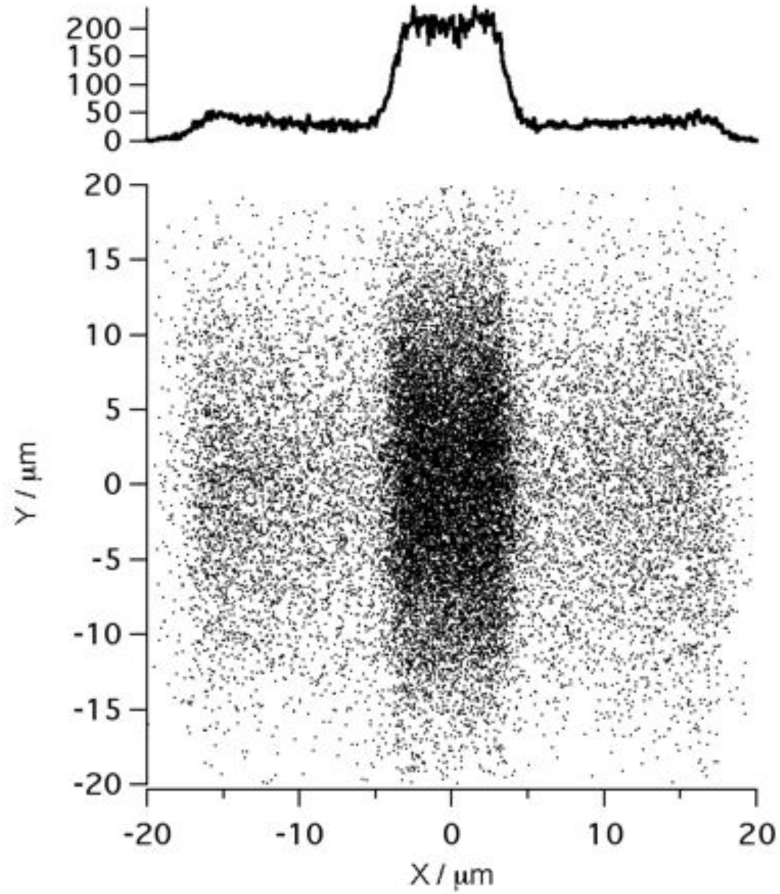


γ=80 mm, α=4 , A=150 nm



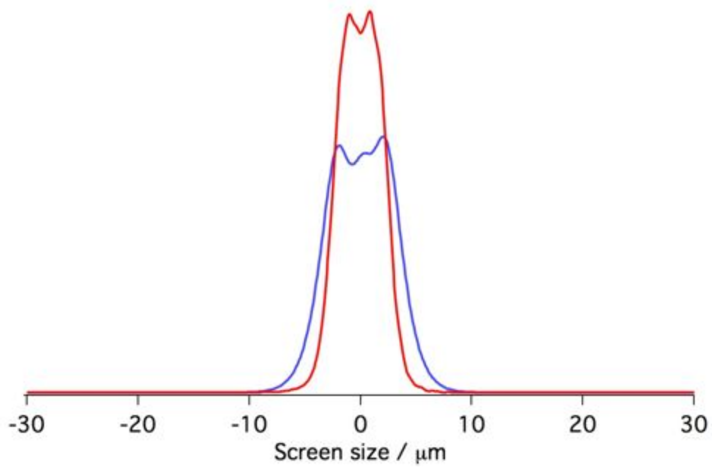
Flat-top spot with tales for irradiating the sample and probing the temperature with a pyrometer



