ACTOP11 4th Workshop on Adaptive and Active X-ray & XUV Optics

FERMI@Elettra Free Electron Laser: First commissioning results and active optics project

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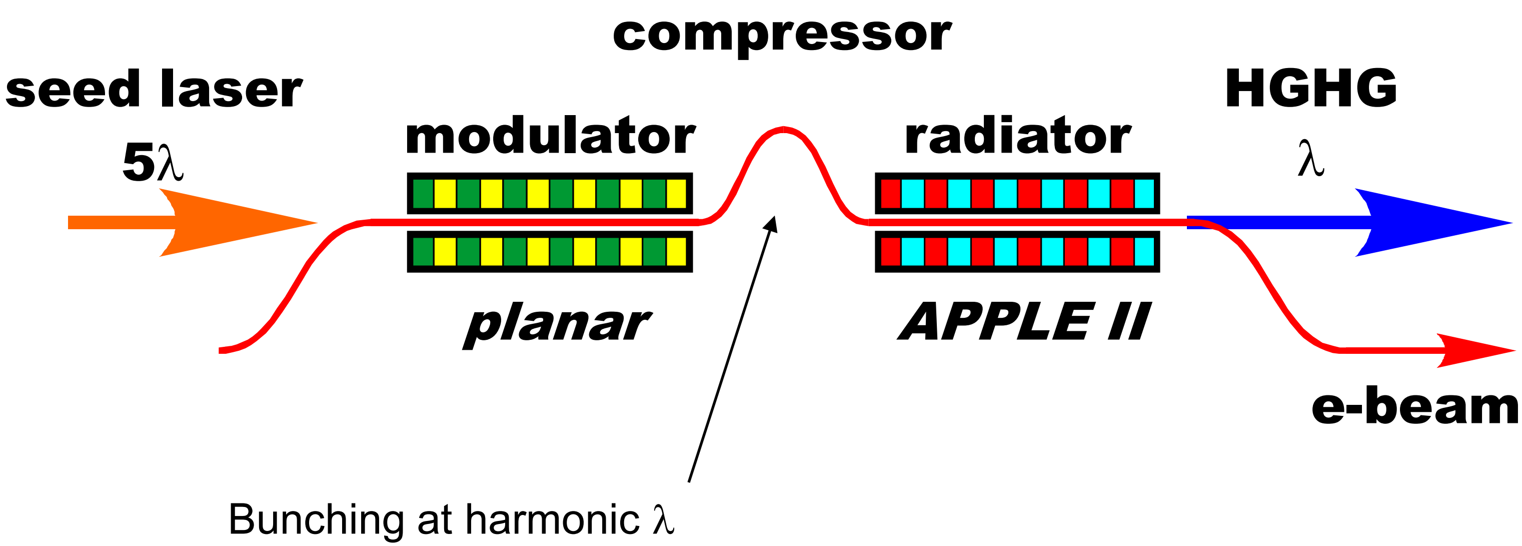
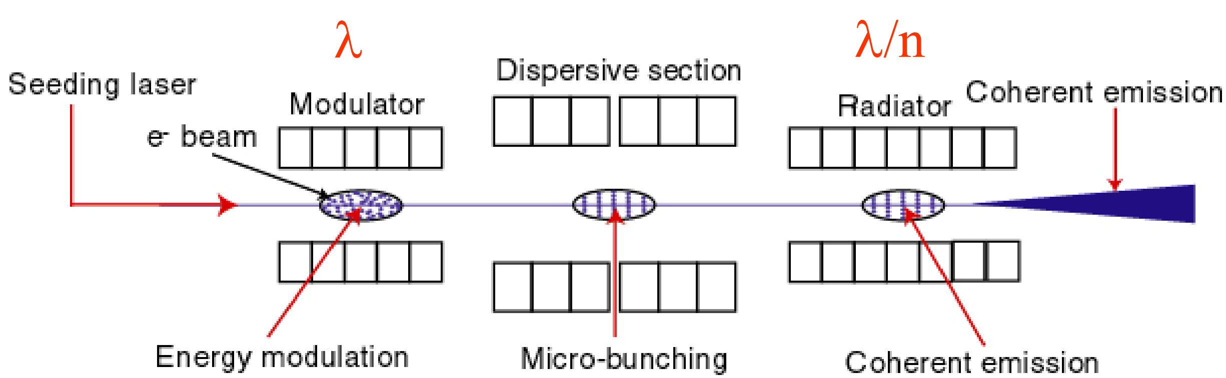
4^{th} – 5^{th} April 2011
Diamond Light Source, Oxfordshire, UK

The Fermi project

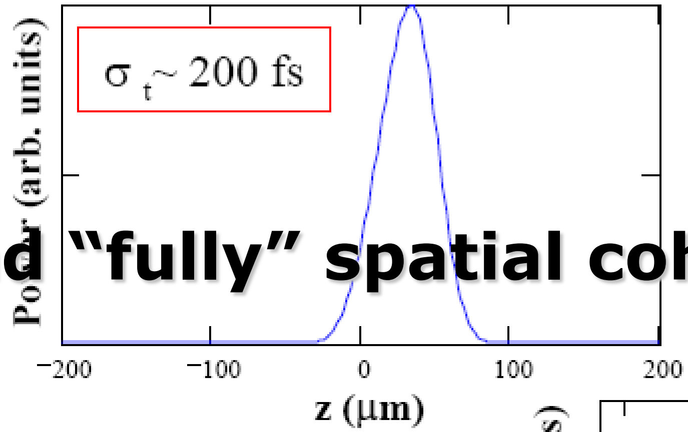
High Gain Harmonic Generation





Performances

Pulse profile

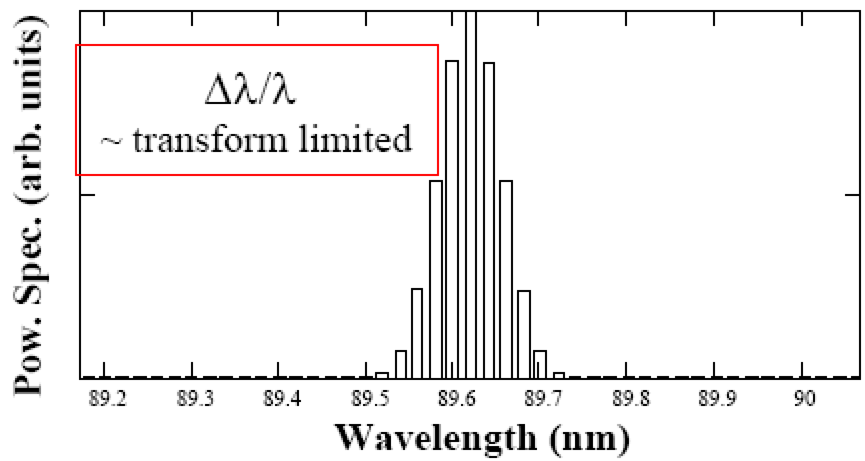


Pulse length ~ bunch length
"Clean" (~ transform limited) spectrum

$\omega\,\tau \approx 2\,\pi$

… and "fully" spatial coherent

Spectrum profile



With a pulse length of 200 fs one gets (after 16.5 m)
~10^{14} photons/pulse

Peak brillance ~ **10^{31}** Photons/s/mm^2/mrad^2/0.1%bw

FEL 1 and FEL 2 Output Characteristics

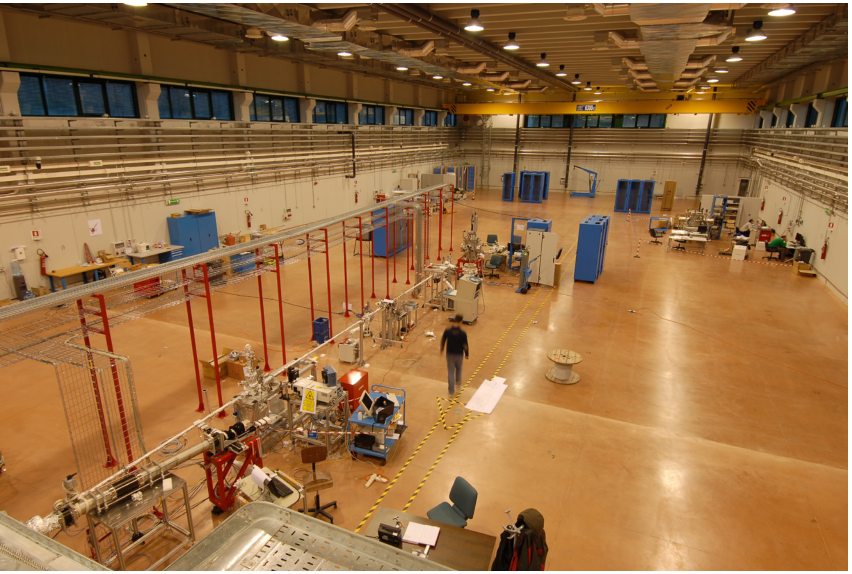
QuickTime™ e un
decompressore
sono necessari per visualizzare quest'immagine.

