Beam handling devices

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EXPERIENCE AT SYNCHROTRON
Realization of beamlines at ELETTRA

ALOISA: Advanced Line for Overlayer, Interface and Surface Analysis

- Wiggler-ondulator source
- Crystal monochromator

Energy 3-8 keV, resolving power 7500

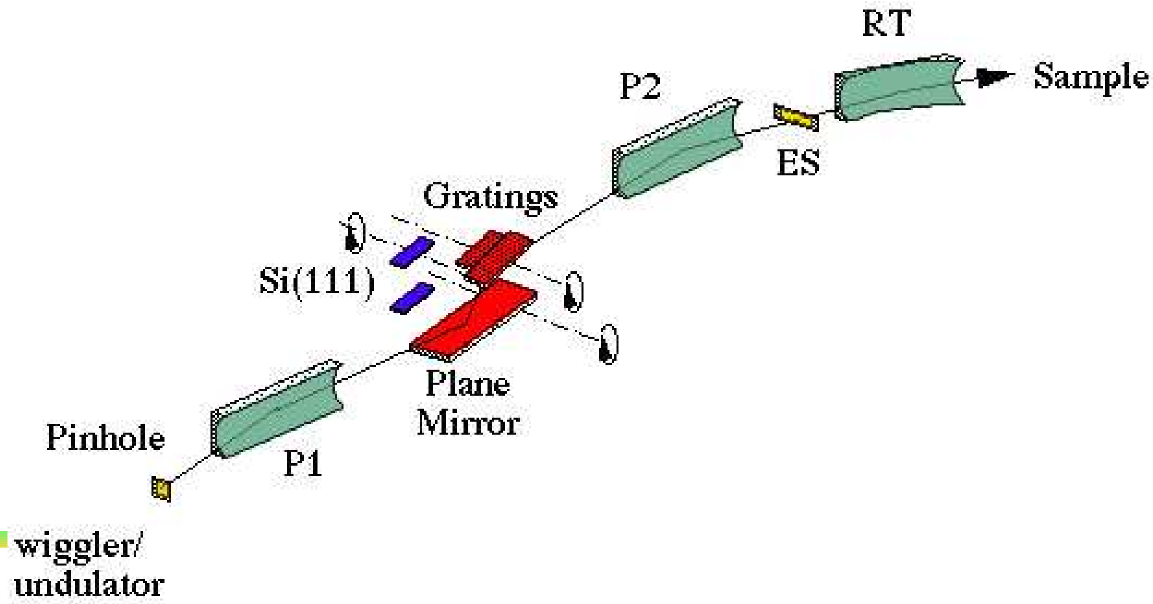
- Grating monochromator

Energy 150-2000 eV, resolving Power 8000

- Plane-grating design

BEAR: Bending magnet for Emission Absorption and Reflectivity

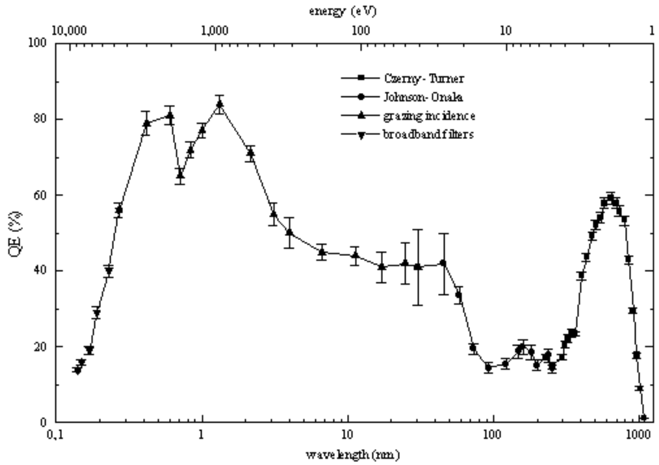
- Bending-Magnet source
- Plane-grating design
- Photon Energy range: 4 eV-1400 eV
- Resolving power: >3000
- Polarization selection



LAB EXPERIENCE

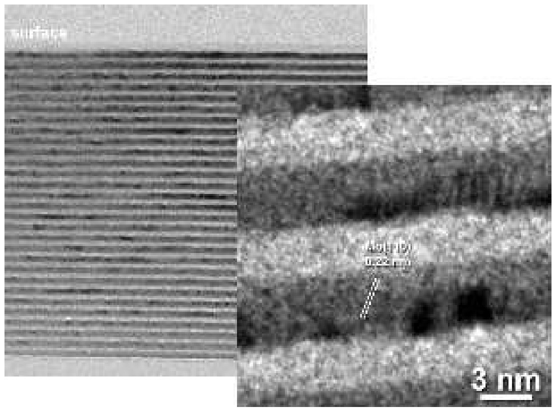
Realization of lab facilities in the visible, UV and soft X-ray spectral region (6-500 nm)

