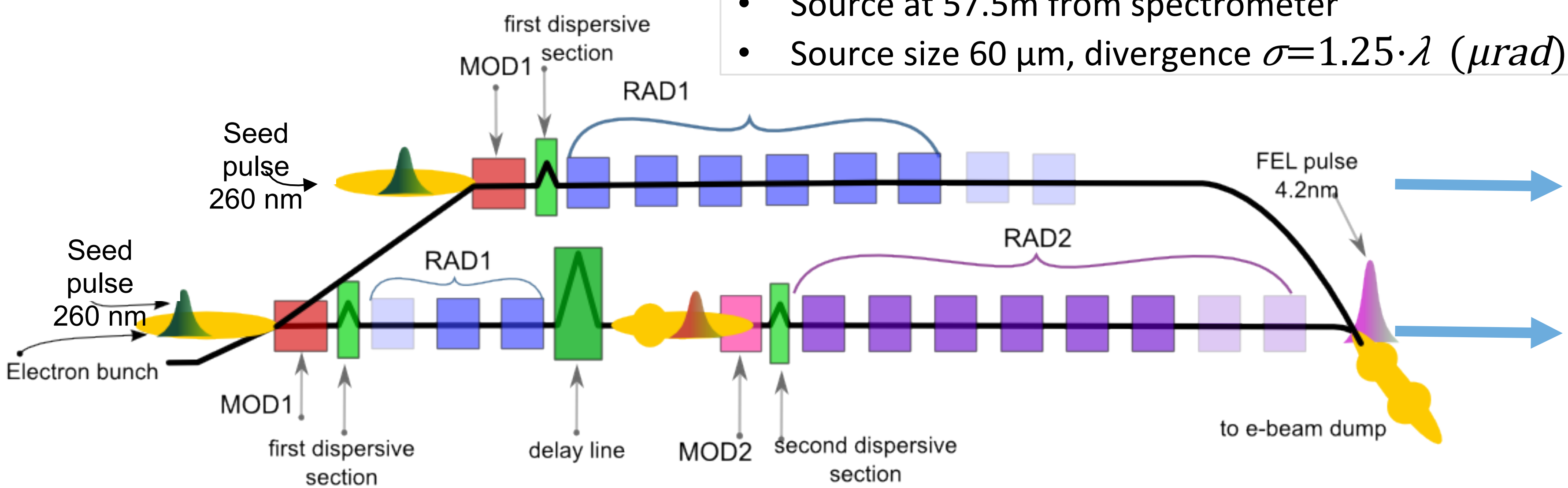
Recent results from PADReS at Fermi@Elettra

Nicola MAHNE
on behalf of PADReS group

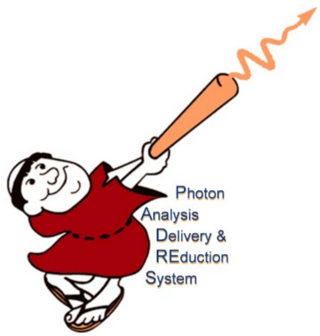
Photon
Analysis
Delivery &
REduction
System

Fermi@Elettra

- FEL1: $20nm \leq \lambda \leq 65nm$ (continuosly tunable)
- Bandwidth (best) 5x10-4 @ 32 nm
- Energy per pulse 30-100 μJ (depending on wavelength)
- Source at 57.5m from spectrometer
- Source size 60 μm, divergence $\sigma = 1.25 \cdot \lambda \ (\mu rad)$



FEL2: $5nm \leq \lambda \leq 20nm$
Source at $49.8m$ from spectrometer
Source size $123\ \mu m$, divergence $\sigma = 1.5 \cdot \lambda \ (\mu rad)$



Photon
Analysis
Delivery and
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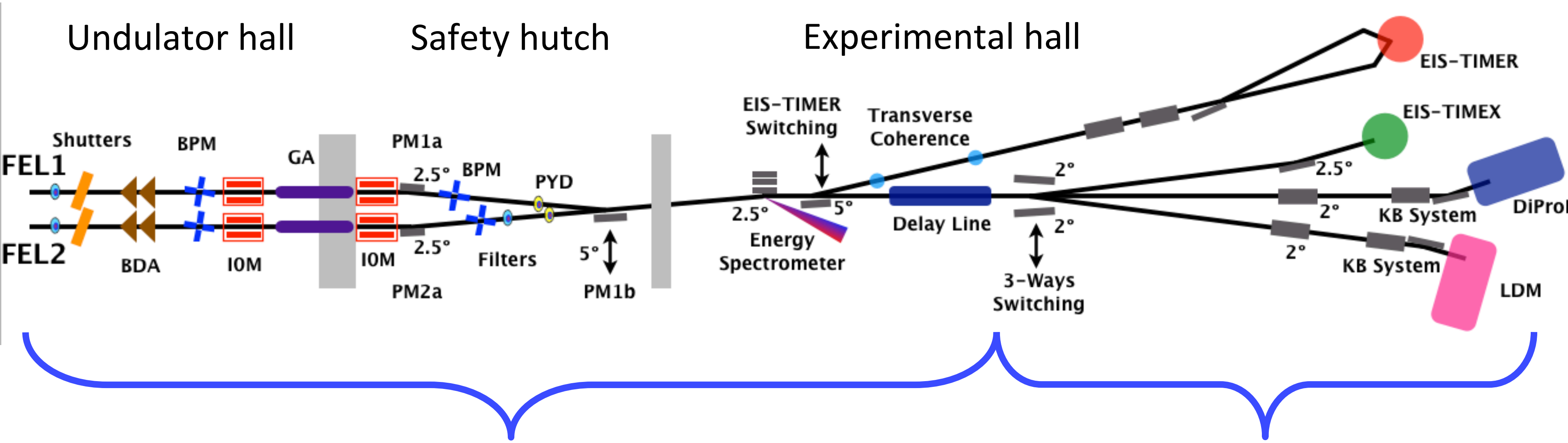
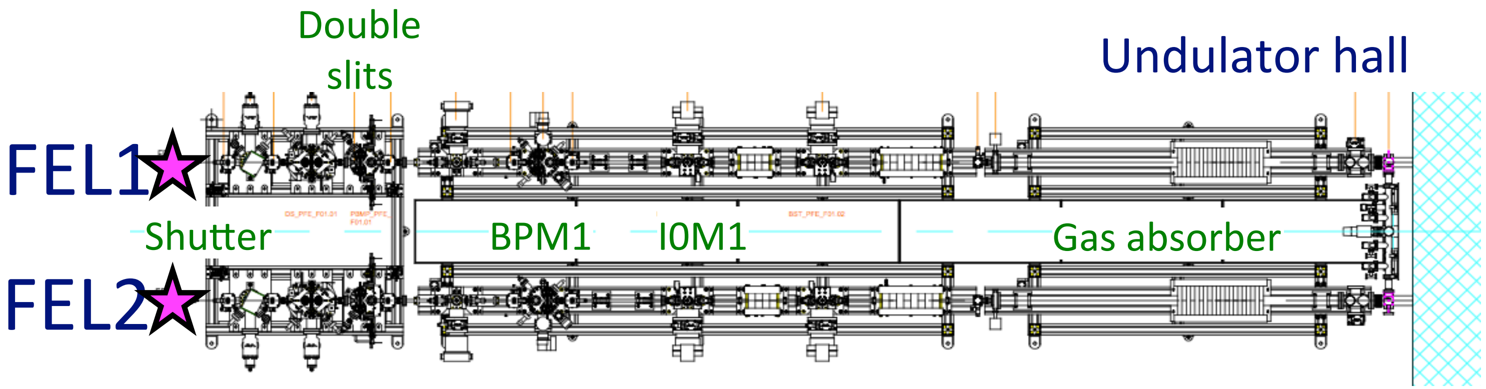
System