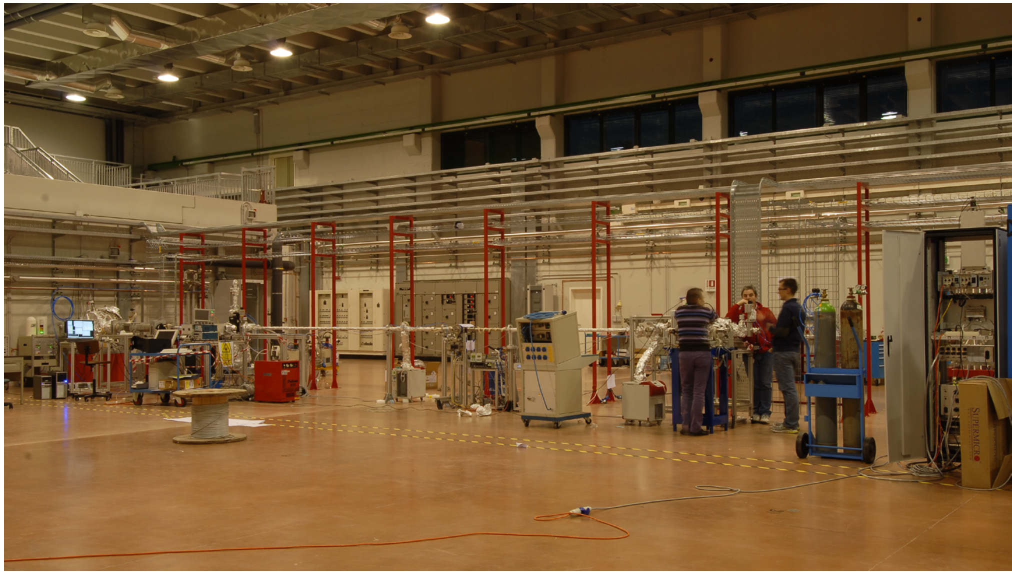
Courtesy by E. Allaria, W. Fawley

Actual Status

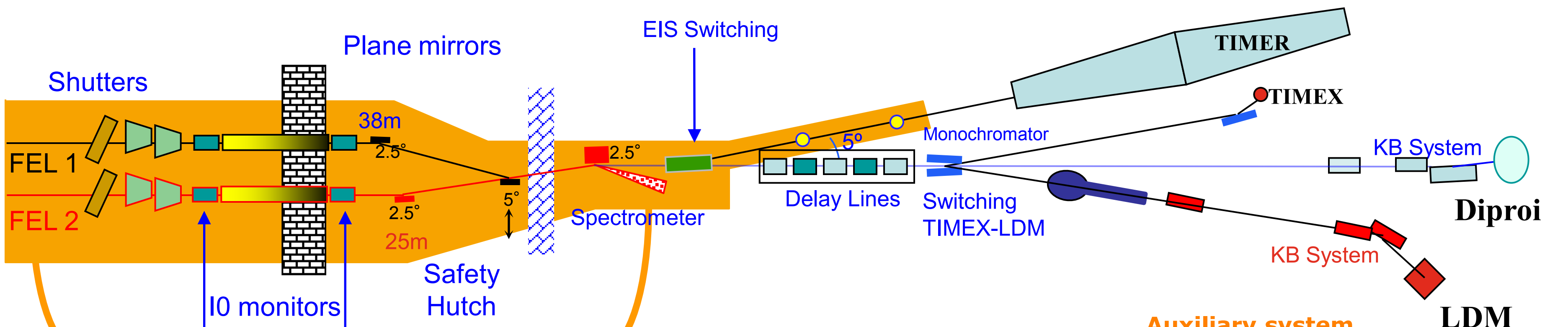
6 Runs of beam already performed
Run 6 finished yesterday

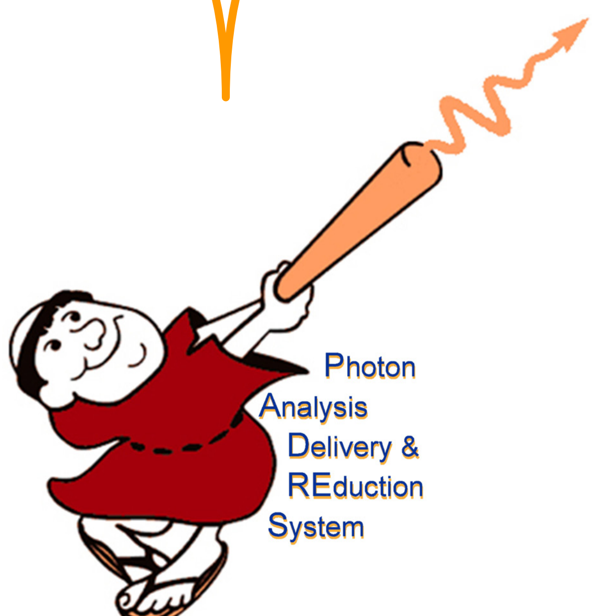
4 (1-4) runs dedicated to Linac
1 run dedicated to Linac + Undulator (oct-dec 2010)
(last week of run 5 dedicated to photon transport)
last day of run 5 the first HHG seed FEL radiation spectra collected
1 run (run 6) dedicated to FEL generation and characterization
Last days dedicated to the first experiments.





PADReS





Auxiliary system

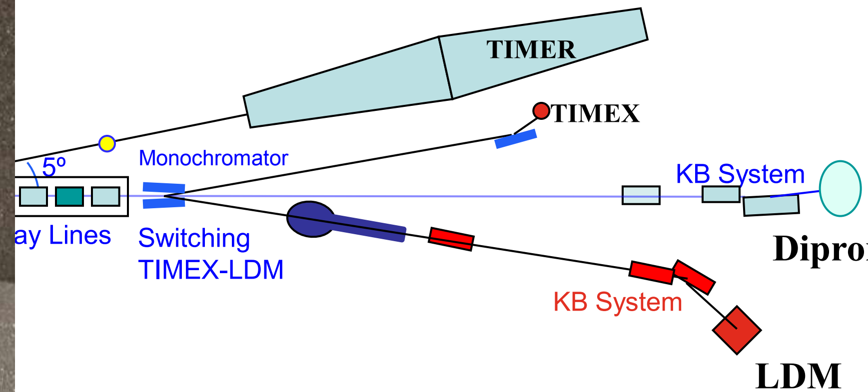
User facilities

Invasive diagnostics

On line (S2S) diagnostics

Shutters/Valves
Beam defining apertures
Beam position monitors
On line Intensity monitors
Differential pumping
Gas reduction system
Radiation protection optical system
Switching - selecting mirrors
On line photon spectrometer
Coherence measurement system
YAG-photodiode chambers
Fast shutter

Intensity Monitors



on the atomic photo-ionization
are gas at low particle density
(Neon, Xenon or Nitrogen)

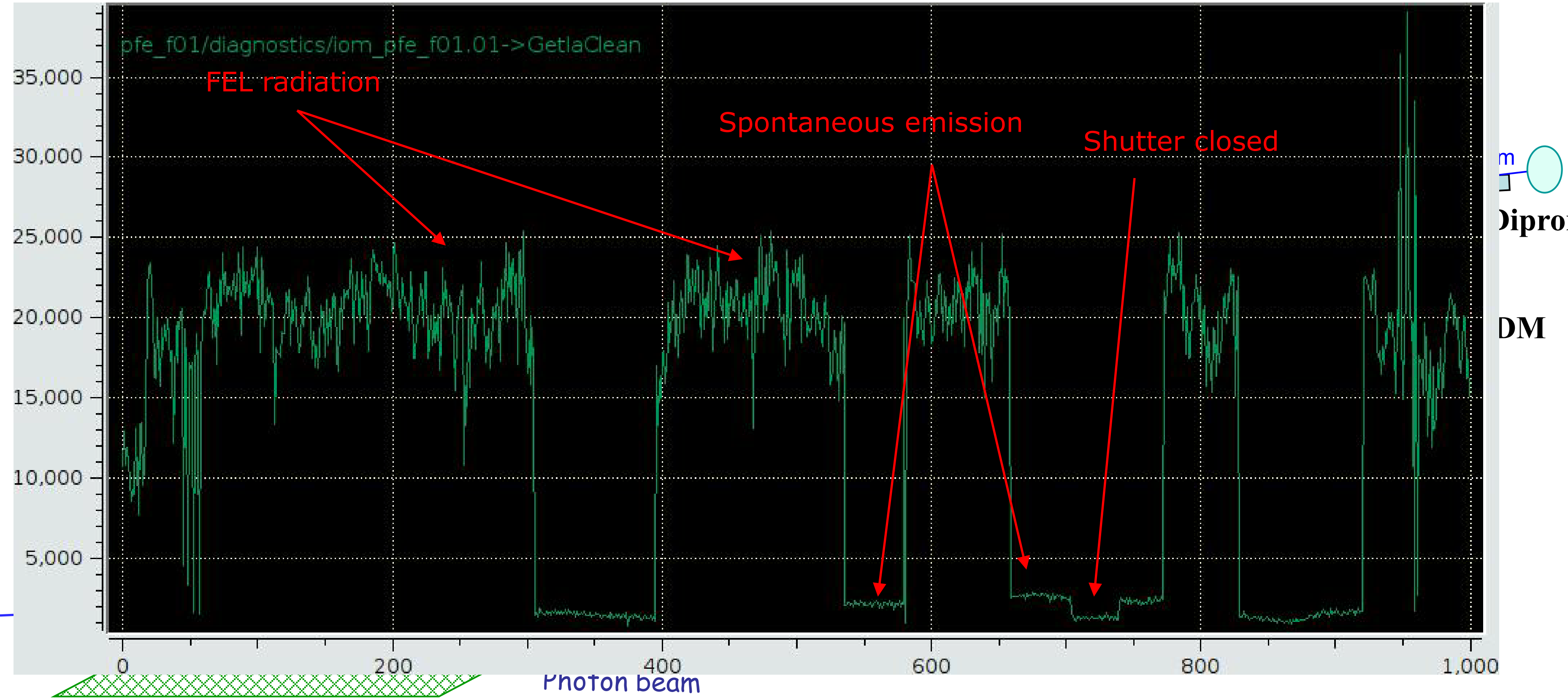
MAIN FEATURES
- ULTRA-WIDE INPUT CURRENT RANGE **(from ±140 fA up to ±10 mA)**
- 1, 2, 4-CHANNEL MONITORING
- MULTIRESOLUTION
  - o 16-BIT MODE
  - o 24-BIT MODE
- LOW NOISE (3 ppm of Full Scale)
- LOW DRIFT (3 ppm/° C)

eam

Reading current, it is possible to derive the absolute number of photons per pulse shot-by-shot

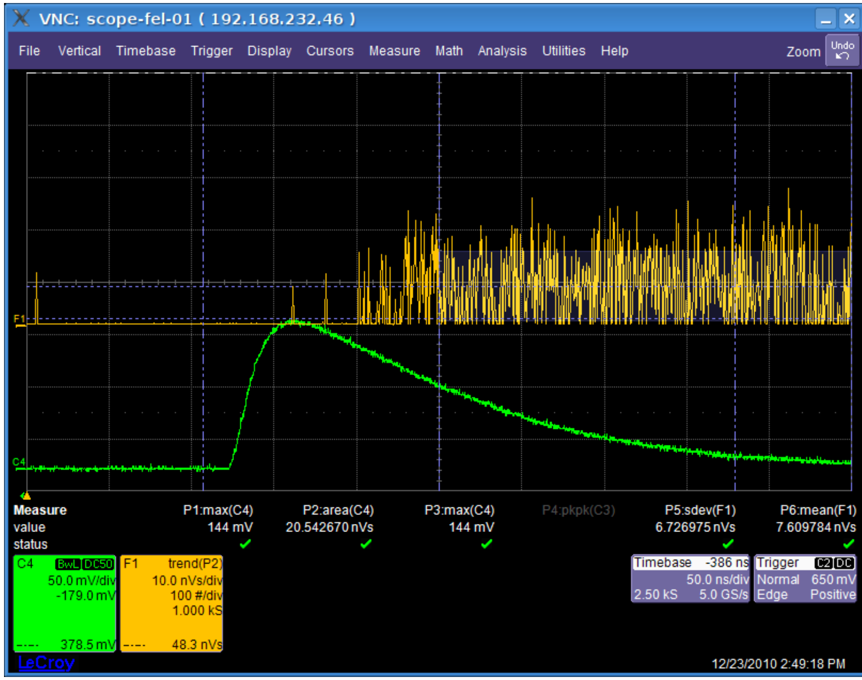
24-Bit, 40 ksample/s, 4-Channel, Low Noise, Wide Dynamic Range