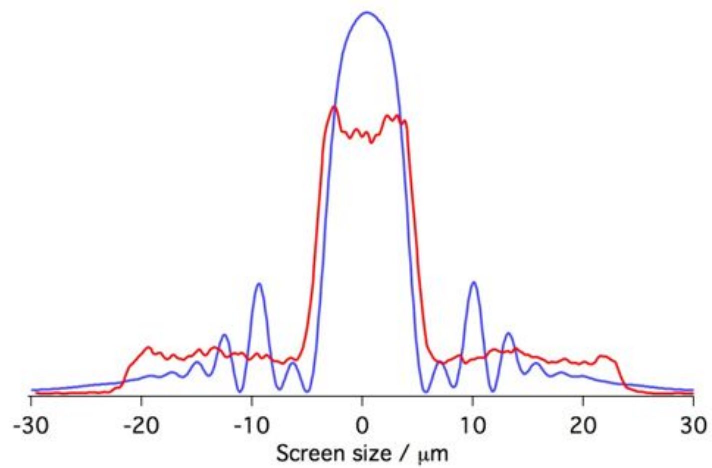


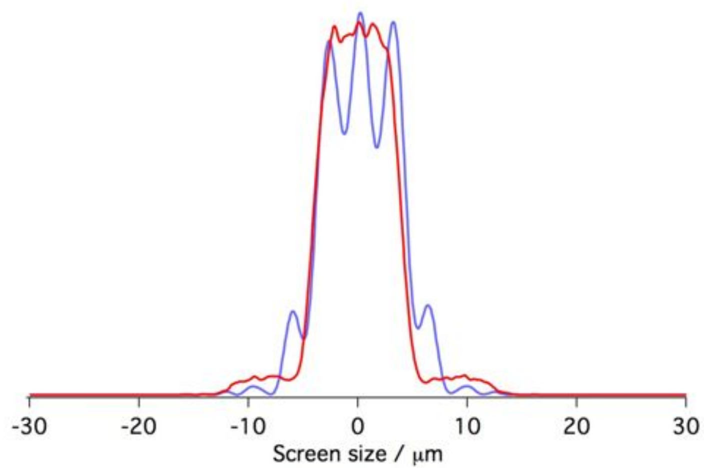
γ=40 mm, α=8 , A=100 nm

Ray tracing Vs wavefront propagation



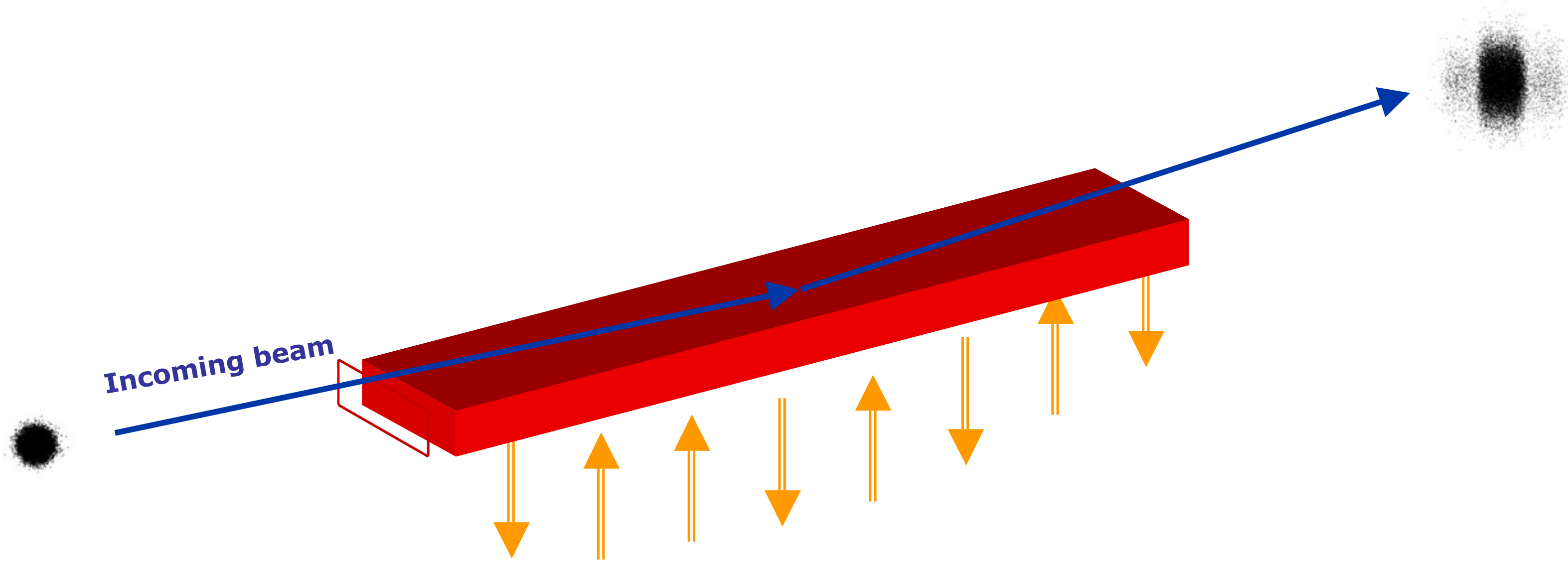
— Ray tracing (Shadow)
— Wavefront propagation (RSC)





The active mirror

The sides of the mirror are clamped and the shape is changed due to the effect of the applied forces below the substrate