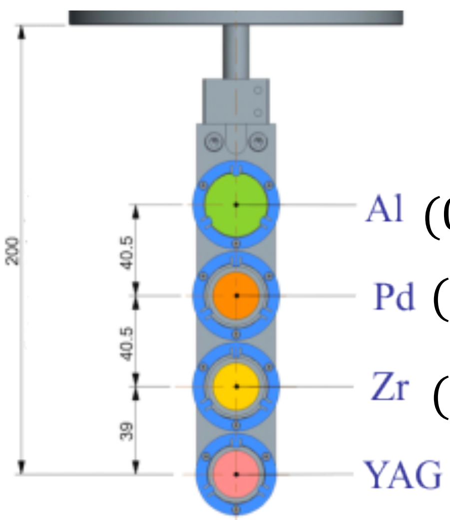
Photon Diagnostics

Beamlines

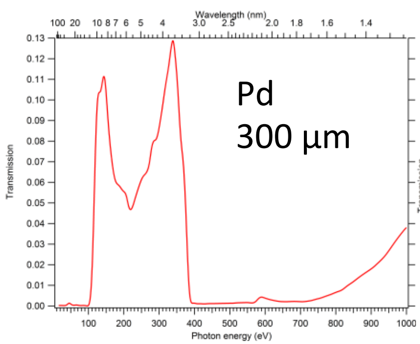


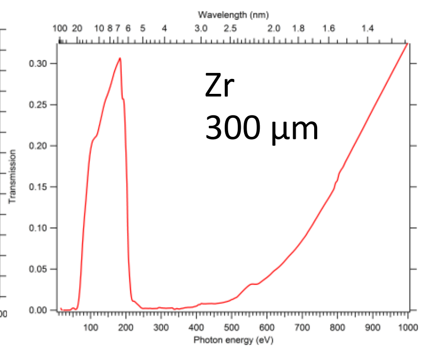
Filters used for

- Intensity attenuation
- Rejection of seed laser
- Rejection of higher harmonics
- Rejection of radiation of the first stage of FEL2 (Pd and Zr)

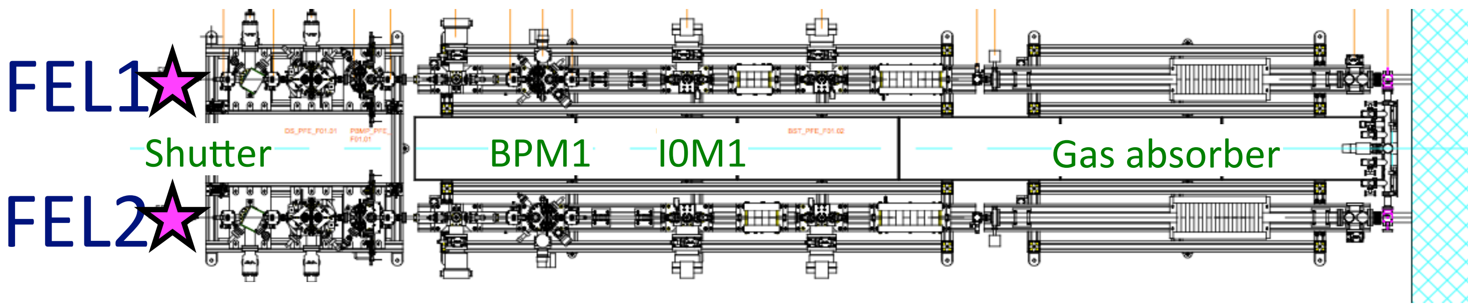


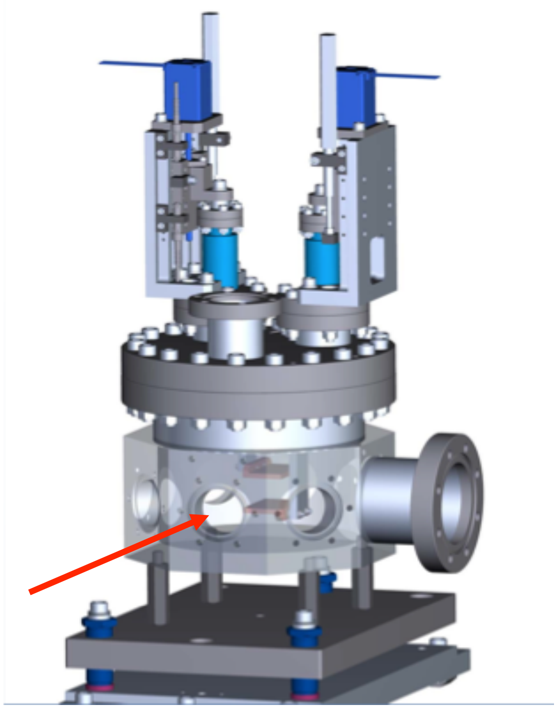
Filter transmissions have been calibrated on the BEAR beamline @Elettra





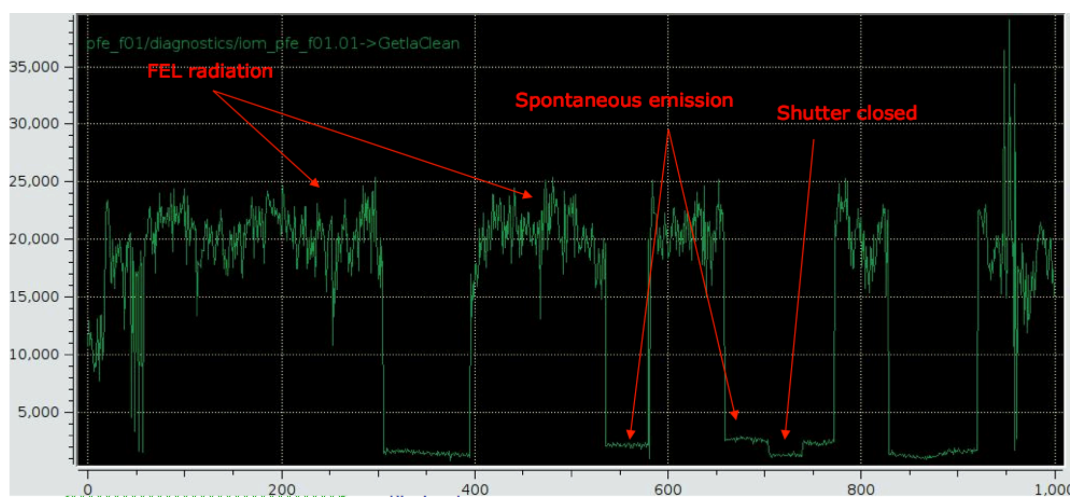
Undulator hall





I0 monitor (IOM)