Intensity Monitors

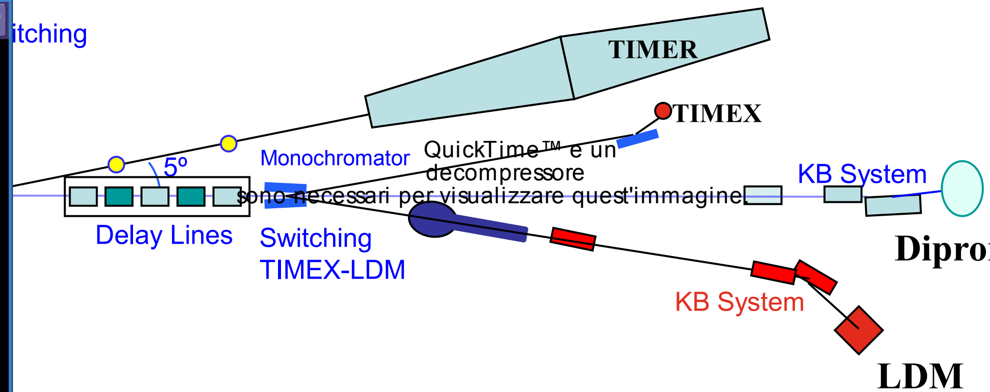


Applied Voltage (Bias)
\+ or - depending on tests/noise

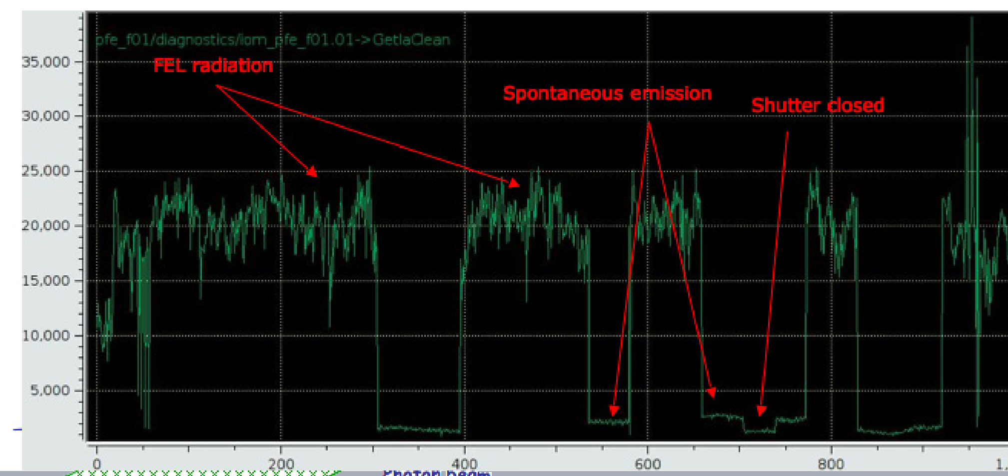
Intensity Monitors calibration



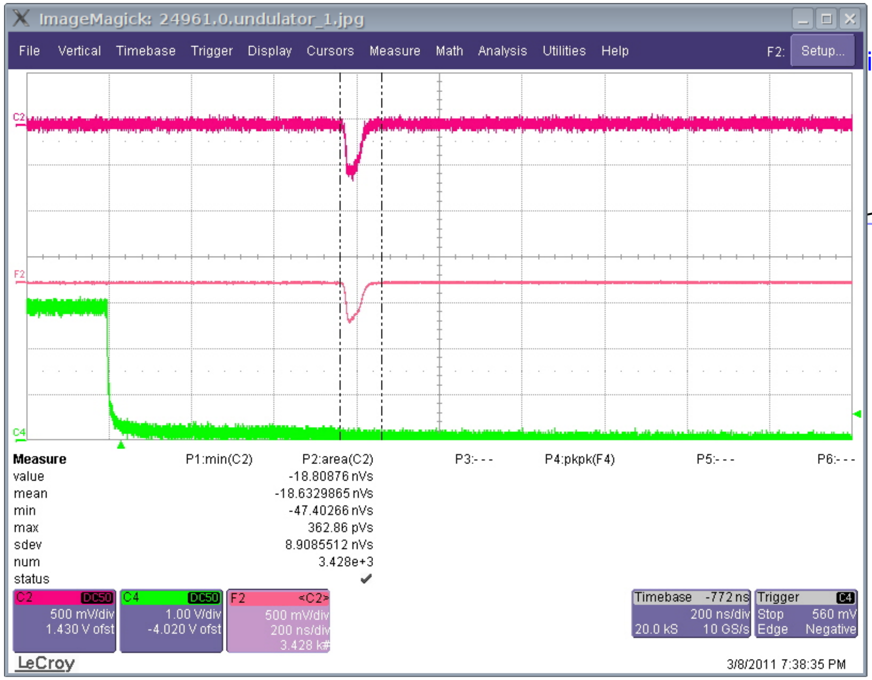
Triggered Photodiode measured via an oscilloscope

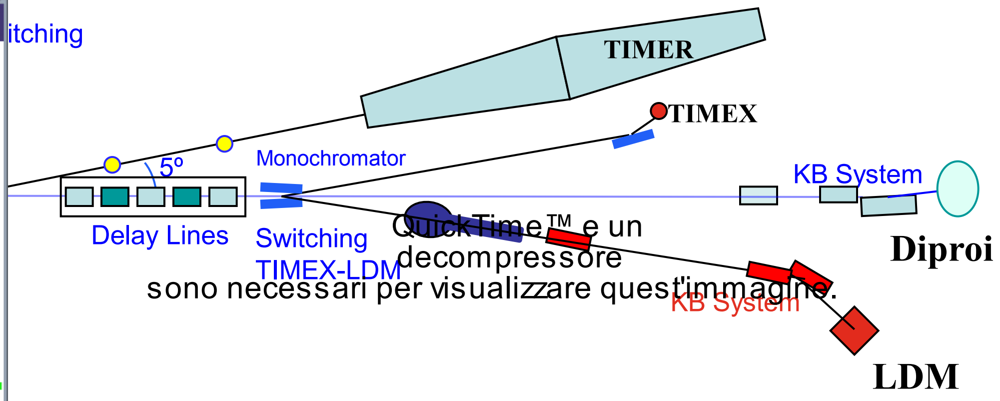


FERMI@Elettra: First coherent emission recorded (dec. 13th 2010)



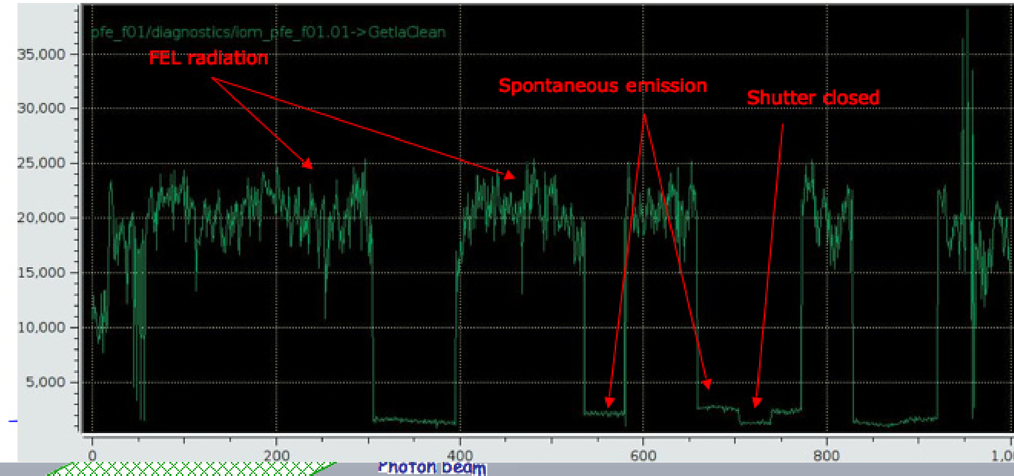
Intensity Monitors calibration



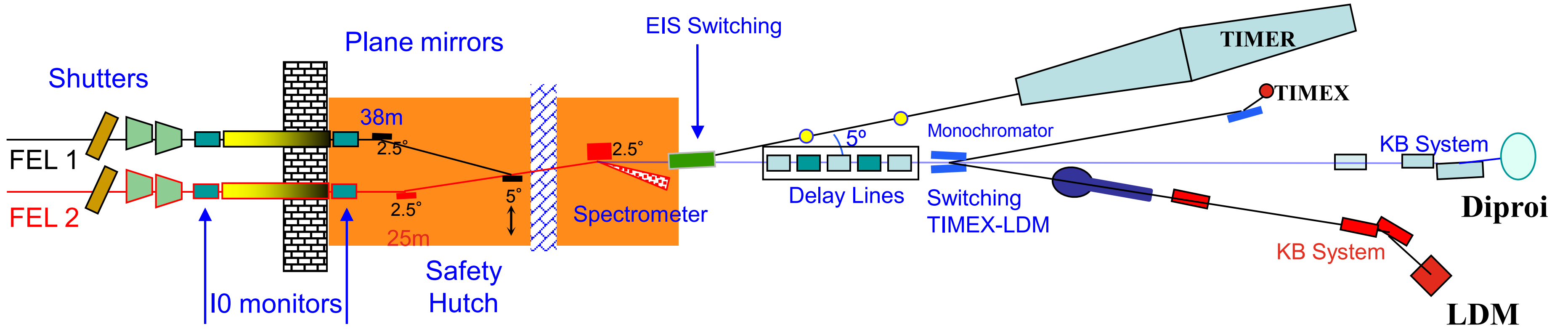


Triggered GMD measured via an oscilloscope DESY team march 2011 (Susanne Bonfigt, Barbara Keitel, Henning Kuehn, Michael Markert, Andrey Sorokin, Kai Tiedtke Svea Kapitzki Juray Krenpaski.)

Measured Intensity 10^11 ph/pulse at 65 nm.