Detector and optics characterization

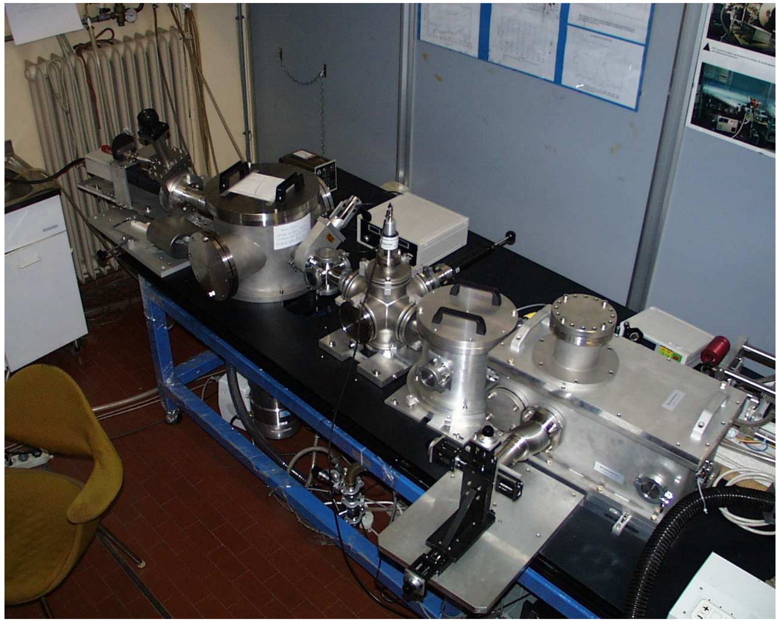


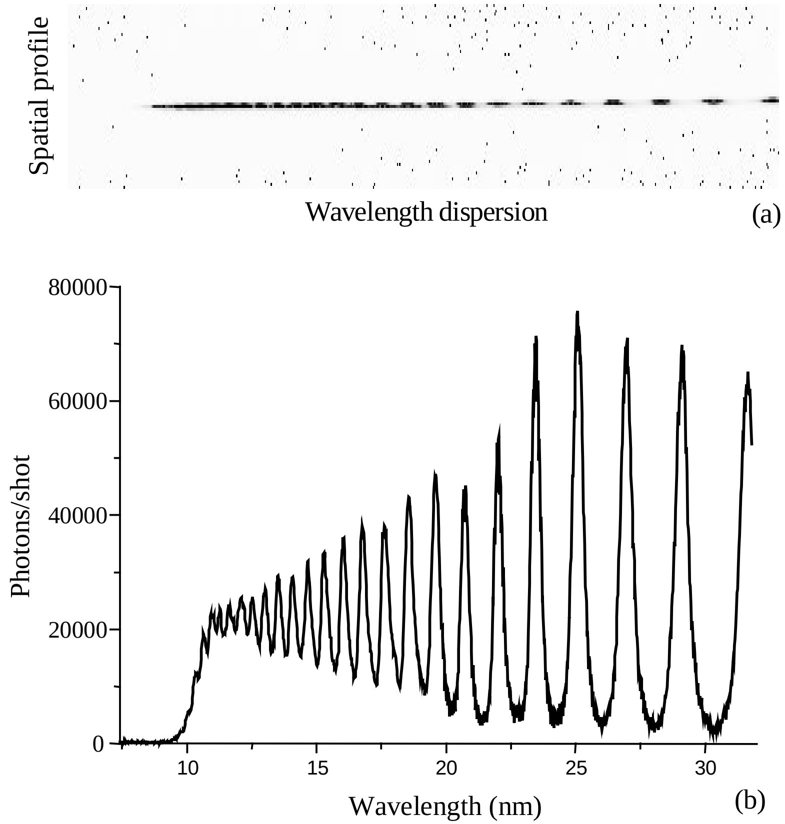
Multilayer development

(collaboration with INFN and Sincrotrone Trieste)