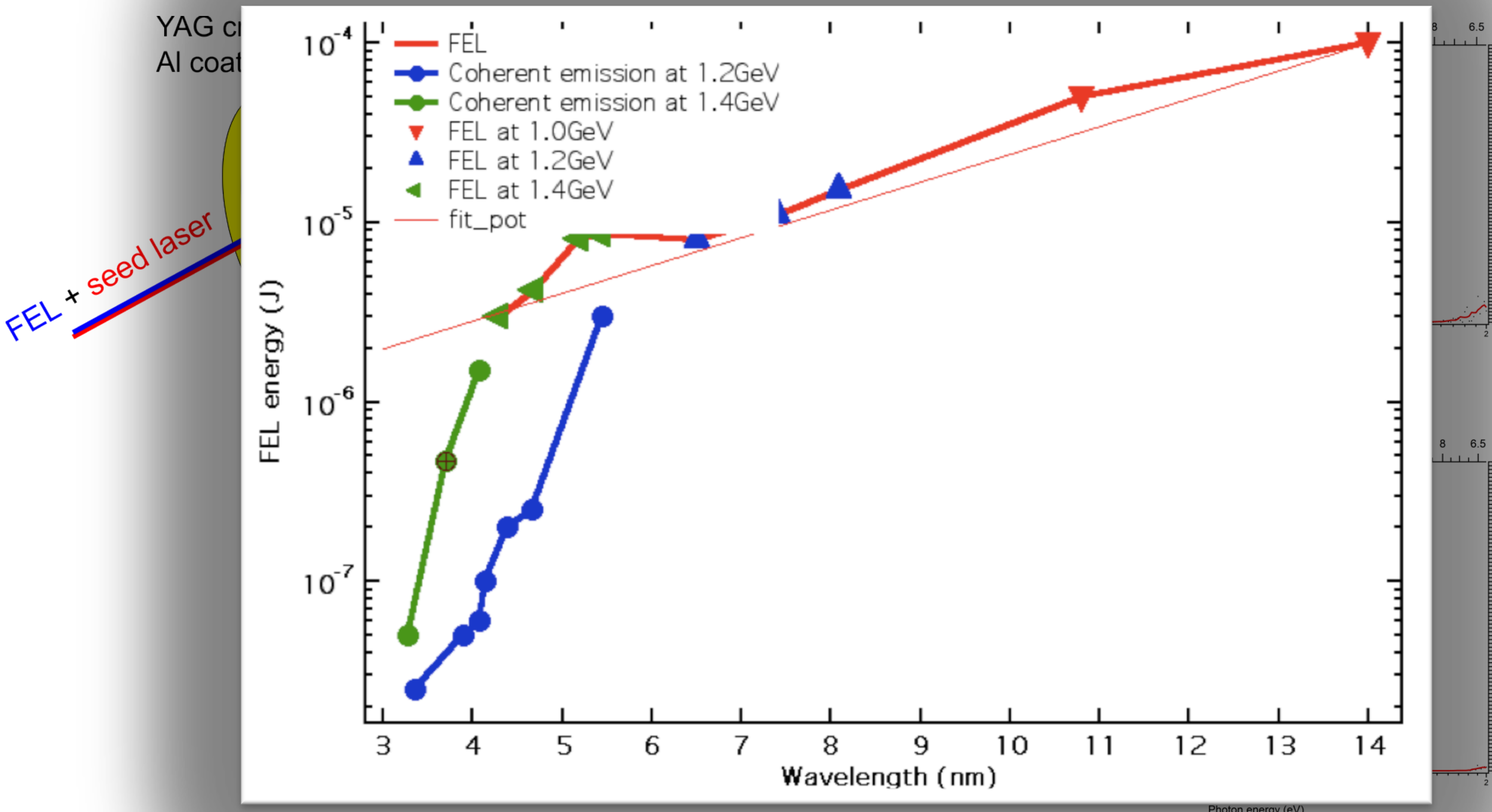
- works online and shot-to-shot
- is "transparent" to radiation
- gives power of radiation per pulse (after calibration)