PADReS optical transport system & diagnostic



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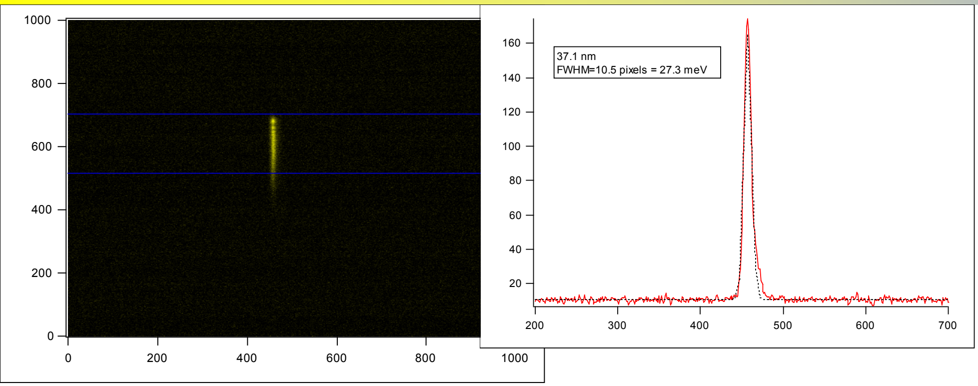
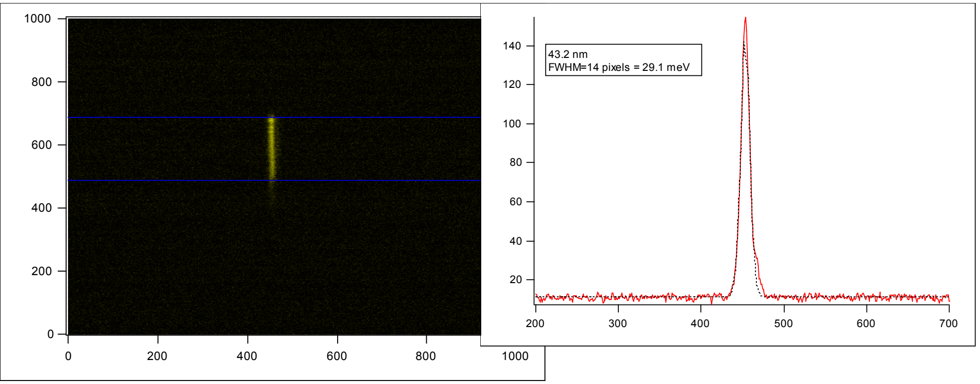
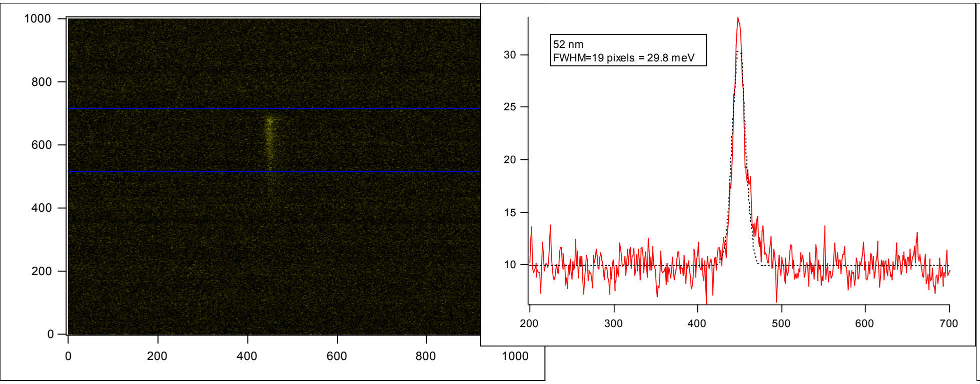
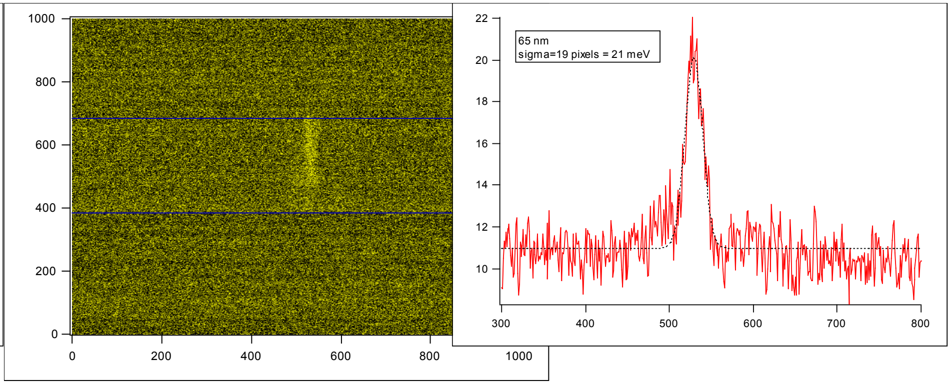
decompressore
sono necessari per visualizzare quest'immagine.