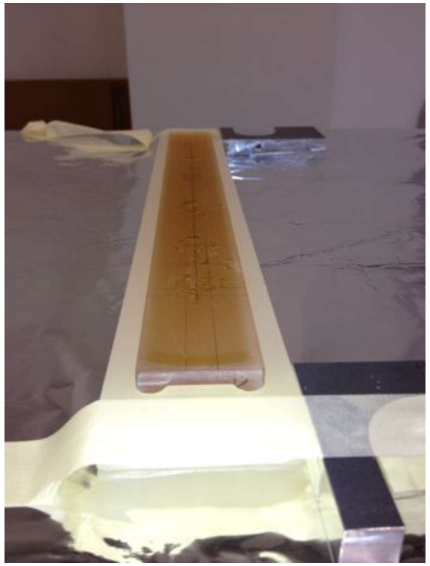


13 Piezo-actuators glued on the bottom of the mirror's substrate

The active mirror

Substrate
400 mm x 40 mm x 10 mm

Optical area
360 mm x 20 mm

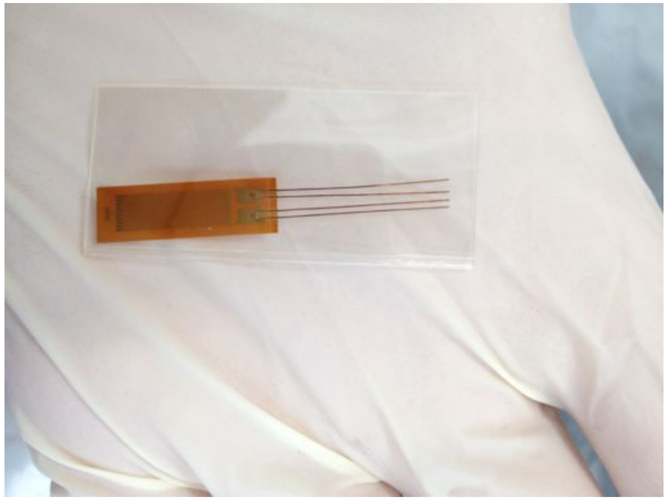


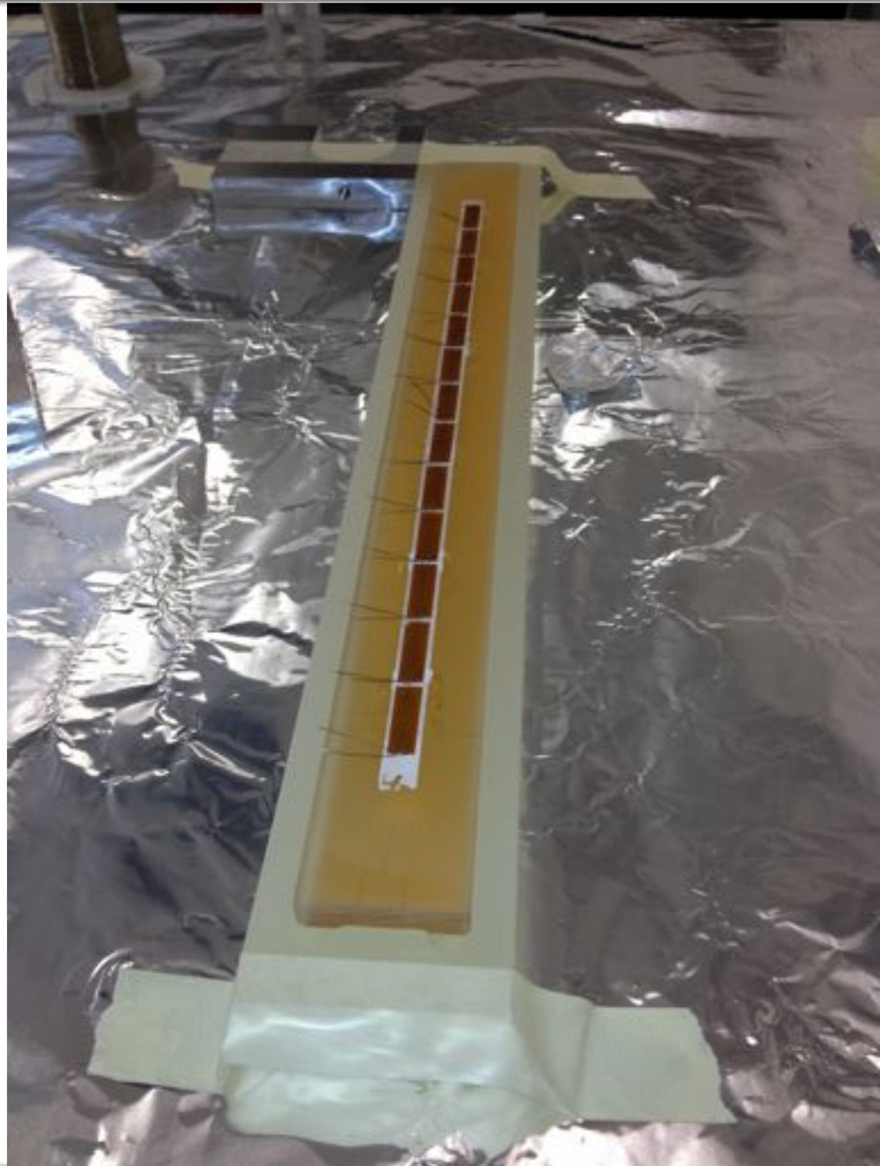
Residual slope errors (after best sphere subtraction):
Tang. < 0.5 μrad rms, Sag. < 5 μrad rms (within 70 mm length)