HIGH-ORDER HARMONIC
Spectrometer-monochromator for HHG



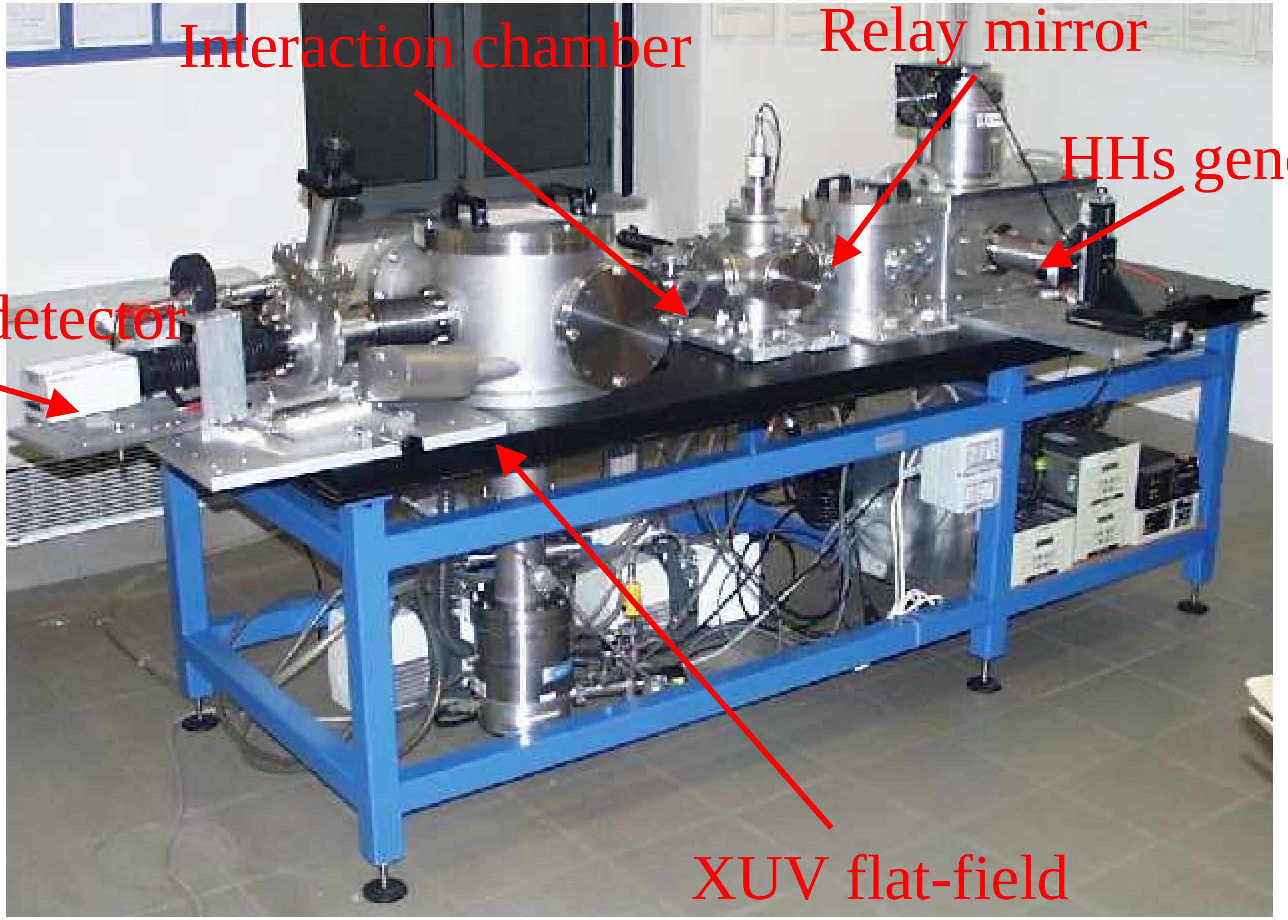


- Source: high-order harmonic radiation generated by the interaction between a fs-laser pulse and a gas jet
- Spectral range: 5-80 nm
- Resolution: 1000 – 2500
- Spectrograph: toroidal mirror and VLS plane grating
- Detector: MCP + phosphor screen + CCD camera (1024×1024 pixel, pixel size 32×32 μm^2)

L. Poletto et al, Rev. Sci. Instr. **75**, 4413 (2004)

The instrument is installed at CRS ULTRAS - Politecnico (Milano)

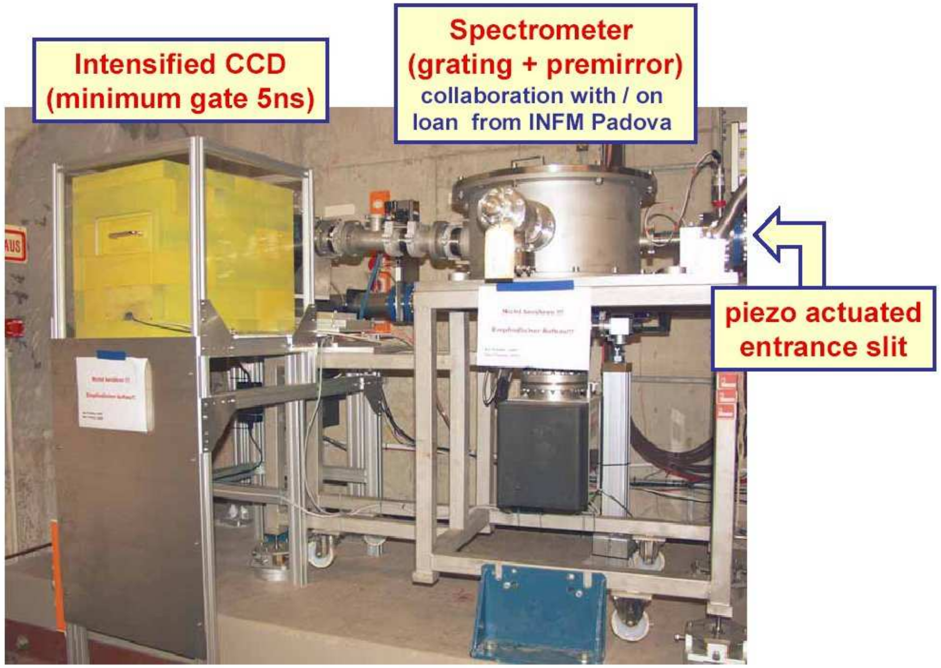
HIGH-ORDER HARMONIC
Polychromatic interaction