Measured HGHG Seeded-FEL spectrum

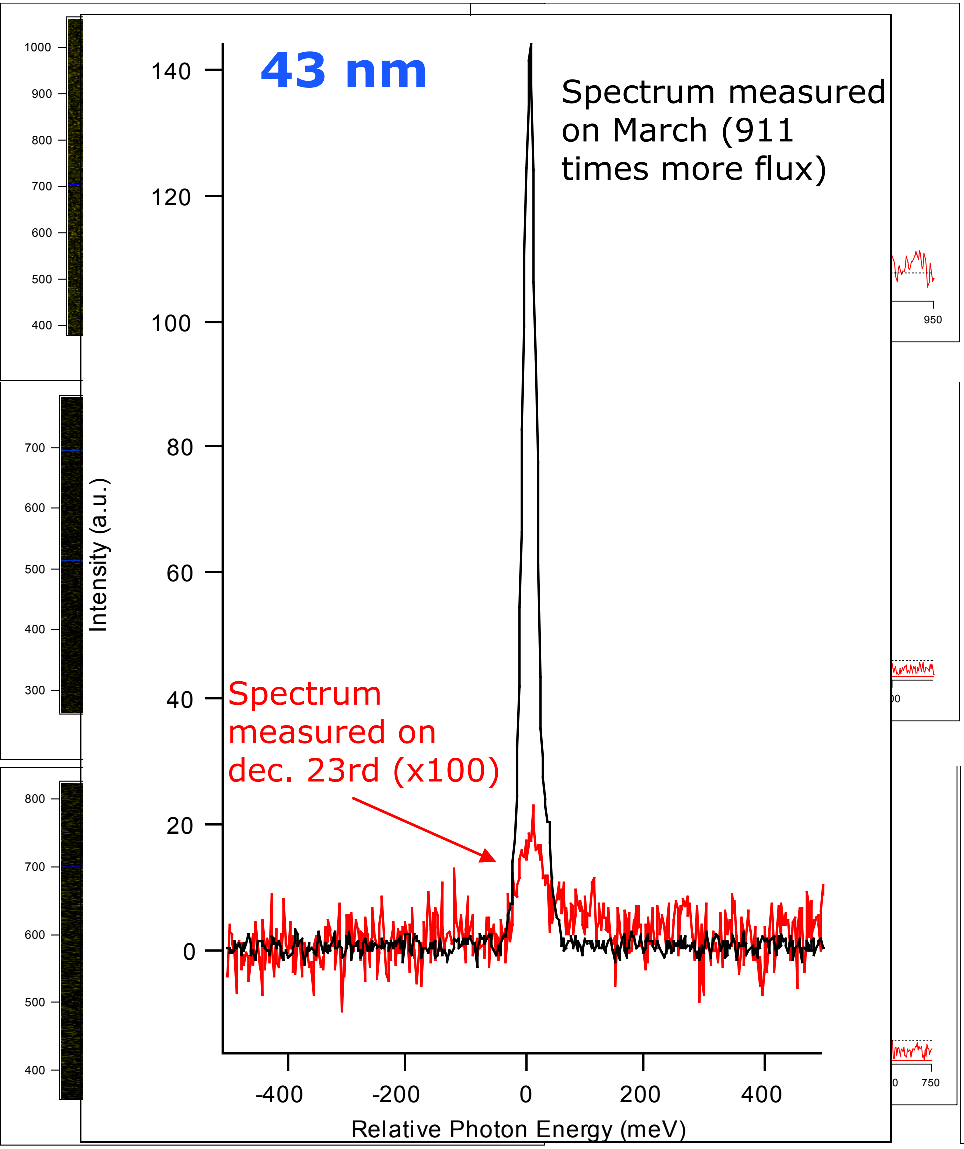






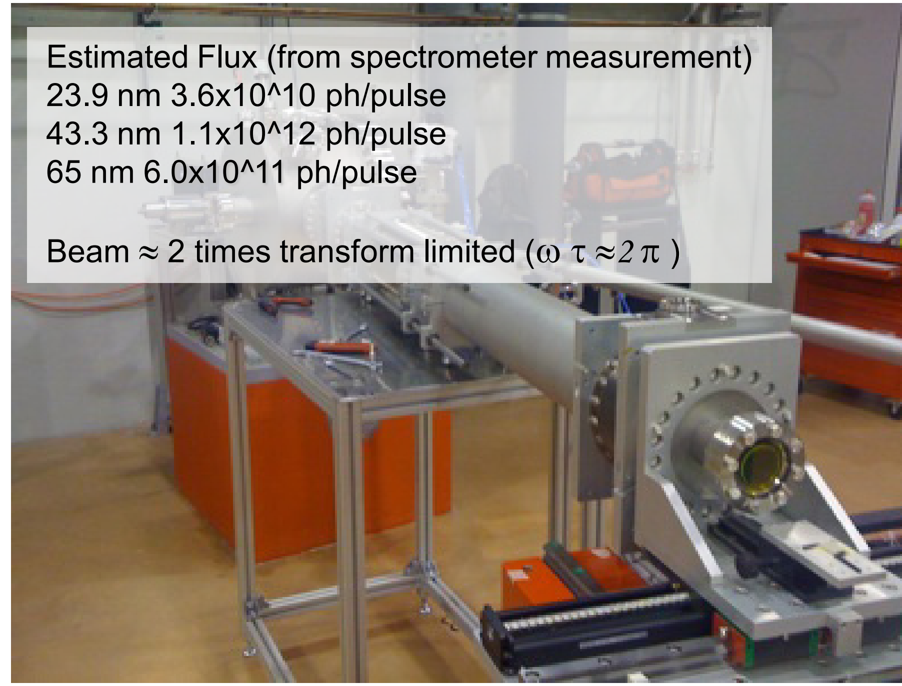


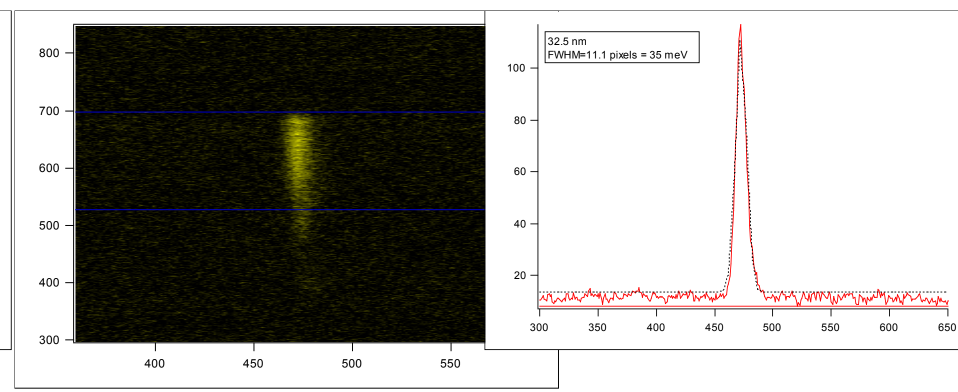
Measured HGHG Seeded-FEL spectrum



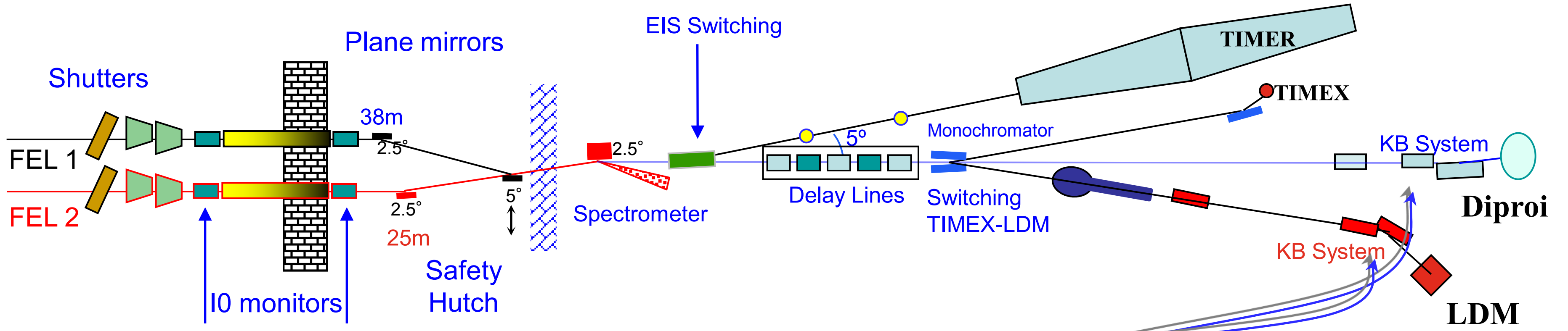
Estimated Flux (from spectrometer measurement)
23.9 nm 3.6x10^10 ph/pulse
43.3 nm 1.1x10^12 ph/pulse
65 nm 6.0x10^11 ph/pulse

Beam ≈ 2 times transform limited ($\omega\ \tau \approx 2\pi$)





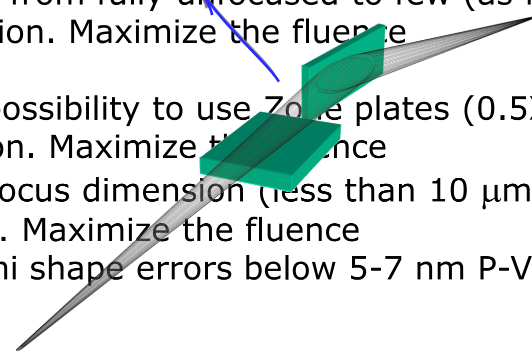
Toward the experimental stations



General requirements

- LDM
  - Spot as small as possible with variable dimension from fully unfocused to few (as few as possible) microns size. Wavefront and coherence preservation. Maximize the fluence
- DIPROI
  - Spot as small as possible (micron size) with the possibility to use Zone plates (0.5X0.5 mm^2 spot dimension). Wavefront and coherence preservation. Maximize the fluence
- TIMEX (have you attended the Svetina's talk?) "fixed" focus dimension (less than 10 μm possibly) with spot profile control (wavelength and experiment dependent). Maximize the fluence

  Wavefront/choerence preservation means at Fermi shape errors below 5-7 nm P-V



Starting conditions

Beam divergence (diffraction limited) from 100 μrad rms @ 80 nm to 5 μrad rms @ 4 nm.
Beam dimension after 80 m > 20 mm FWHM
Source sizes: 290 μm FWHM for FEL 1, 140 μm FWHM for FEL 2
Source distance variable as a function of electron beam energy, photon energy and FEL used.

Active optics project at Fermi

An R&D project started in late 2006 after first “future users meeting”

QuickTime™ e un decompressore sono necessari per visualizzare quest'immagine.

A preliminary result and the quasi-final user requirement was ready in the summer of 2008

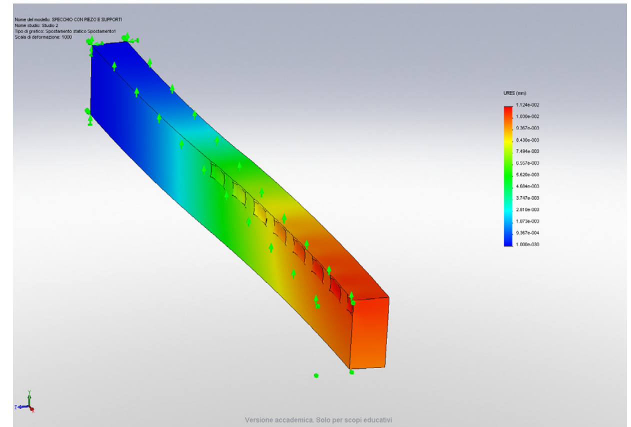
The first working prototype, using piezo patches was ready in the summer of 2009

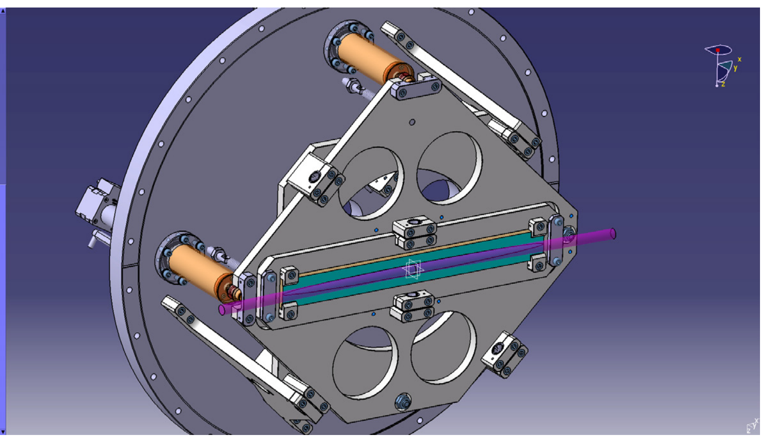
That’s was not good enough for our tight requirement but usable. A solution was found and, at the end we developed 3 different (even if similar) adaptive mirrors.

Integrated manpower dedicated ~ 5 months

Hard X-ray Version

QuickTime™ e un decompressore
sono necessari per visualizzare quest'immagine.





Spot shaping mirror

Mirror dependency

Mirror dimension

Length 400 mm (possible from 250 to 600 mm) Useful 380 mm

Width 40 mm (possible from 35 to 50 mm) Useful 20 mm

Possible shape obtainable:

Spherical shapes: From Flat (R=°) to R = 60 m (on the 400 mm long mirror).

Lower radius can be achieved with extra cost (strongest motors)

Asymmetry up to 1 μm P-V equivalent to any ellipsoidal mirror with minimum focal distance of 1.2-1.4 m at 0.3□grazing angle of incidence.

Shape error below 5 nm P-V, slope errors below 0.5 μrad rms. Roughness below 0.2 nm rms.

Minimum controllable mirror deformation: 0.5 nm on 4 cm spatial period.

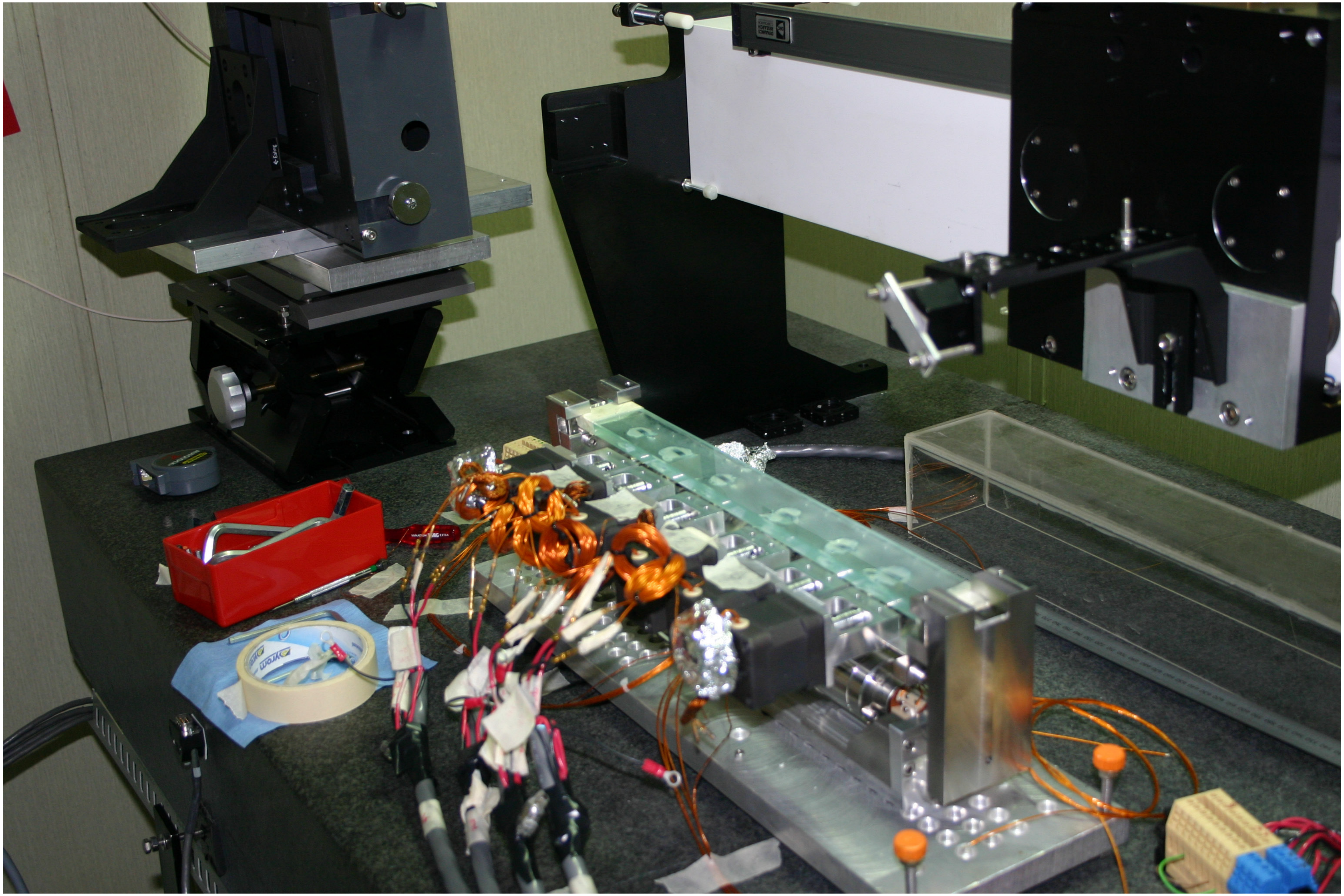
UHV compatibility down to low 10^{-8} mbar

It can be provided with a cooling system adopting copper braids. Maximum power removable 15 W.