Micro roughness < 0.3 nm rms

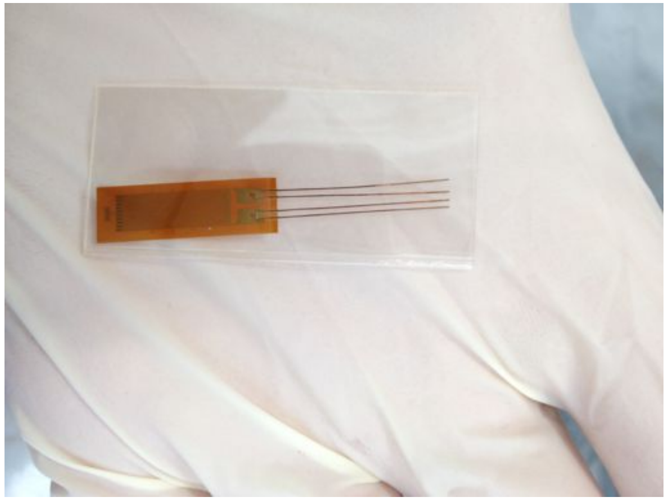
Coating: Gold 50 nm

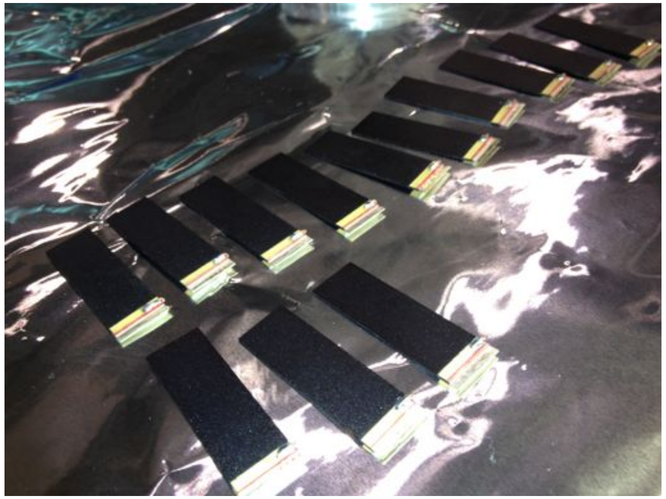
Straing-gauges and piezo





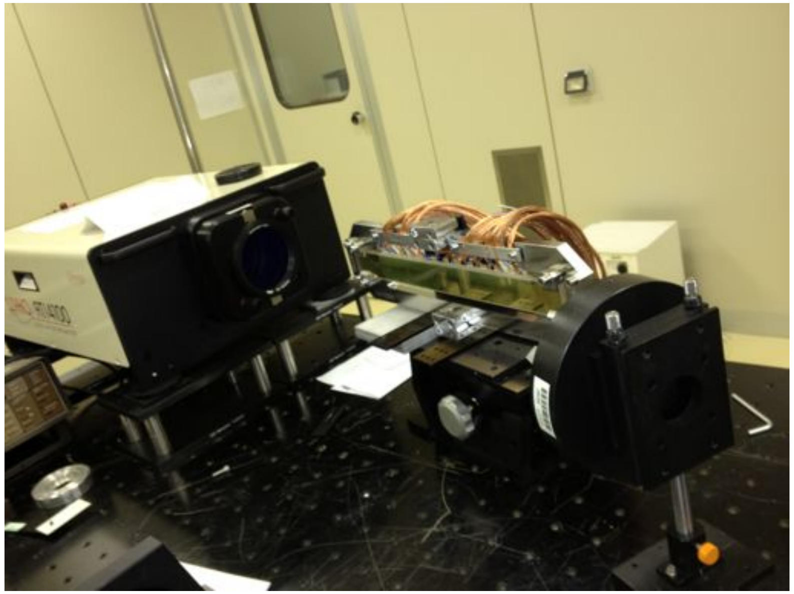