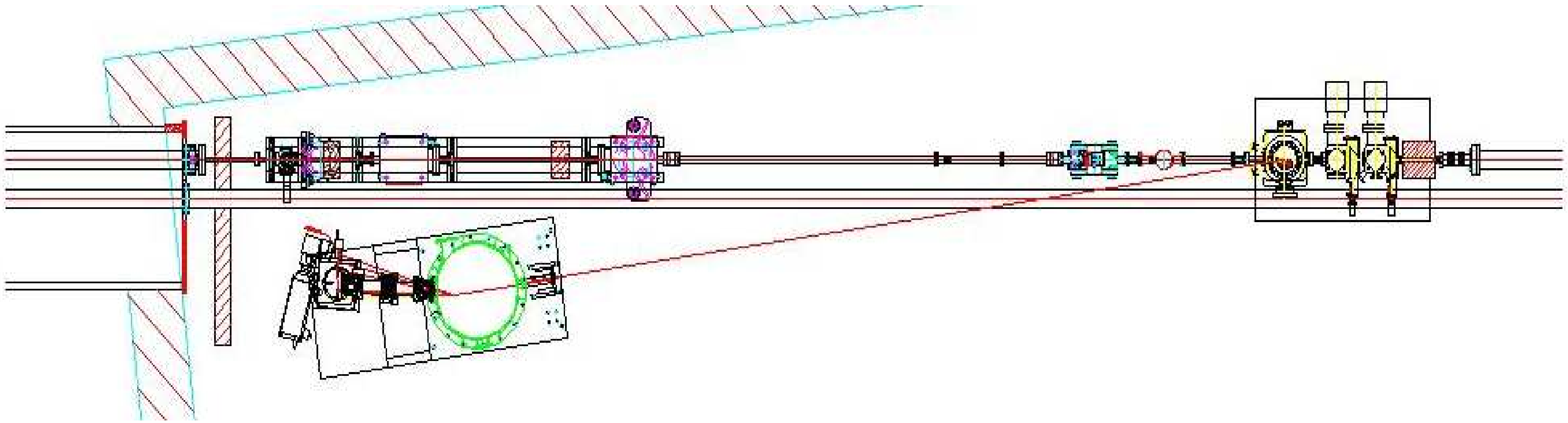


EXPERIENCE WITH FEL RADIATION
Spectral monitoring of the DESY-FEL at 30 nm

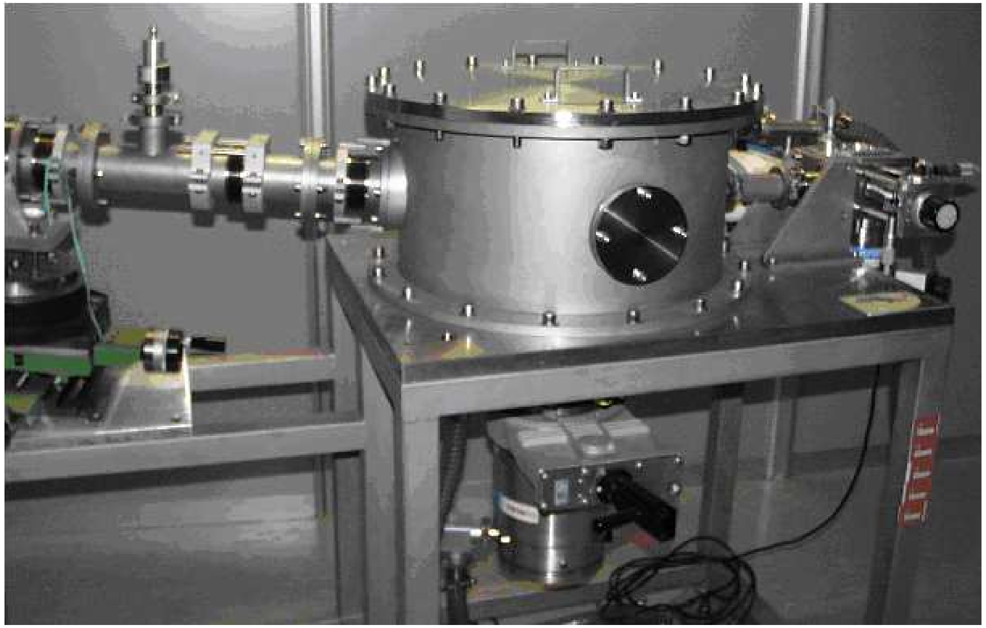
A grazing-incidence flat-field EUV spectrometer has been designed and realized at LUXOR.

The instrument is installed at **DESY** for the spectral monitoring of the **FEL emission in the 25-45 nm spectral region**.





EXPERIENCE WITH FEL RADIATION
The instrument for the DESY-FEL



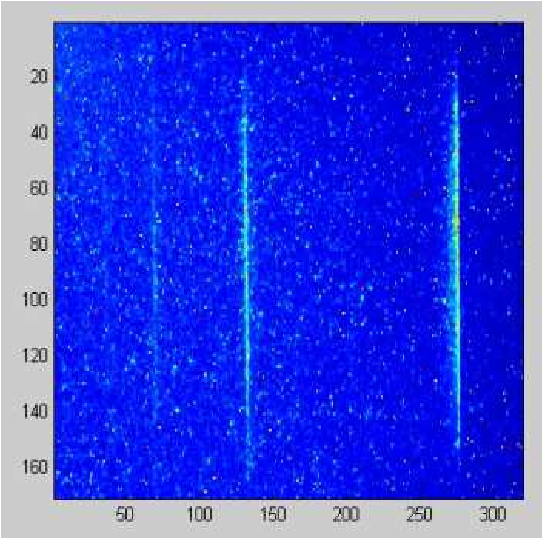
Spectrometer

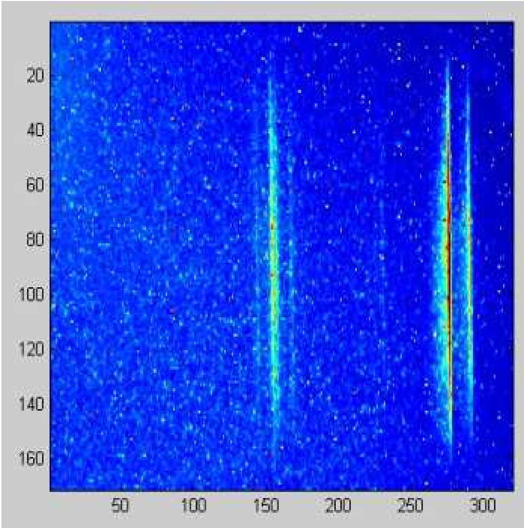
Optics

Entrance slit

Detector

EXPERIENCE WITH FEL RADIATION
Present situation at DESY





Spectra with the hollow-cathode lamp

The spectrometer has been calibrated within 0.02 nm

- The LUXOR spectrometer has been installed and aligned at the end of the LINAC tunnel in July, 2004
- The instrument will be used for the spectral monitoring of the FEL beam during the commissioning phase