Bake out up to 120□feasible.

Anti twist system to avoid distortions in the orthogonal (sagittal) direction

Soft X-ray version



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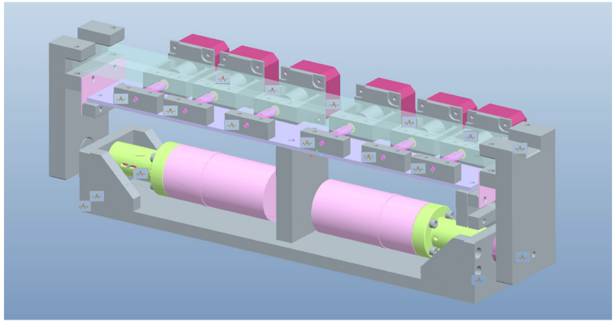

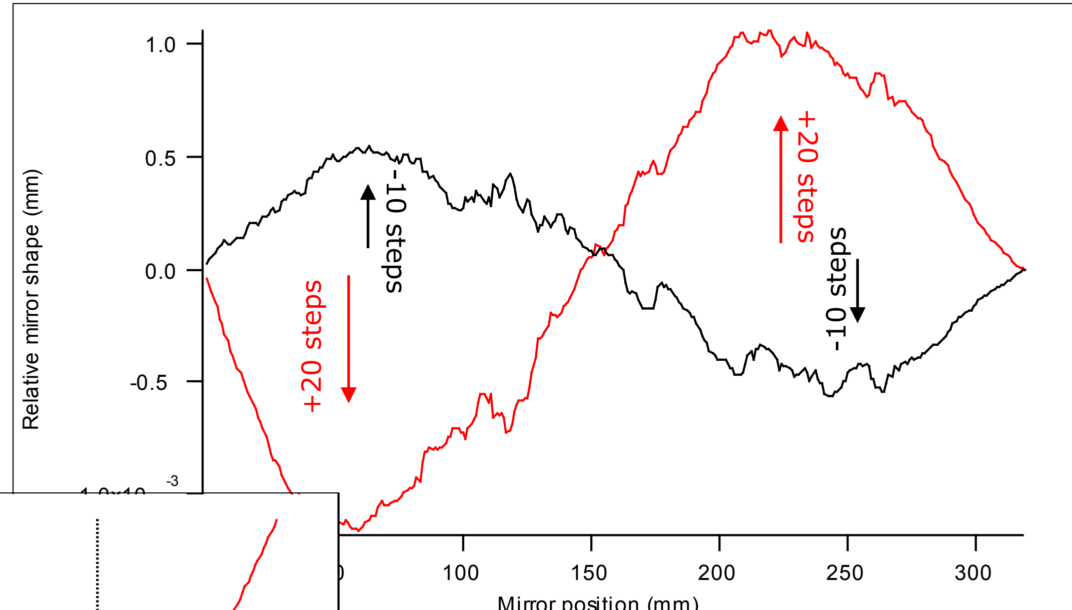

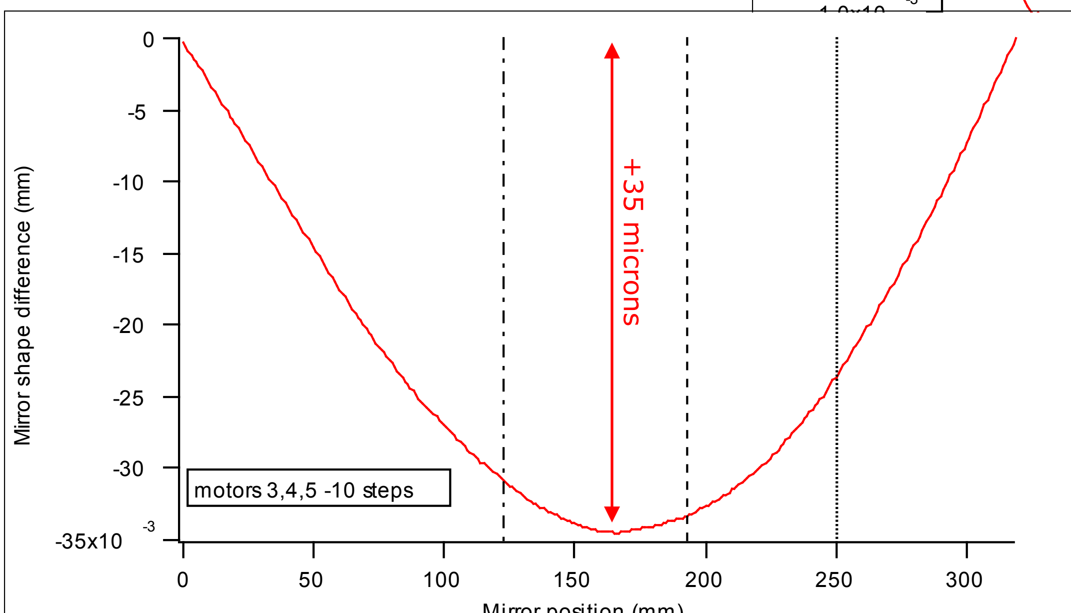

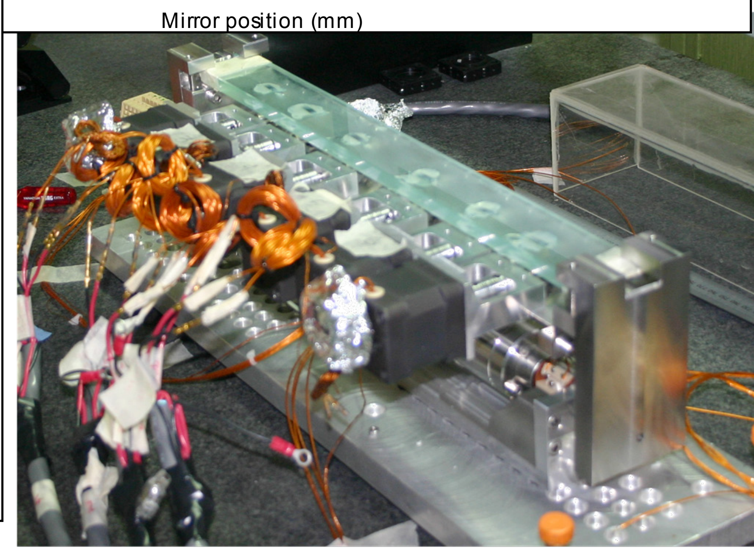

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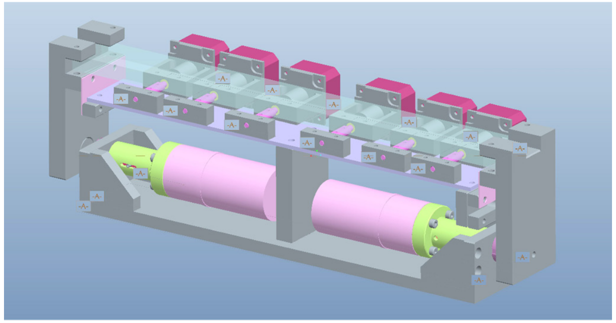