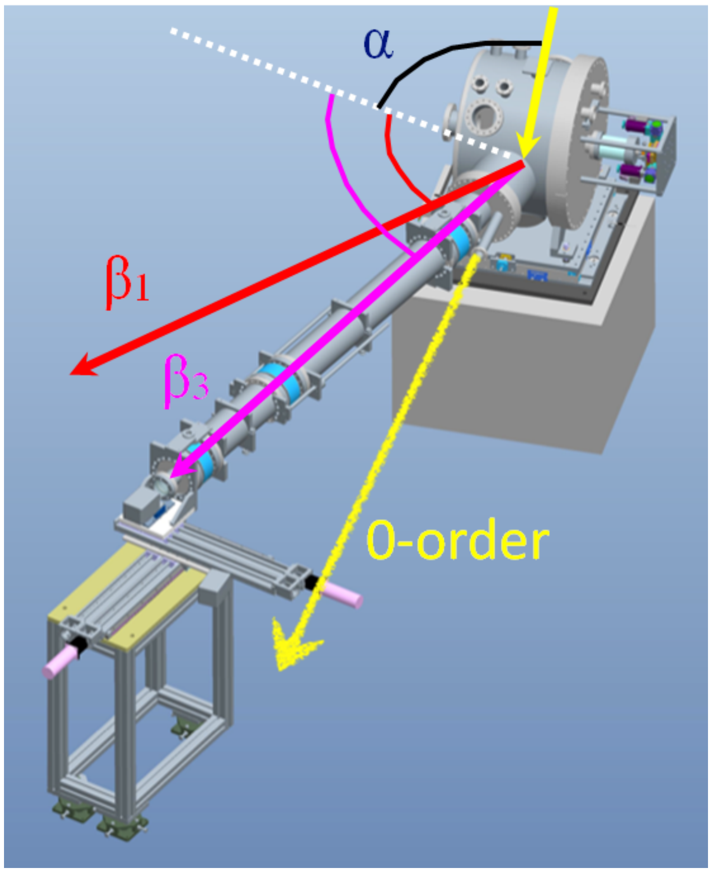
I0M calibration

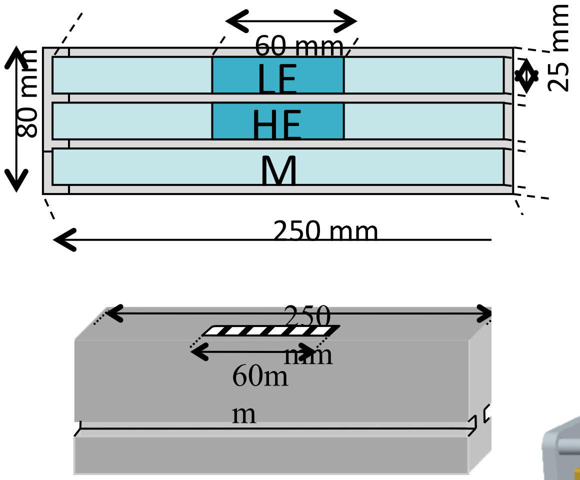
PYD detector

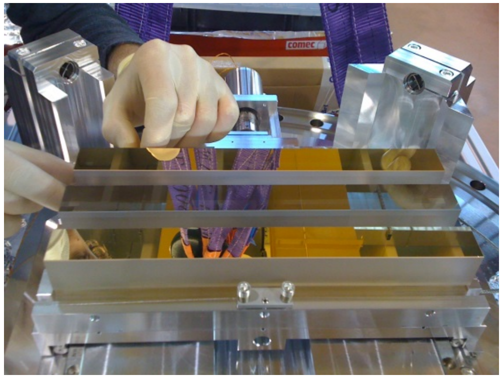
YAG cr
Al coat

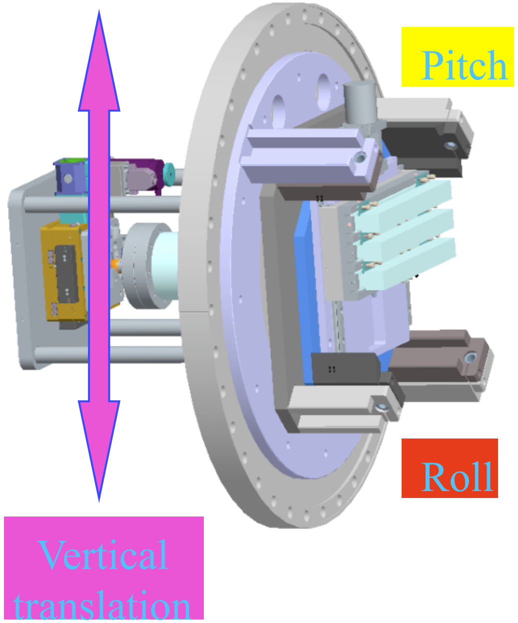


PRESTO: Pulse Resolved Energy Spectrometer: Transparent and Online

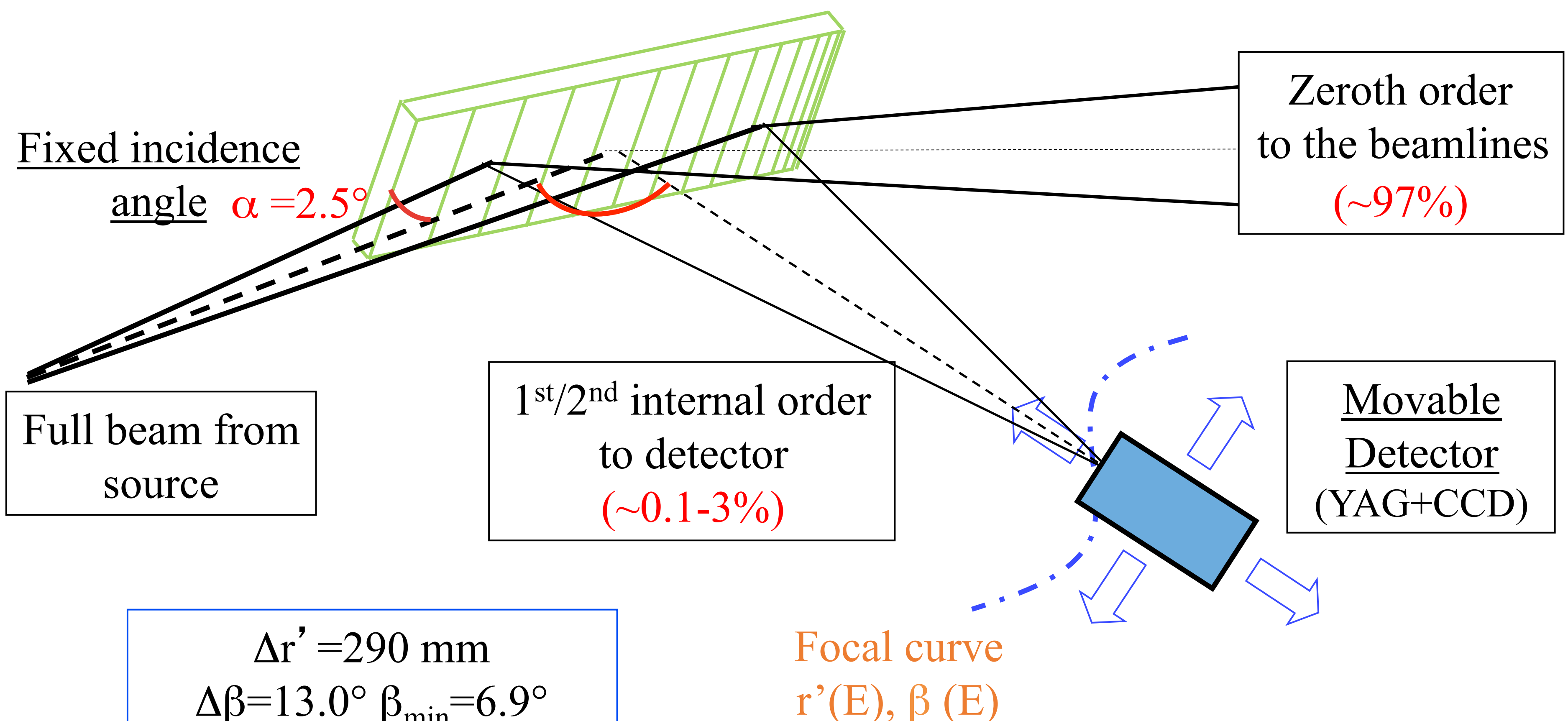








VLS grating

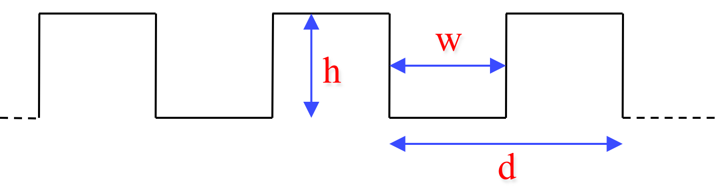


$\Delta r' = 290$ mm
$\Delta\beta = 13.0°$ $\beta_{min} = 6.9°$
$\Delta x = 455$ mm $\Delta y = 560$ mm

Groove density expanded in Taylor series

$$N(w) = D_0 + D_1 w + D_2 w^2 + D_3 w^3 + \ldots$$

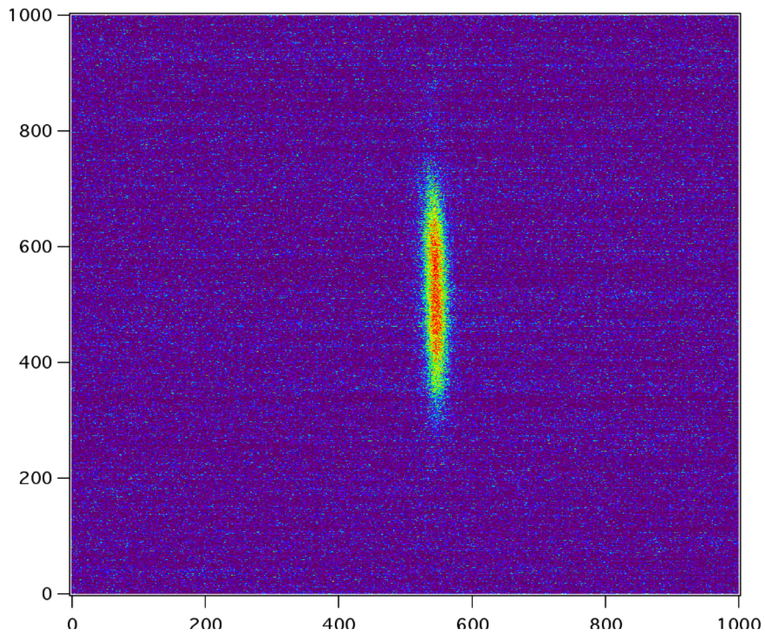
h = groove depth
w = groove width
d = groove spacing

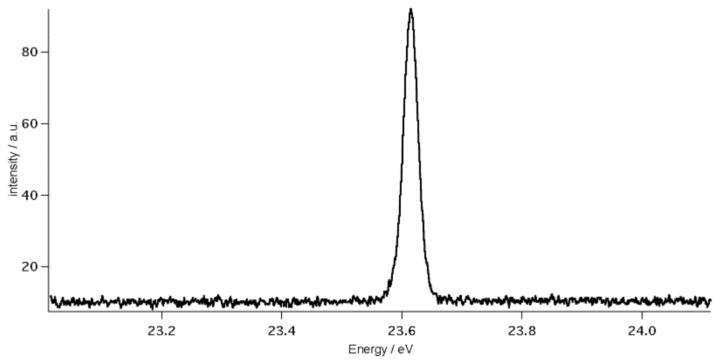


Parameter	LE	HE
Wavelength range m=1 (nm)	24-100	6.6-27
Wavelength range m=2 (nm)	12-50	3.3-13.5.
Energy Resolution (meV)	0.2-2.9	0.3-9.5
D_0 (l/mm)	500	1800
D_1 (l/mm^2)	0.35	1.26
D_2 (l/mm^3)	$1.7x10^{-4}$	$6.3x10^{-4}$
Groove profile	Laminar	Laminar
Groove height (nm)	12	4
Groove ration (w/d)	0.60	0.65
Coating Material / Thickness	a-C / 50 nm	Au / 50 nm

HORIBA JOBIN YVON

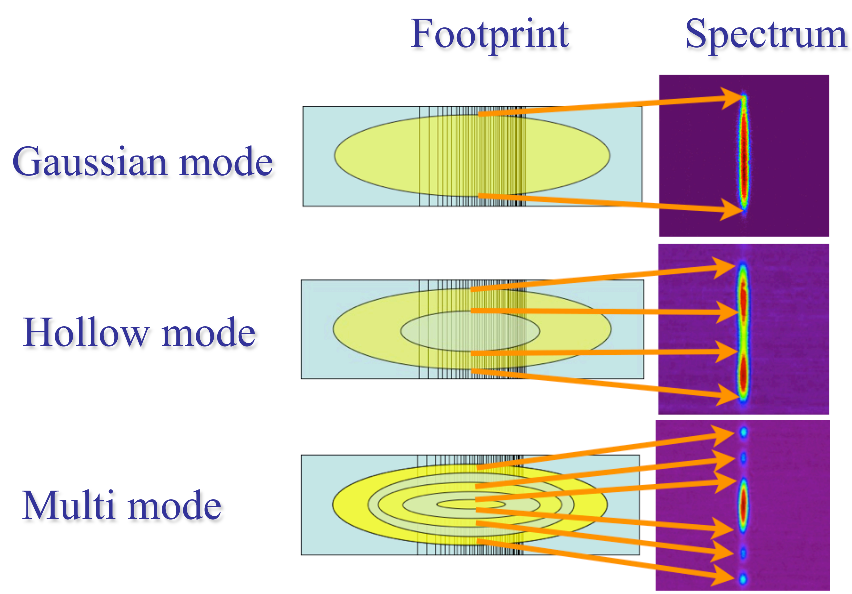
INCOATEC
innovative coating technologies gmbh