First lasing at 30 nm of the VUV-FEL at the TESLA Test Facility was obtained in January, 2005

FOCUSING SYSTEMS

BEAM-SPLITTING AND RECOMBINING

FOCUSING WITH MIRRORS (1/2)

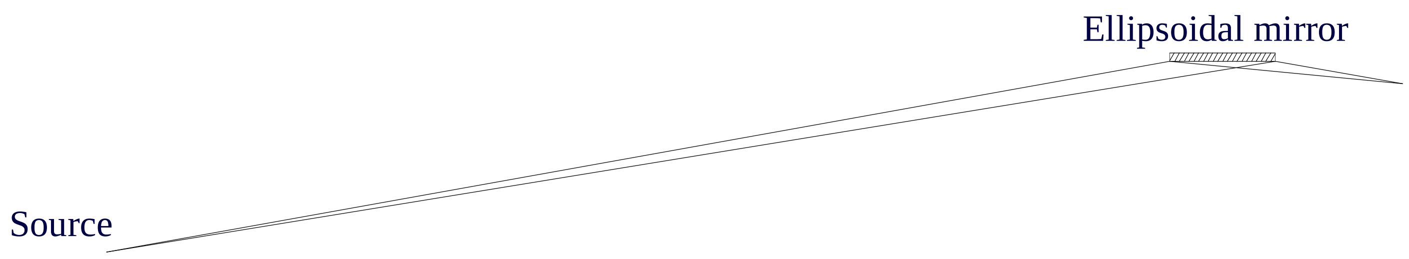
General requirements

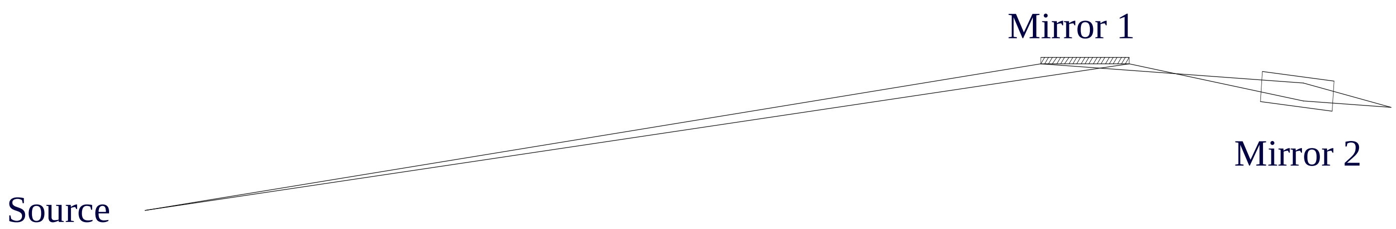
- Focusing at the **DIFFRACTION LIMIT**

  ⇒ the FEL beam is highly collimated

  ⇒ demagnification to reduce the diffraction limit (e.g. a 10 μm diff. lim. spot @4 nm requires f/1000 ⇒ 1 mrad)

- Grazing-incidence optics (high reflectivity and low power density)
- Aberrations (configuration and slope errors) lower than diffraction





FOCUSING WITH MIRRORS (2/2)

Variable focusing on the sample

- sample movement
- mirror rotation and translation
- bendable mirror

Power density on the optics

The power density on the mirror must be below the damaging threshold

Sample/thickness		damage threshold [J/ cm^2]
Cu	bulk	0.5
Au	10 nm	0.04
Si	bulk	0.03
Graphite	40 nm	0.06
YAG	bulk	0.07

Andrejczuk A. et al. DESY annual report 2001

SPECTRAL SELECTION OF ULTRA-SHORT PULSES
THE PROBLEM OF TIME-COMPENSATION (1/3)

Grating monochromators

The design of grating monochromators for the selection of a spectral band of a short pulse gives problems related to the **preservation of the pulse time duration**

For a grating, the optical path of a ray differs from that of the neighbor by the quantity $\delta = m\lambda$, where m is the diffraction order. The total difference between the paths on first to last groove is $\Delta = N m\lambda$

Es: λ=40 nm, 500 gr/mm, 10 mm illuminated area, first order $\Rightarrow \Delta = 200$ µm, $\Delta T = 660$ fs

The time broadening is irrelevant for ps pulses but devastating for fs pulses

The mechanism which originates the path difference must be canceled

- equalization of path lengths for different spectral components
- combination of two diffractive elements in negative dispersion
- correction of the optical aberrations

P. Villoresi, Appl. Opt. **38**, 6040 (1999)

L. Poletto, Appl. Phys. B **78**, 1013 (2004)

SCHEMES FOR PATH LENGTHS EQUALIZATION: COMPENSATED MONOCHROMATOR (2/3)