Straing-gauges and piezo

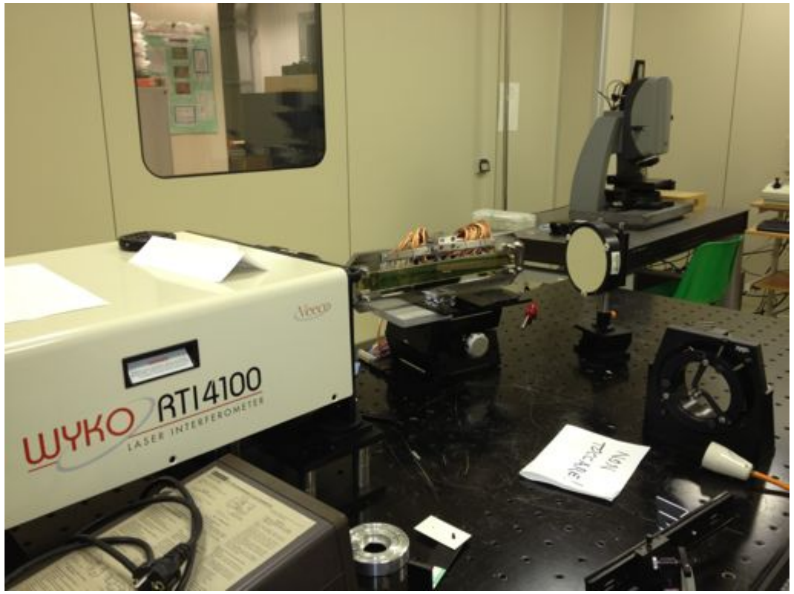




Straing-gauges and piezo

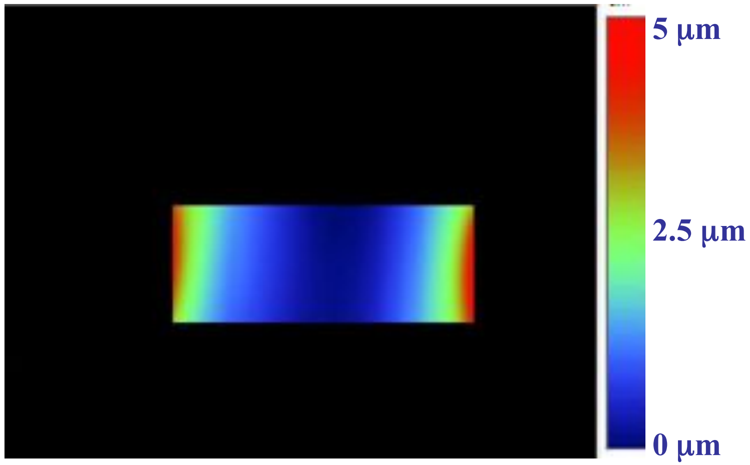
Metrology results





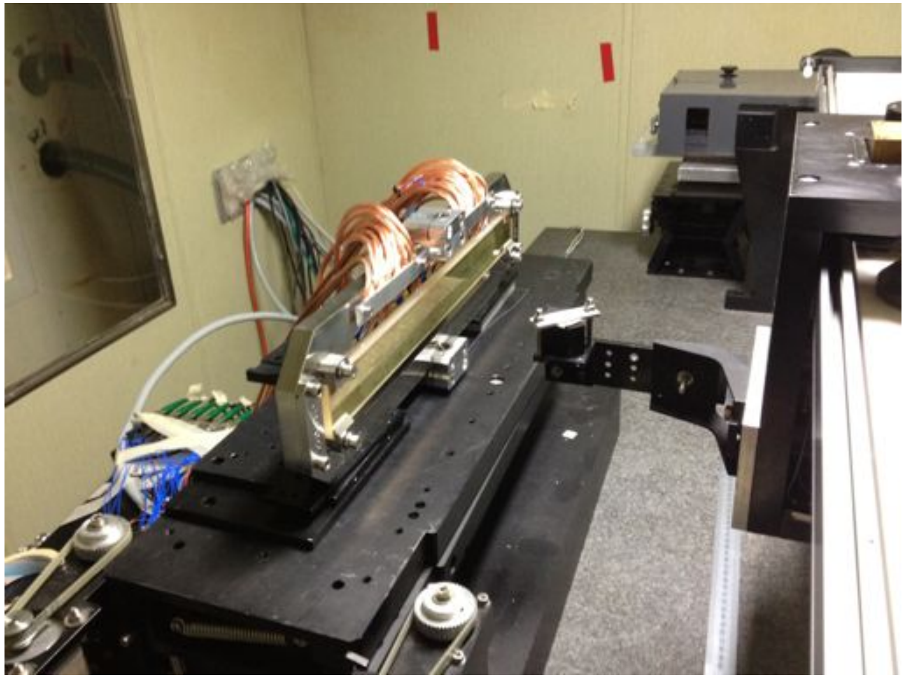
Central part (300 mm)