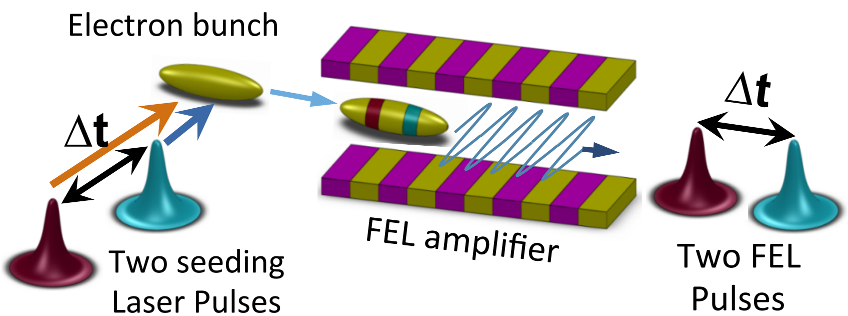
PRESTO gives information on:

- Energy distribution
- Energy peak position
- Energy Bandwidth
- Vertical intensity distribution (projected)
- Angular divergence
- Intensity estimation

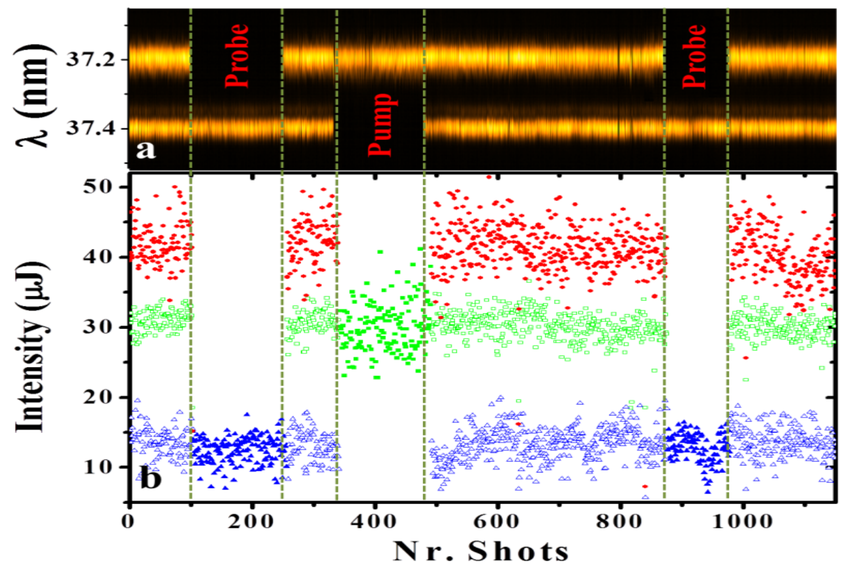


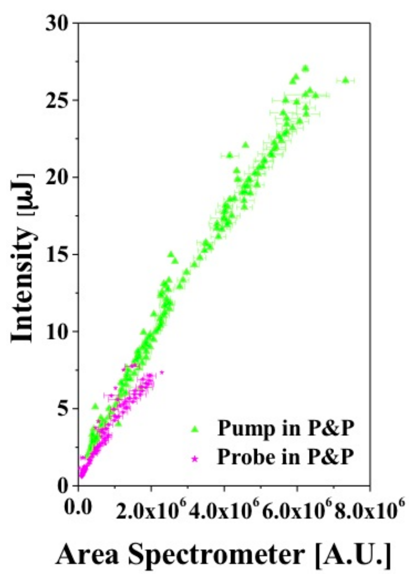
Two-colors experiment

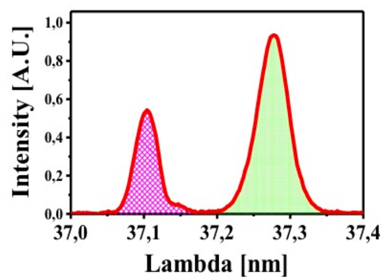
Pulses Generation Scheme



Achievable delay: 300 – 700 fs (Dec. 2012)

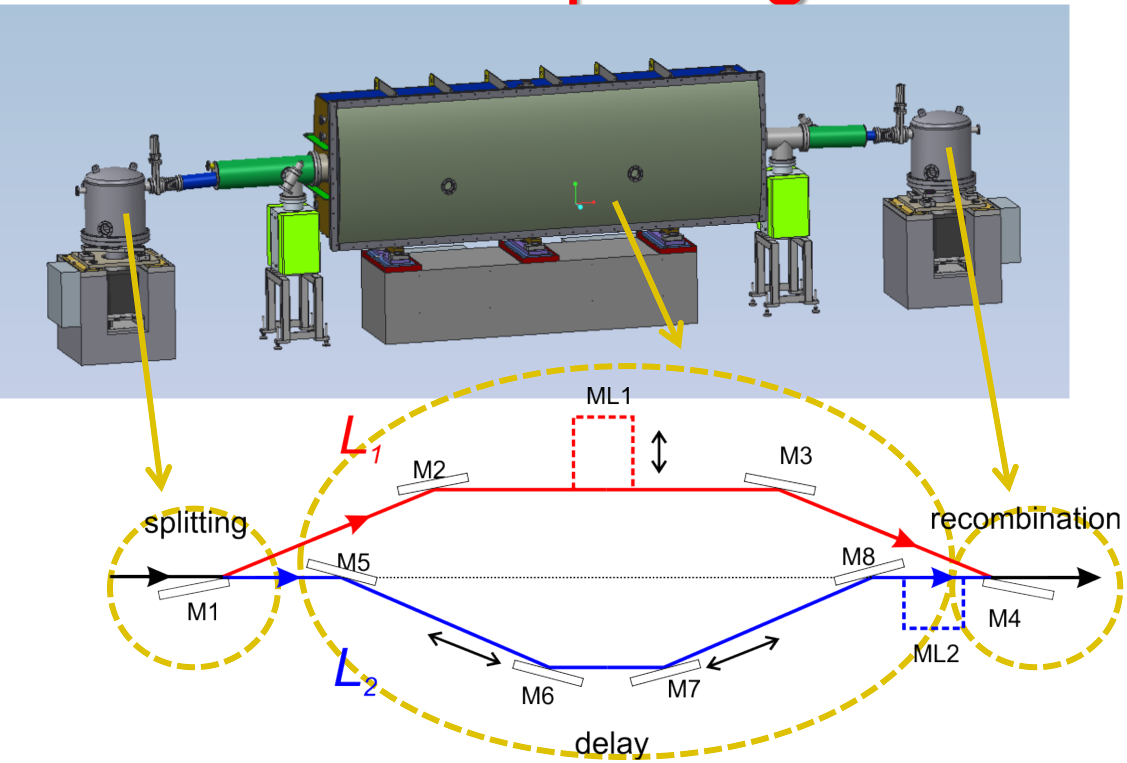




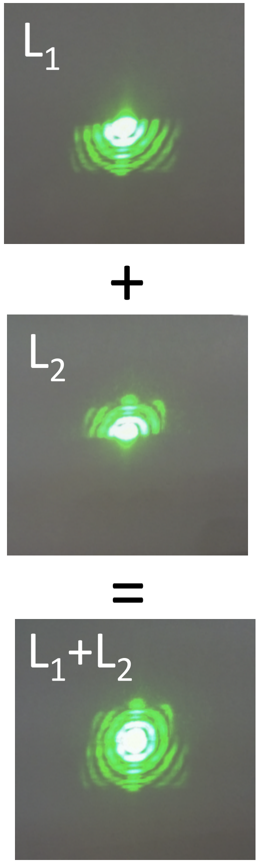


Possibility of measuring simultaneosly the intensity of the two components measuring the areas of the peaks