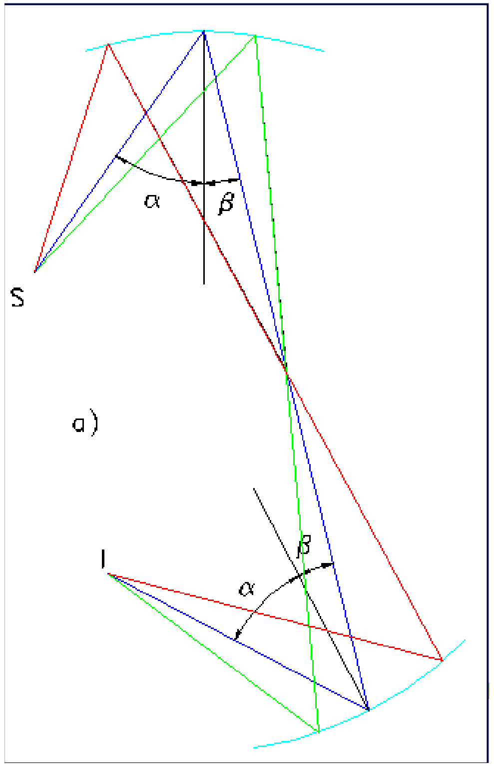
TWO GRATINGS in COMPENSATED CONFIGURATION / SUBTRACTIVE DISPERSION

Spectral selection

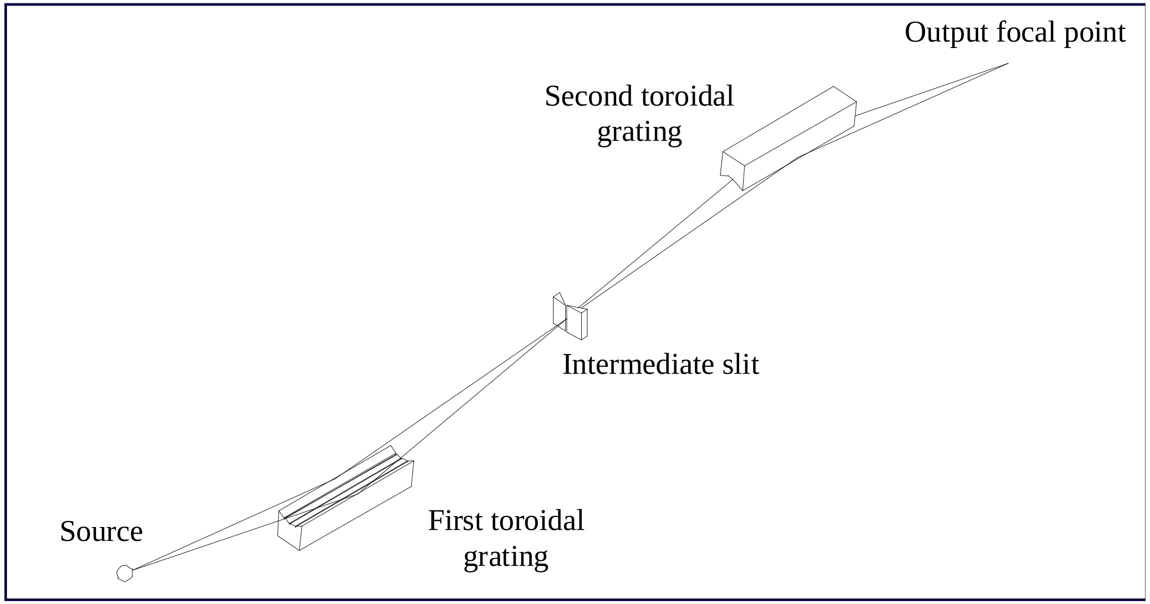
An intermediate focus is formed between the two gratings, where a slit carries out the spectral selection of the harmonics

Wavelength scanning

The wavelength scanning is performed by grating rotation



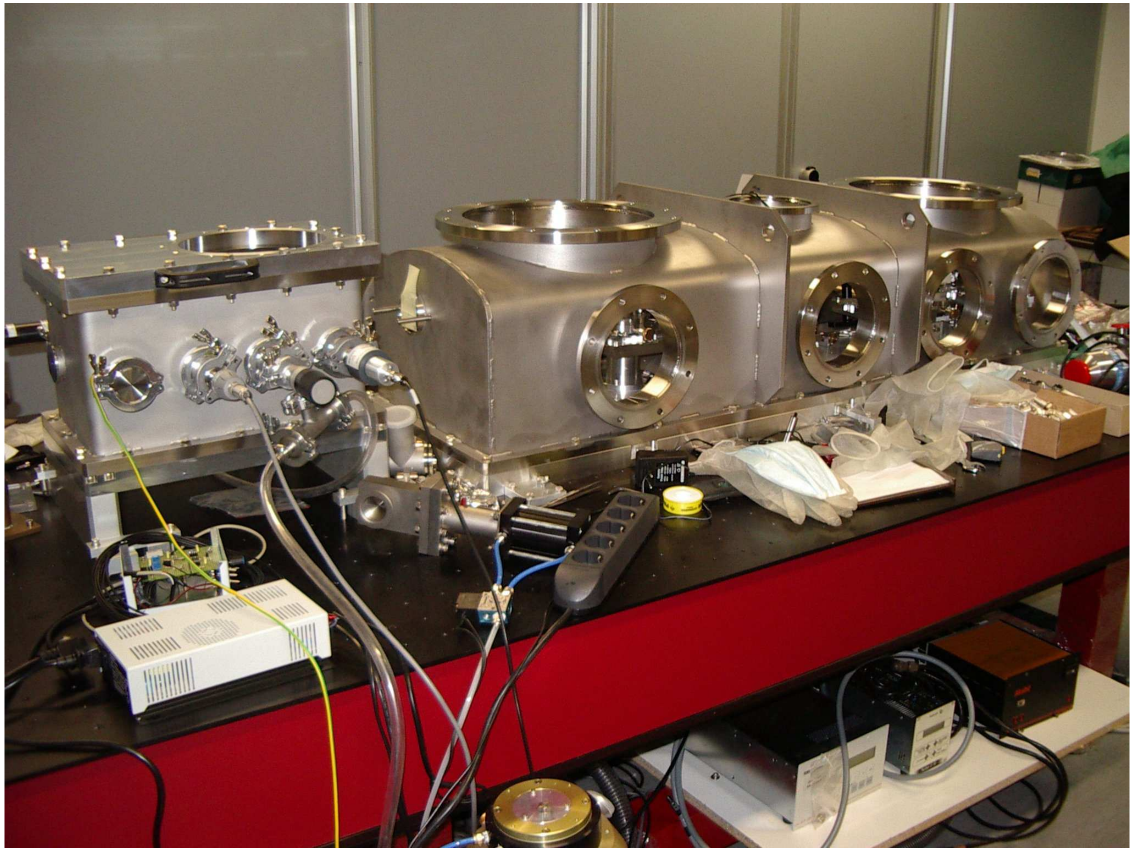
Normal-incidence time-compensated monochromator