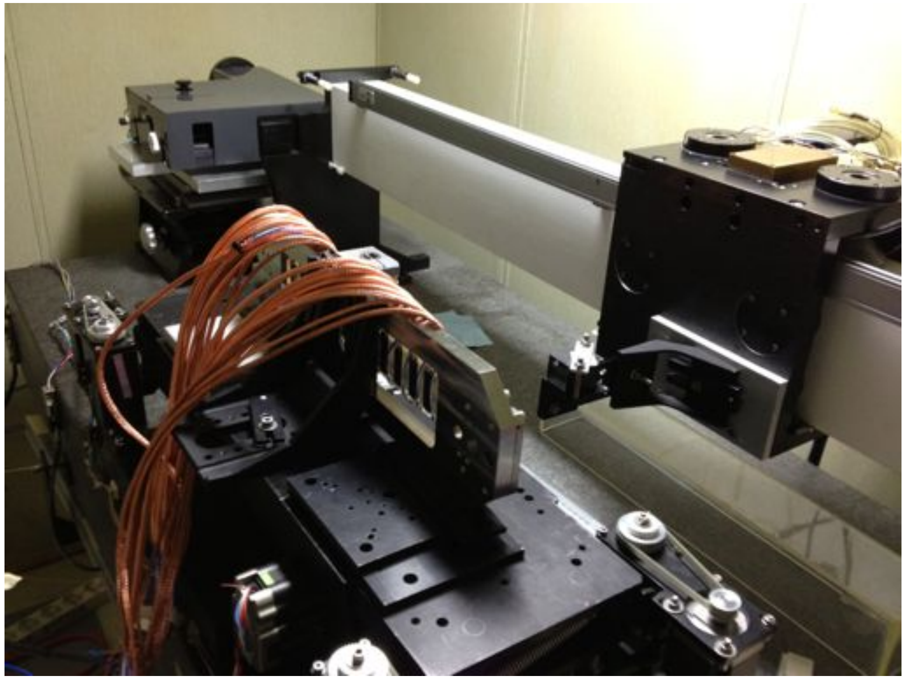
$P_tV = 2\ \mu m$



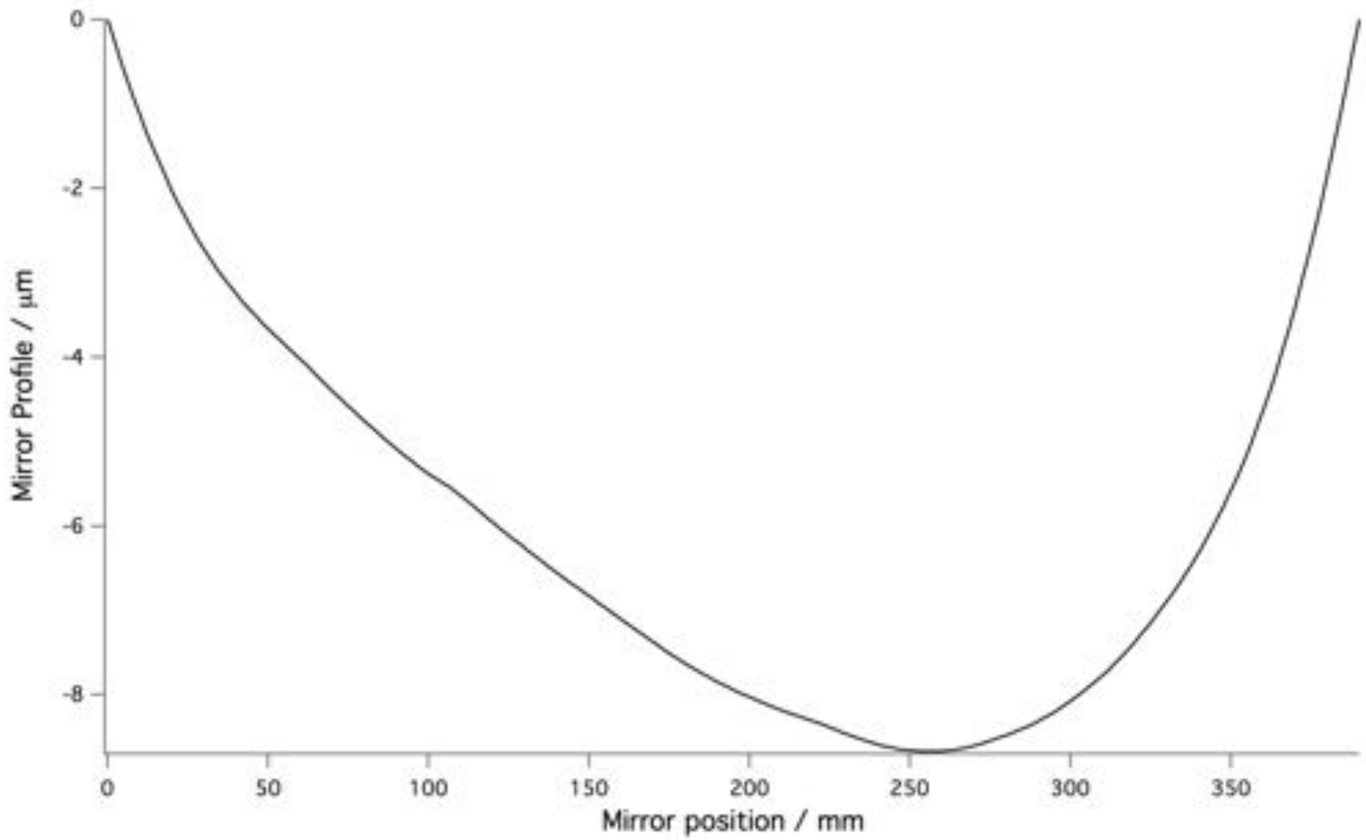
Torsion free

Metrology results LTP





Metrology results LTP



Central part (300 mm) P_tV = 4.5 µm

ACT

The Adaptive Correction Tool (ACT) calculates

- the iteraction matrix for a bimorph mirror with N piezos

-the voltage to apply to the piezo-actuators in order to obtain the desired mirror profile