Splitting and delay line



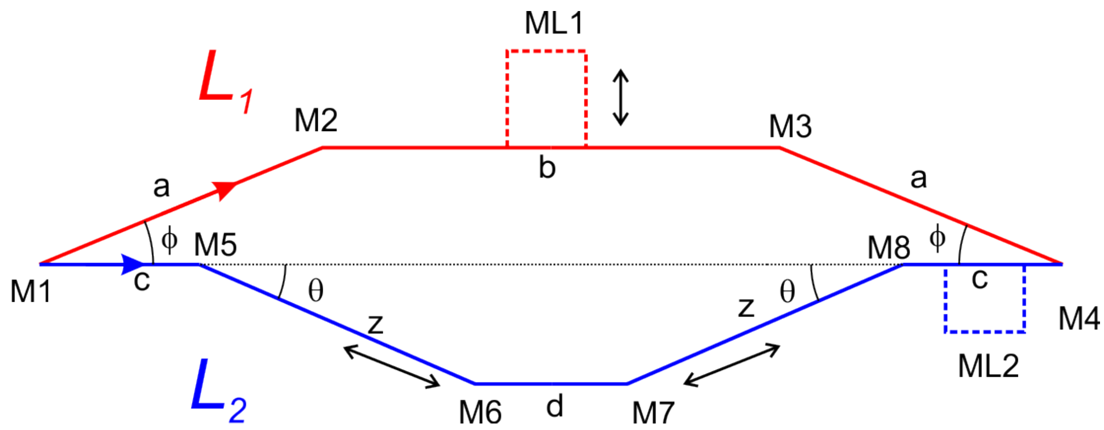
First tests (visible laser)



- 8 x Au coated plane mirrors
- Two additional delay acchieved with ML mirrors at 45° (to be defined)

To be commissioned soon with FEL…

Delay



$$\Delta L = L_1 - L_2 = 2a(1-\cos\phi) - 2z(1-\cos\theta)$$

without ML branches

$$(290 \pm 0.01)\ mm \leq z \leq (1150 \pm 0.01)\ mm$$

$$-0.45\ mm \leq \Delta L \leq 9\ mm$$

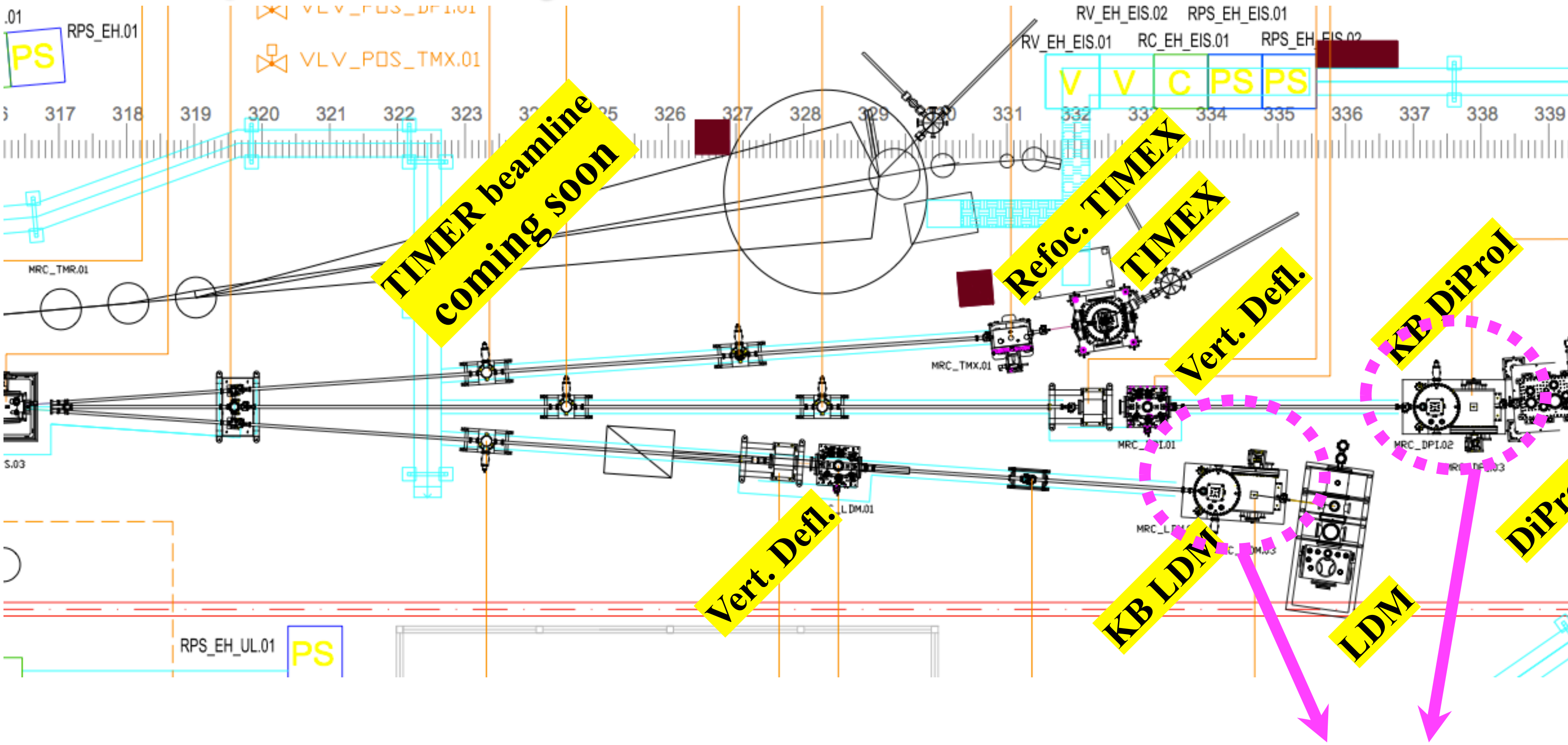
$$-1.5\ ps \leq \Delta t \leq 30\ ps$$

$\pm 0.1\ fs$

With ML1: $\Delta t_1 = 0.3 \div 1.5\ ns$

With ML2: $\Delta t_2 = 0.33\ ns$

Optical layouts of the beamlines



So far 3 beamlines installed and operative:

EIS-TIMEX, DiProI, LDM

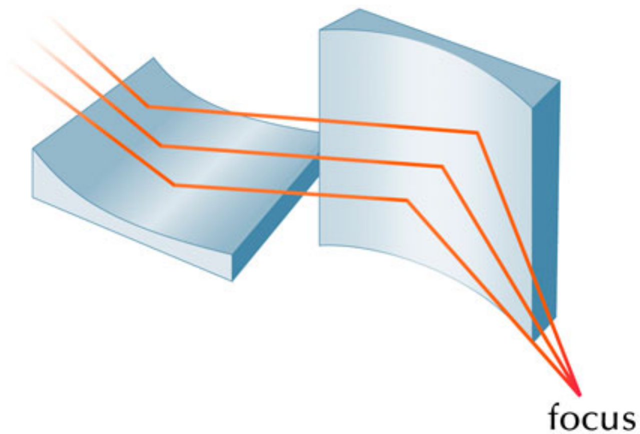
Kirkpatrick-Baez (KB) active optics systems

K-B active optical system (DiProI + LDM)

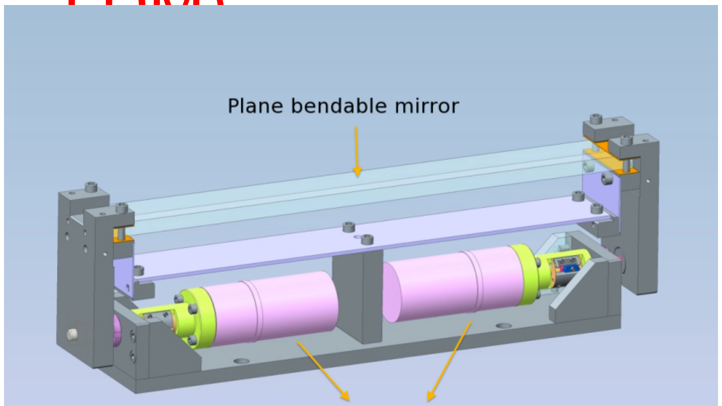
Necessity of high fluence in the focal plane ⟹ small spot ⟹ great demagnification