Grazing-incidence time-compensated monochromator

TIME-COMPENSATED MONOCHROMATOR IN CONICAL DIFFRACTION (3/3)

A time-compensated monochromator in conical diffraction is being realized at LUXOR



BEAM SPLITTING AND RECOMBINING @40 nm (1/3)

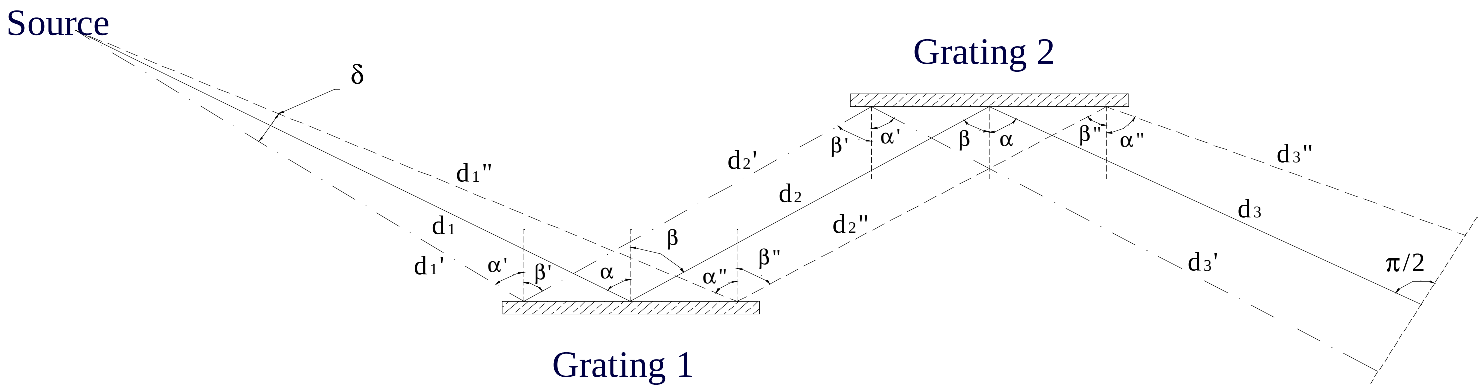
THE SPLITTING IS PERFORMED BY A DIFFRACTION GRATING

- **The minimum pulse duration is <=100 fs**
- A grating gives a spread in the optical paths equal to $\Delta = Nm\lambda$

Example: 200 lines/mm, grating size 30 mm, λ = 40 nm $\Rightarrow \Delta$ = 240 um $\Rightarrow \Delta T$ = 800 fs

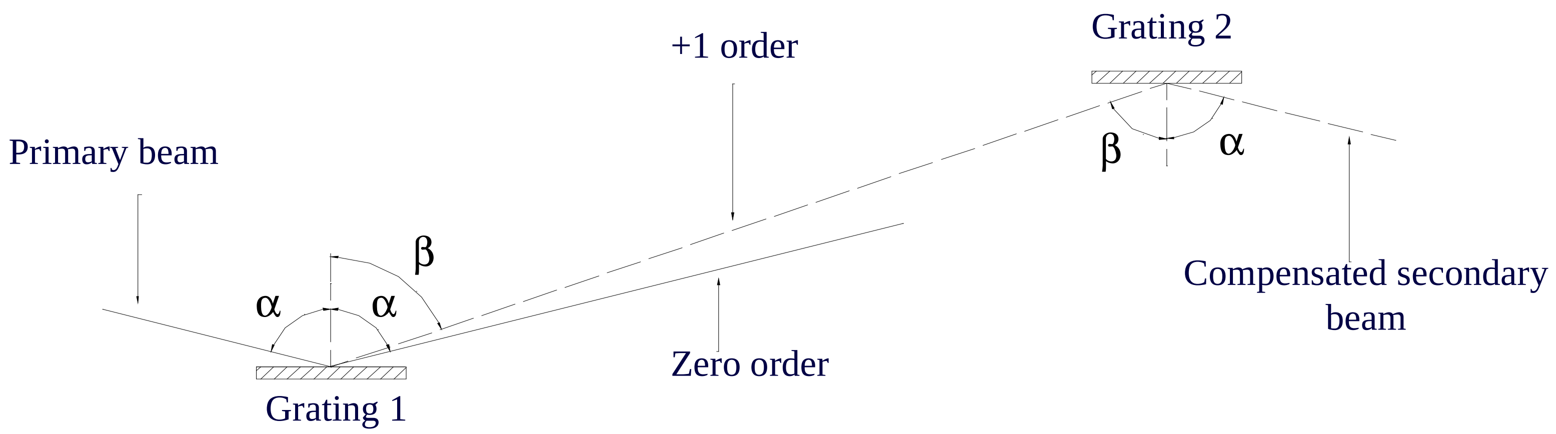
- A grating gives a spectral spread of different spectral components