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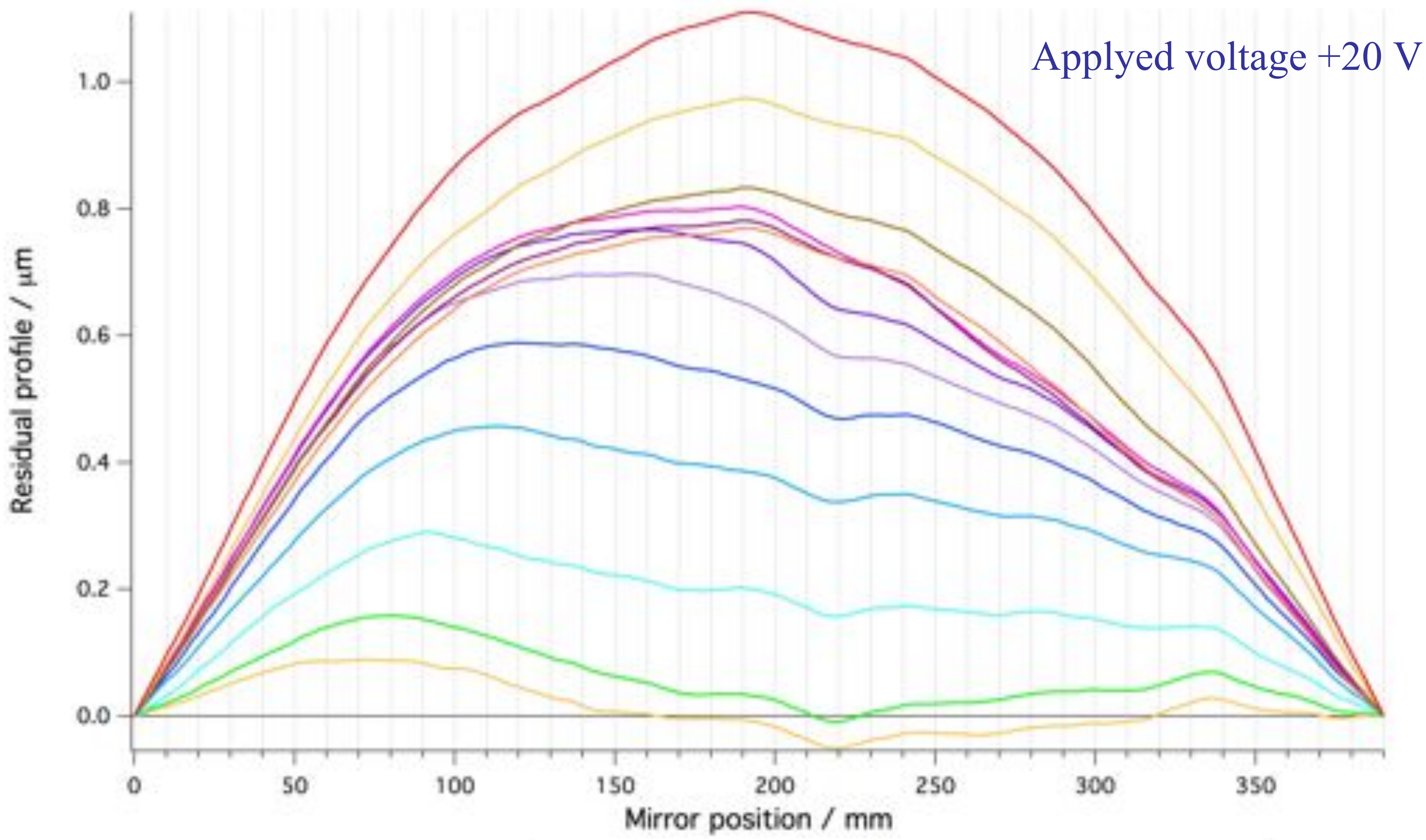
Adaptive Correction Tool