Advantages of K-B system with bendable mirrors

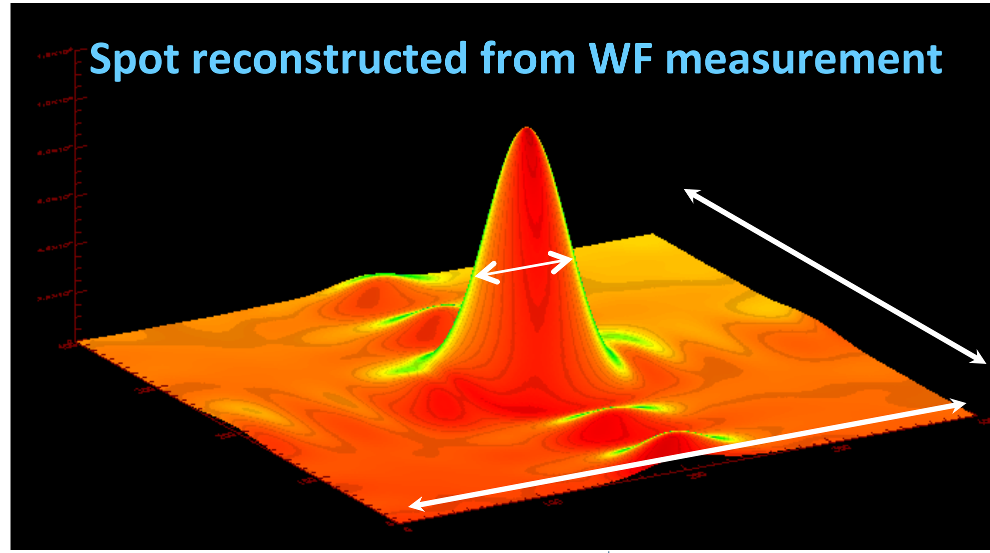
- Decoupling of vertical and horizontal components
- Focalization of two sources (FEL1 and FEL2), placed at different distances, with the same mirror pair
- Possibility of changing the focal plane position
- Possibility of correction of the beam wavefront with different source conditions



K-B active optical system (DiProl + LDM)

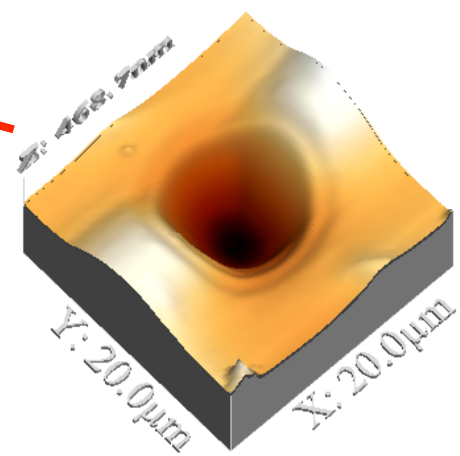


Mirror:
fused silica substrate + 50nm Au coating



Collaboration with Laser-Laboratorium Göttingen e.V. DESY

Spot size:
$10\times10\ \mu m^2$ FWHM



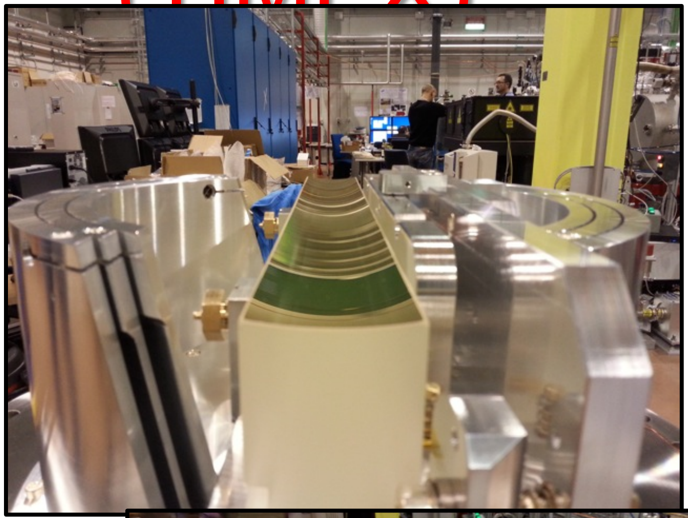
Damage on PMMA

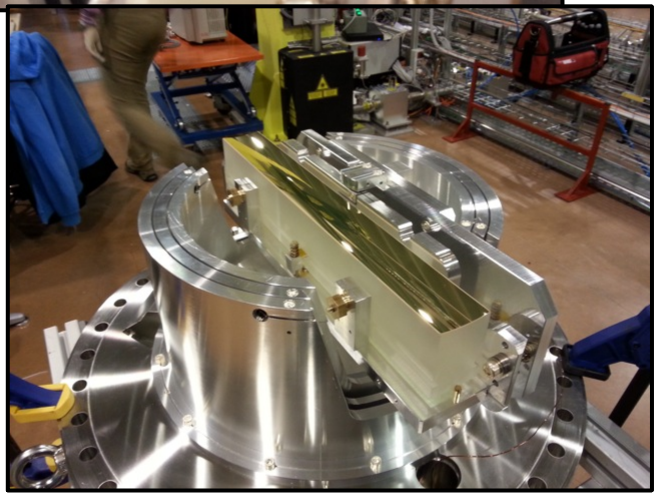
To be compared with

- Diffraction limited spot size = $4.1\times5.9\ \mu m^2$
- Simulated spot size (using the profiles measured with LTP) = $5.1\times6.0\ \mu m^2$

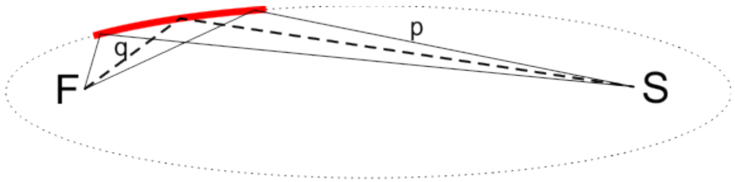
$\lambda=37.2 nm$

Focusing with ellipsoidal mirror (TIMEX)

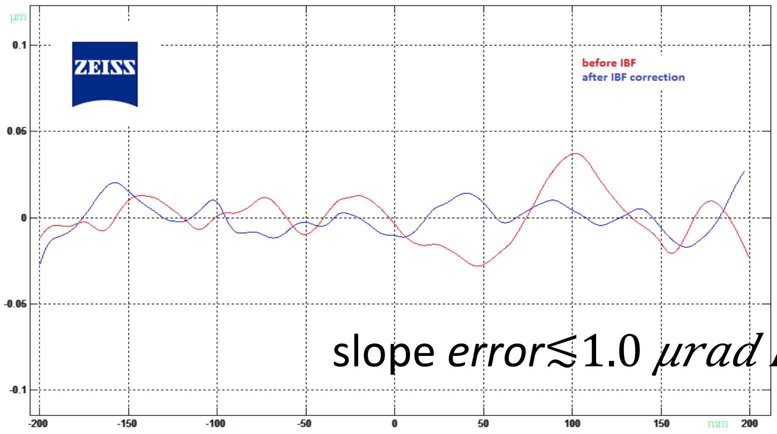




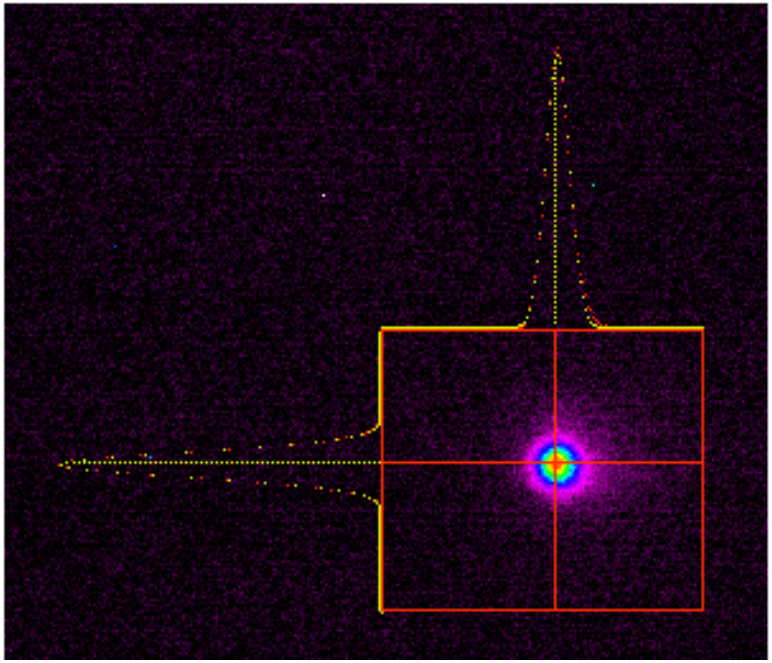
Necessity of high fluence in the focal plane $\Longrightarrow$ small spot $\Longrightarrow$ great demagnification