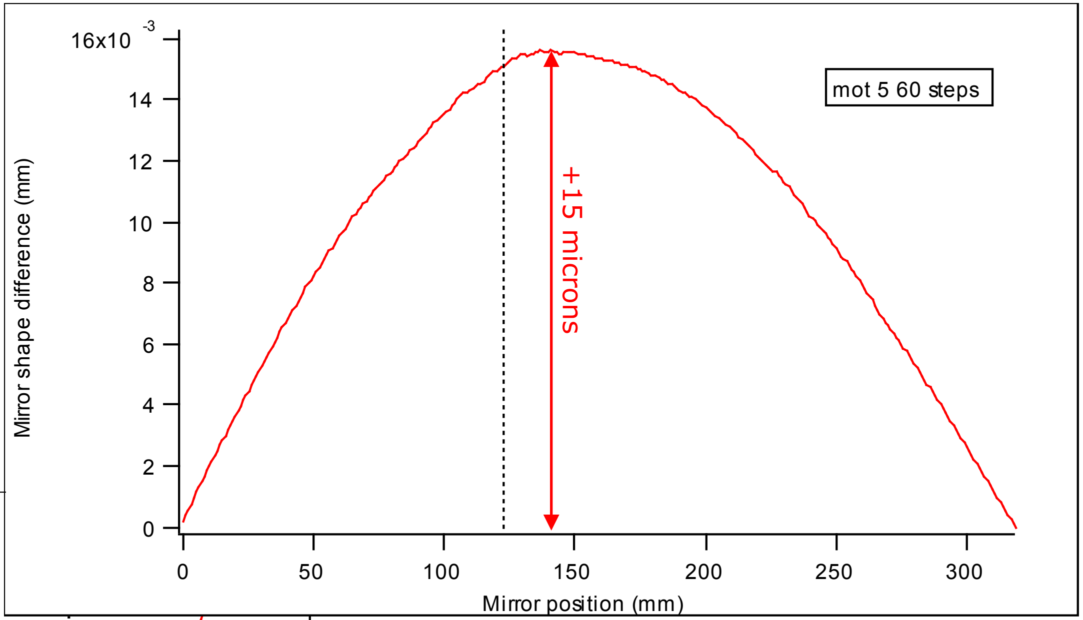

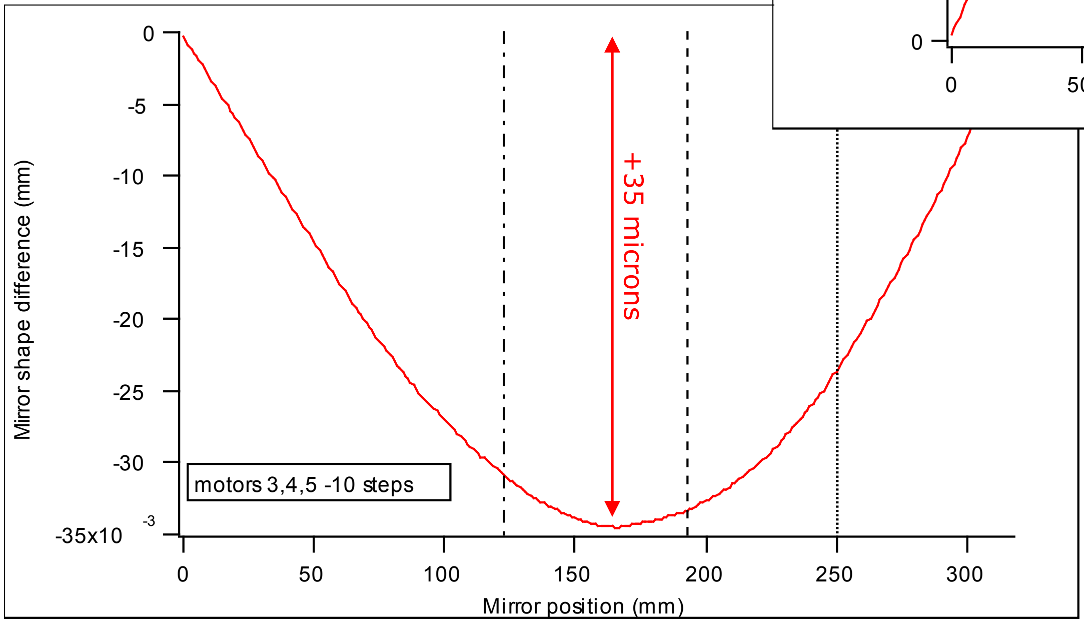

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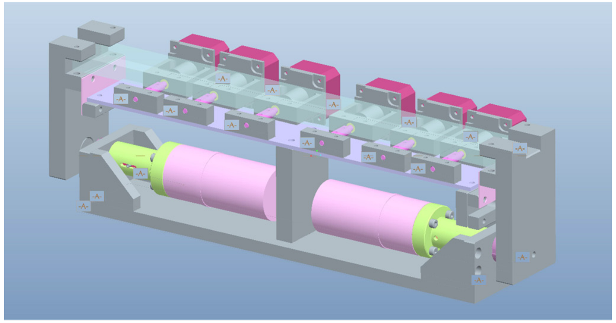

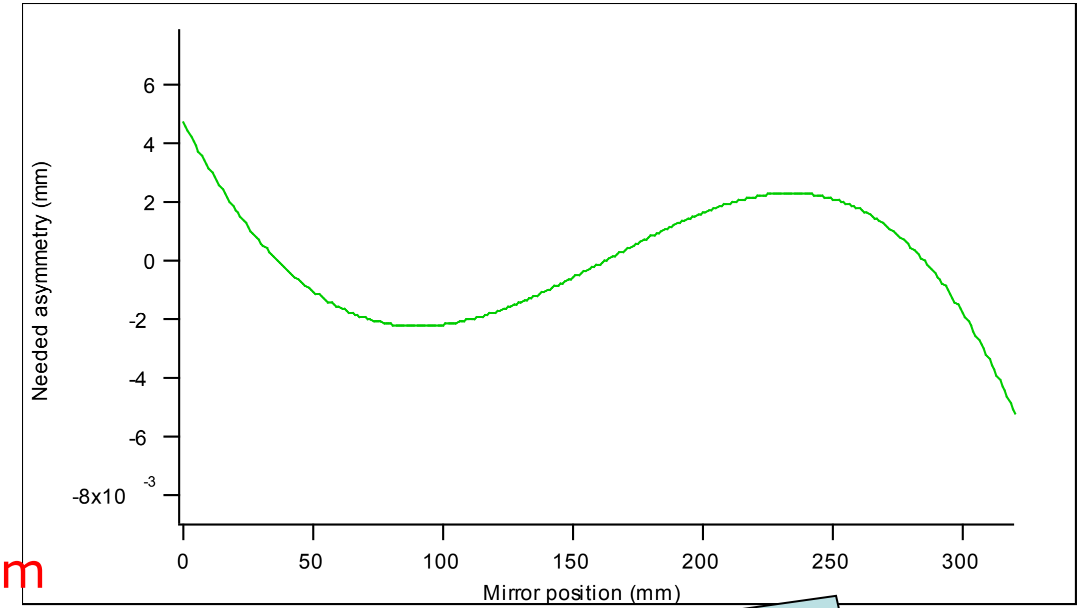

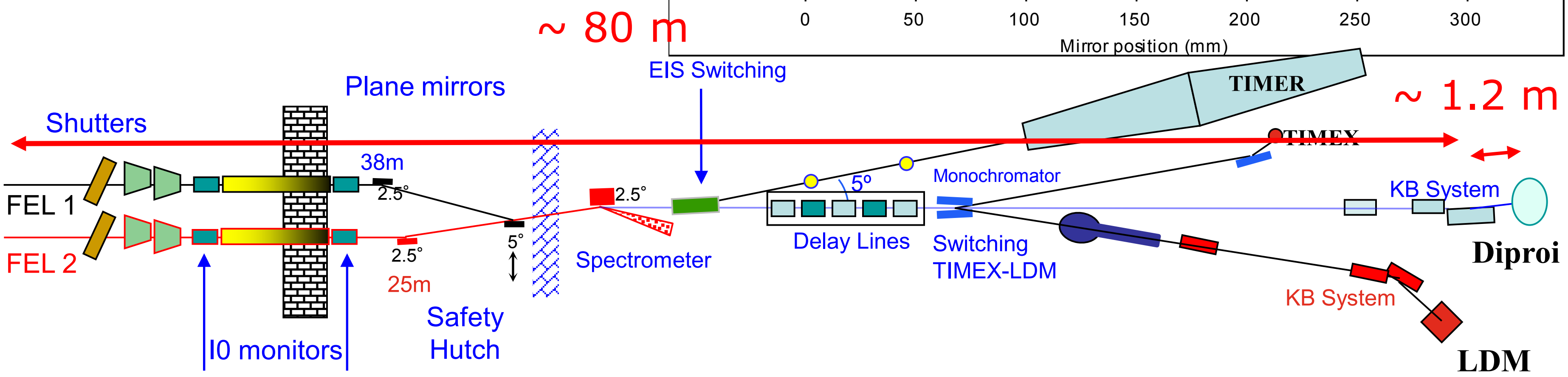

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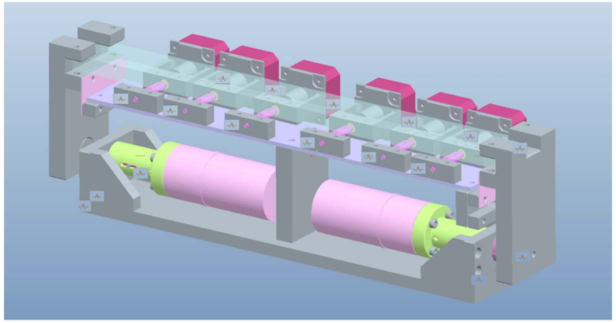