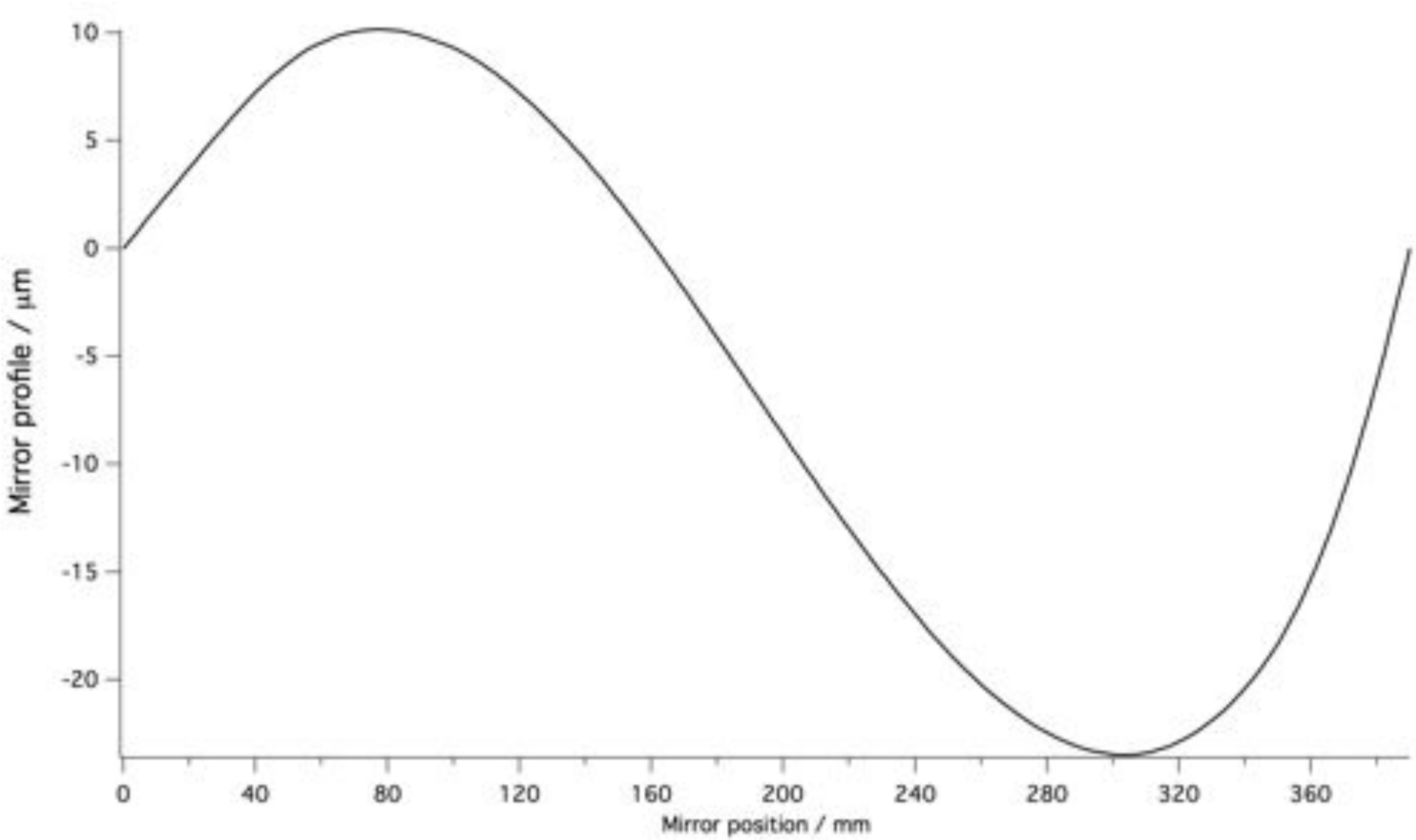
CH.	Voltage Correction
00	-12.4 V
01	-13.7 V
02	-2.6 V
03	-10.1 V
04	+4.6 V
05	-4.7 V
06	+16.6 V
07	+1.1 V
08	-9.1 V
09	-8.2 V
10	-9.8 V
11	-8.3 V
12	-7.0 V

ACT



Applyed voltage +20 V
Residual profile / µm
1.0
0.8
0.6
0.4
0.2
0.0
0
50
100
150
200
250
300
350
Mirror position / mm

Metrology results LTP



$P_tV \sim 34$ µm !!!!!!!

Metrology results LTP

Summary and outlooks

Performed both ray tracing and wavefront propagation simulations

Mirror + Staing-gauges and piezo actuators work fine

Design a brand new holder (suggestions are very welcome)

We will use the same scheme for the KB system for correcting the FEL wavefront deformations (L. Raimondi tomorrow morning)

TIMEX beamline will be operative in a temporary configuration for the first user dedicated beamtime

Thank you for your attention!

Colleagues and collaborators

F. Bencivenga, R. Borghes, G. Bortoletto, C. Callegari, M. Cautero, F. Cianciosi, R. Cucini, D. Cocco, F. D'Amico, A. Di Cicco, N. Mahne, C. Masciovecchio, E. Principi, L. Raimondi, R. Sergo, D. Spiga, G. Sostero, M. Zangrando