Source distance:	$84.85\ m$
Focal distance:	$1.4\ m$
Inc. angle:	$2.5°$



slope error$\lesssim 1.0\ \mu rad\ RMS$



Mirror design <u>optimized for FEL2</u>.
Nevertheless with <u>FEL1</u> ($\lambda = 27\,nm$), we obtained a Gaussian focus with $\sigma = 4\,\mu m$ (FWHM=$9.4\,\mu m$)!

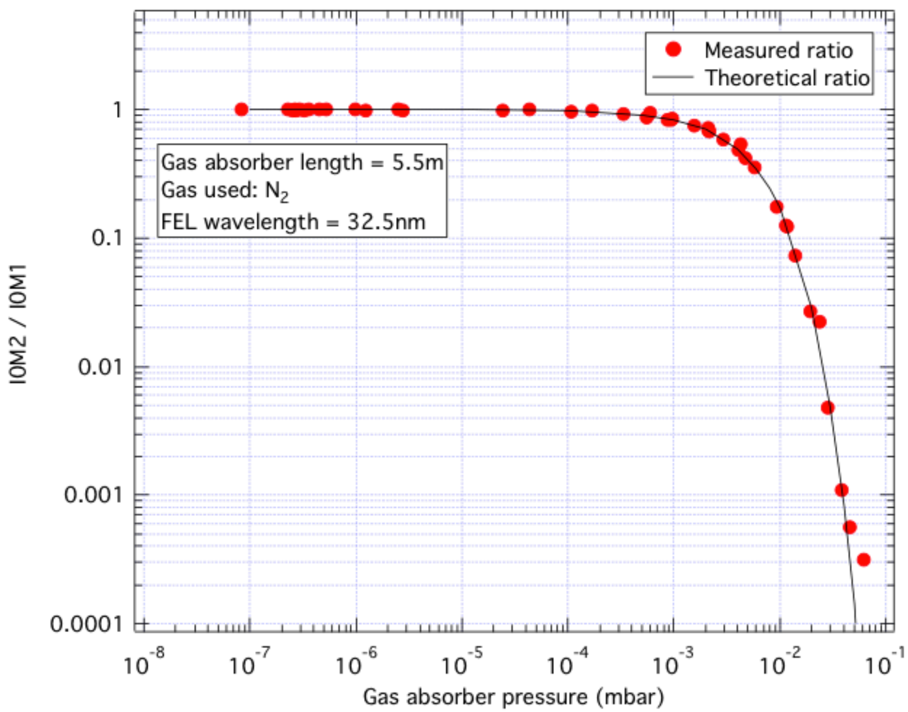
Summary

PADReS can…

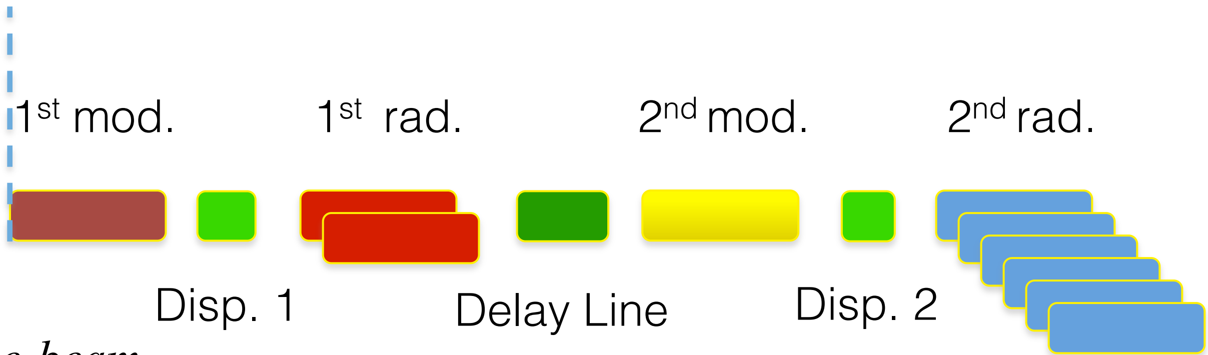
- give information on
  - radiation intensity (I0M, PRESTO) *shot-to-shot*
  - spectral content of the radiation (PRESTO)
  - "quality" of the beam (PRESTO)
- reject "undesired" components of the light (seed laser, higher harmonics, radiation of the 1st stage in FEL2) by means of filters
- split the beam and delay the two parts (pump and probe experiments, measure of the longitudinal coherence,…)
- provide good focusing in the experimental stations, using K-B active optics system (DiProI and LDM) or ellipsoidal mirror (TIMEX)
- …

Thank you for your attention!

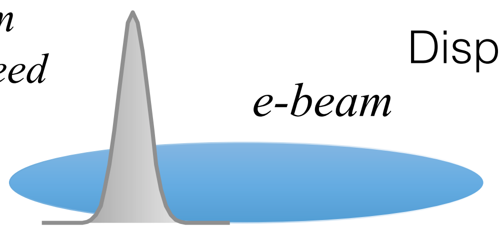
With gas absorber the FEL intensity can be reduced by 4 order of magnitude.

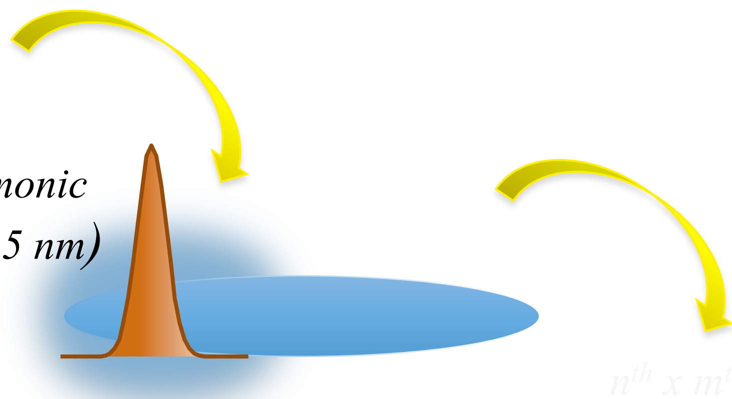


Position:

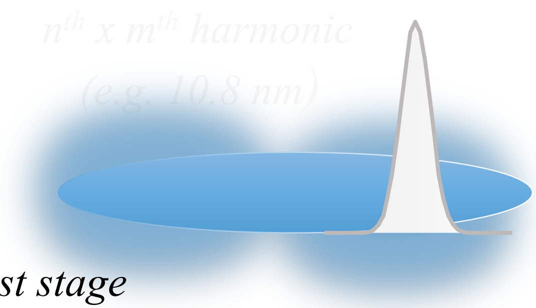


The seed @260nm is on the tail of the e⁻ beam





The first stage converts the seed to the n^{th} harmonic (8^{th} harmonic @32.5nm)



The delay line shifts the first stage output to a fresh portion of the e-beam

The second stage converts the first stage to the n^{th} x m^{th} harmonic of the seed (24^{th} harmonic at 10.8nm)