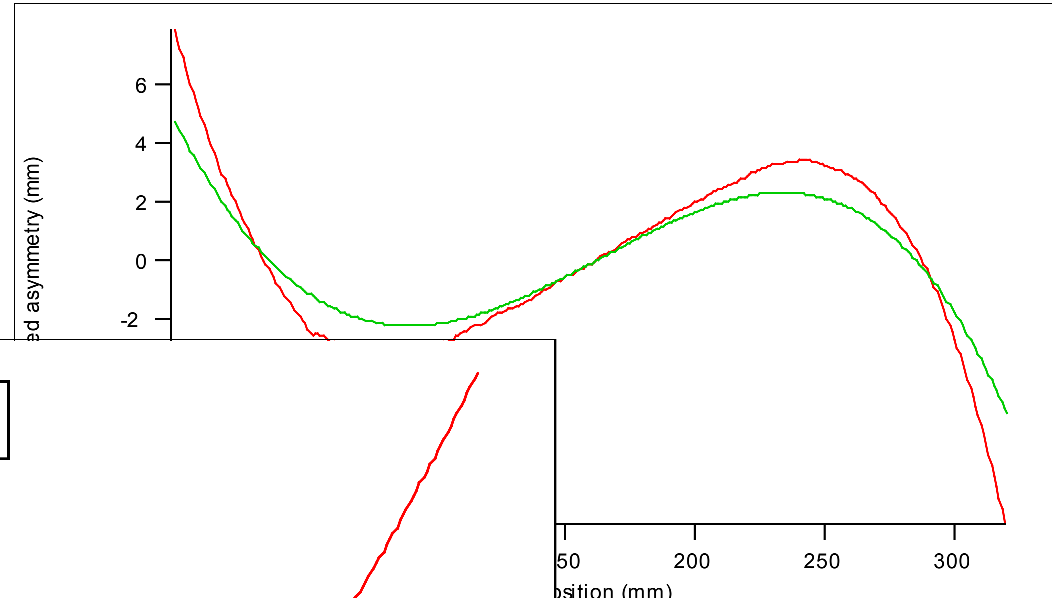

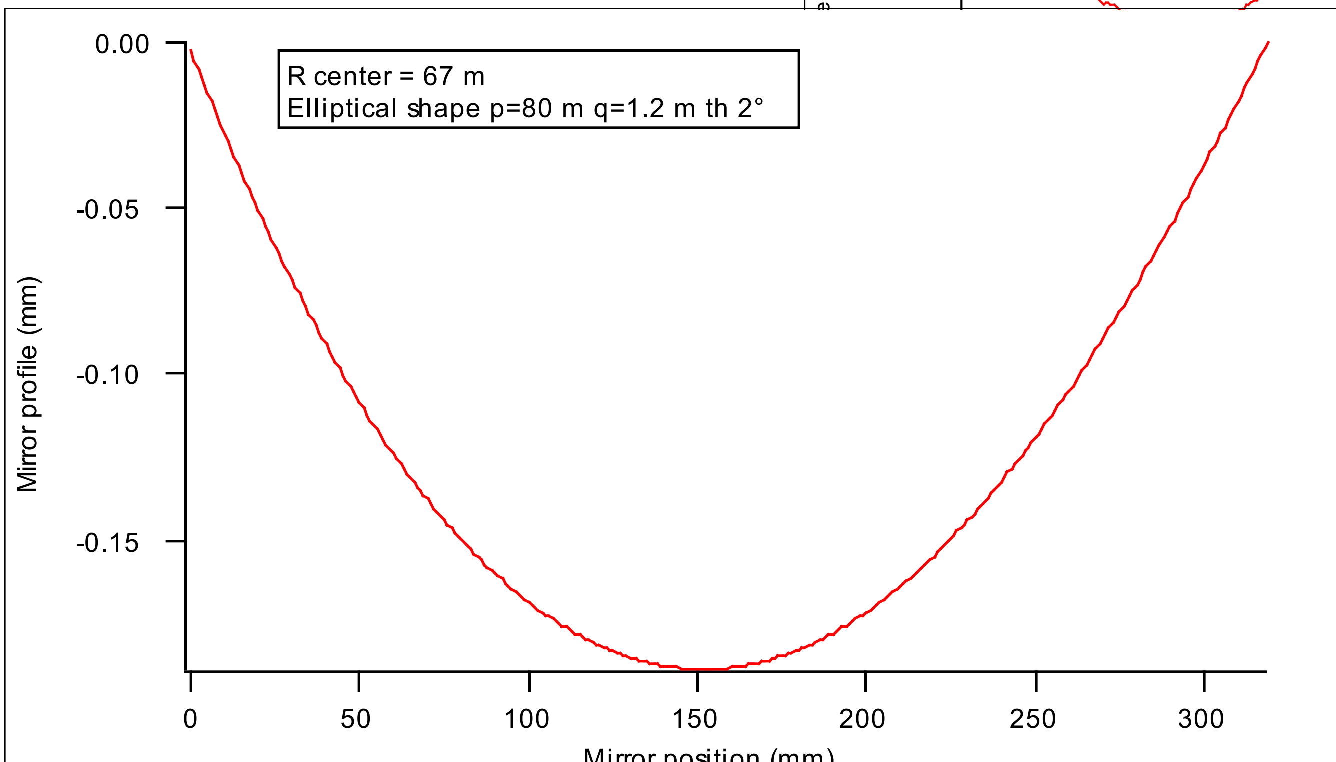

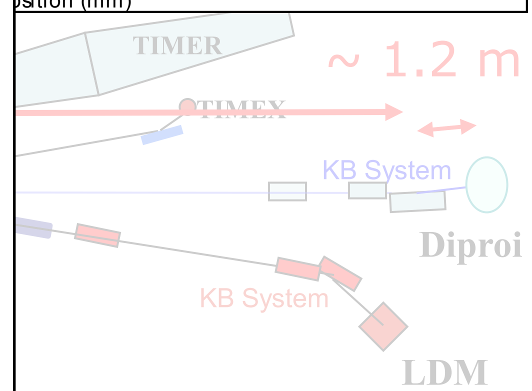

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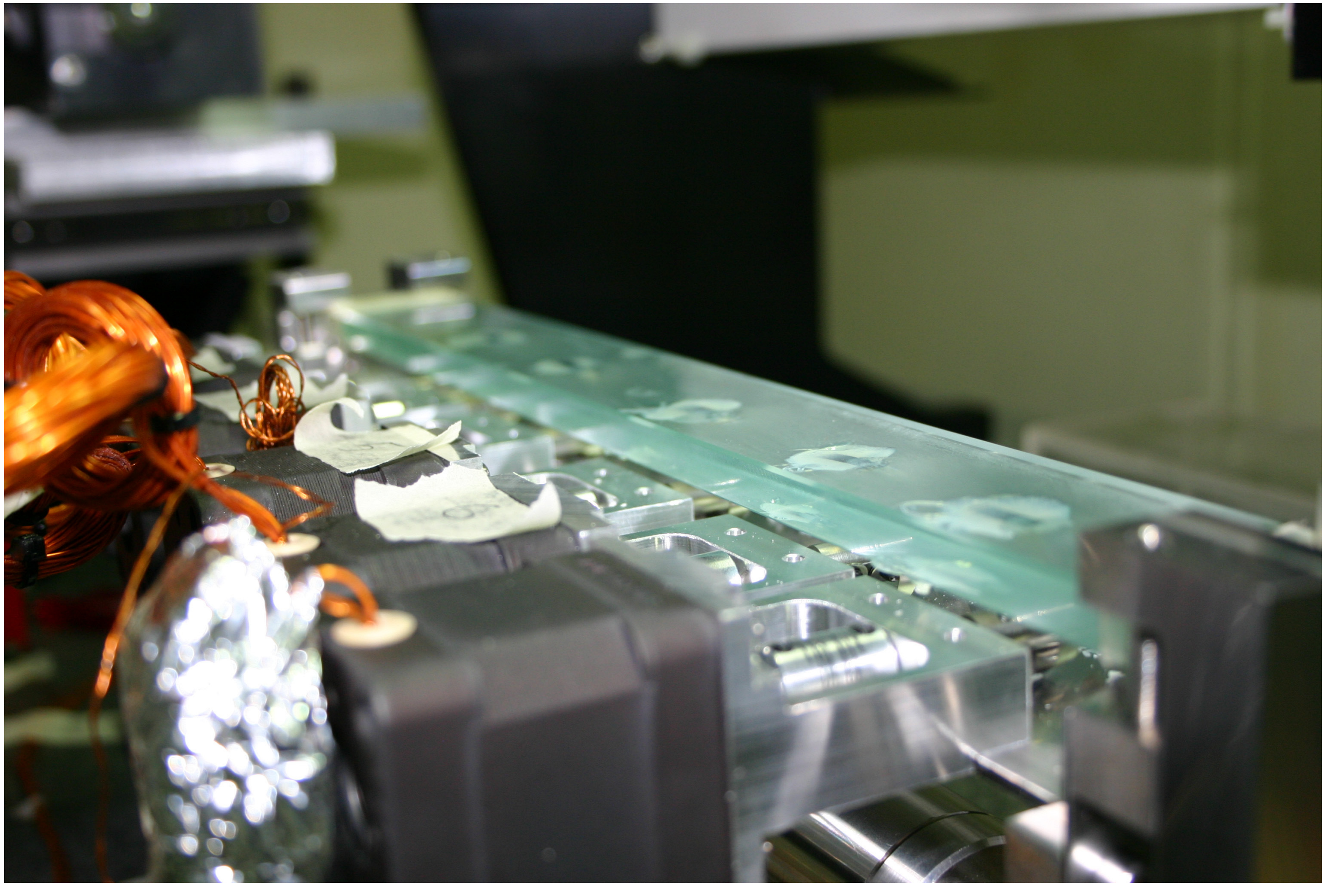
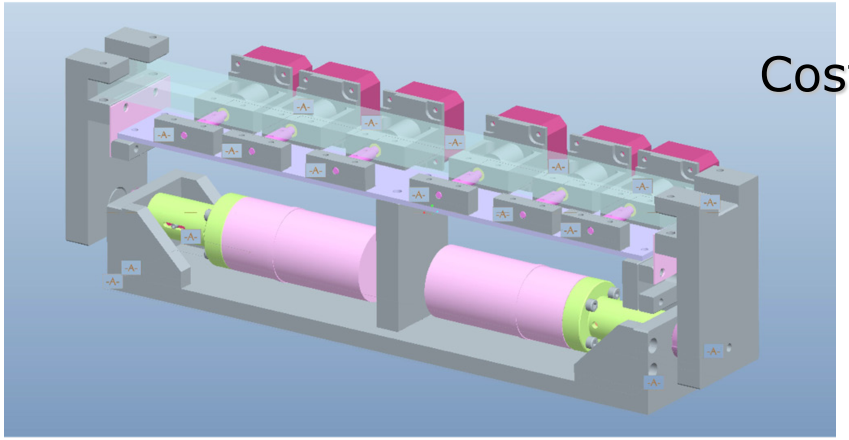


Some "small" thing to be considered:

- Great care on the gluing of the stainless still stripes.
- Proper dimensioning of the stripes (thickness and width) to avoid large stroke
- Proper rolling procedure of the stripes to balance minimum ad maximum correction amplitude.
- Glue must be UHV compatible, beakebale, resistant but still flexible (non vitrifying one)
- Proper dimensioning of the lateral support and motor (stronger force at the edges need stronger local corrections)
- ……….

Soft X-ray version



Cost per mirror (as shown in picture) < 25k€

Should be operative in July 2011!

Mirror dimension
    Length 400 mm (possible from 250 to 600 mm) Useful 380 mm
    Width 40 mm (possible from 35 to 50 mm) Useful 20 mm

Possible shape obtainable:
    Spherical shapes: From Flat (R=°) to R = 40 m (on the 400 mm long mirror).
Lower radius can be achieved with extra cost (strongest motors)

Asymmetry up to 14 μm P-V equivalent to any ellipsoidal mirror with minimum focal distance of 1.2 m at 2□grazing angle of incidence or 0.8 m at 1□. (shorter focal distances for larger angles of incidence can be achieved at extra costs)
Shape error below 10 nm P-V, slope errors below 0.5 μrad rms.
Roughness below 0.3 nm rms. Smaller values can be achieved. To be discussed
Minimum controllable mirror deformation: 2 nm on 8 cm spatial period.
UHV compatibility down to low 10^{-8} mbar
It can be provided with a cooling system adopting copper braids. Maximum power removable 15 W.
Bake out up to 120□feasible.
Anti twist system to avoid distorsion in the orthogonal (sagittal) direction

Conclusions

- We have a Seeded FEL working (first ever S-FEL spectra measurement performed)
- We need to improve it but we are on the right way
- We have a tested prototype for the KB mirror satisfying the requirement

- Final mirror will be characterized on may, installed on June, operative on July!!!
- 50 more meters of Photon transport system, 40 actuators, 5 mirrors, 1.5 km of cables and few other stuff to be installed and tested within june

Next machine run will start on may 14. If someone wish to take part of the commissioning…. she/he is welcome (there are several night shifts to be assigned…)

Thank a lot and see You soon in Barcelona!

PADReS TEAM & co.
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M. Cautero
G. Sostero
M. Pellizzo
J. Krempasky
The DESY team
University of Camerino
University of Padua
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