⇒ TIME-COMPENSATED CONFIGURATION WITH ZERO-DISPERSION

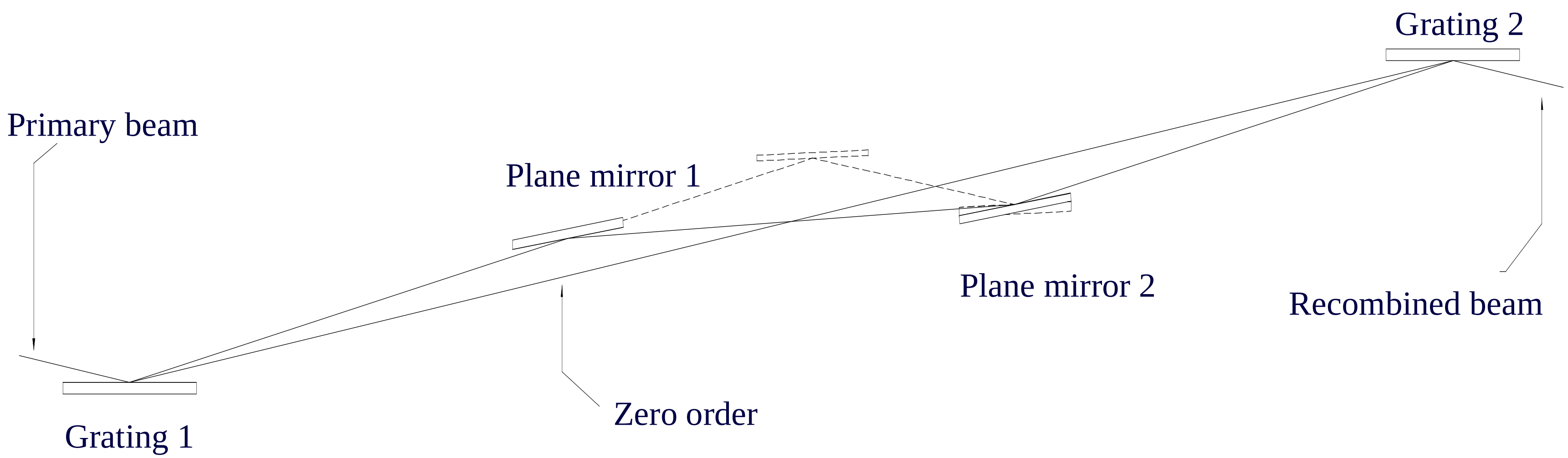


SPLITTING OF THE PRIMARY BEAM IN SECONDARY BEAMS (2/3)

2 secondary beams (zero order, +1 order) ⇨ two blazed gratings



BEAM RECOMBINING IN THE SAME DIRECTION (3/3)



Two plane mirrors

Mirror 1: rotation and translation

Mirror 2: rotation

REFERENCES

- P. Villoresi, Appl. Opt. **38**, 6040 (1999)
- L. Poletto, P. Azzolin, G. Tondello, SPIE Proc. **5194**, 95 (2003)
- L. Poletto, P. Azzolin, G. Tondello, SPIE Proc. **5194**, 105 (2003)
- L. Poletto et al, SPIE Proc. **5534**, 37 (2004)
- L. Poletto et al, SPIE Proc. **5534**, 144 (2004)
- L. Poletto, P. Azzolin, G. Tondello, Appl. Phys. B **78**, 1009 (2004)
- L. Poletto, Appl. Phys. B **78**, 1013 (2004)

For information

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BEAM DIAGNOSTICS

ON-LINE SINGLE-SHOT DIAGNOSTICS of the photon beam are necessary for the characterization of the source and the definition of the experimental conditions:

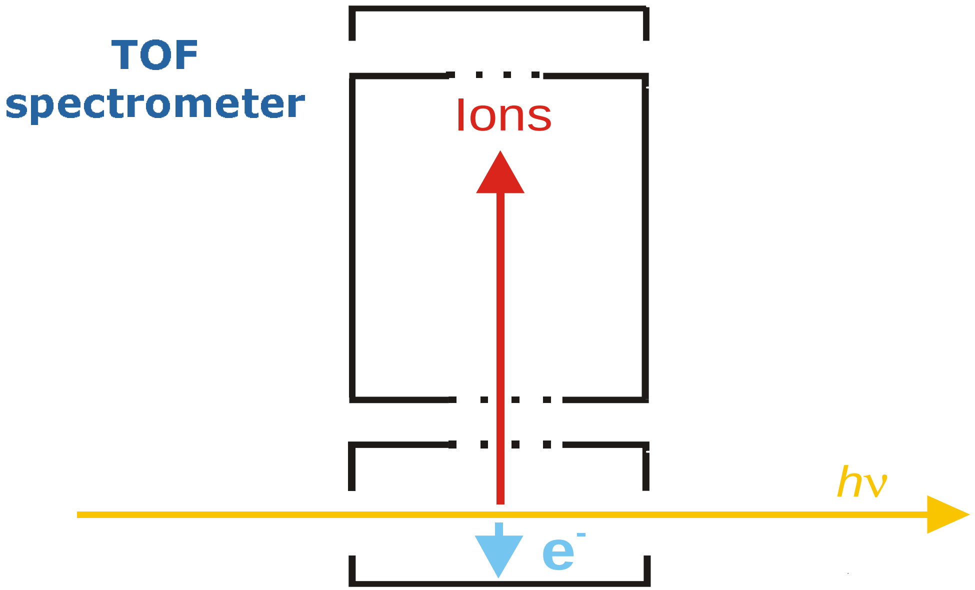
- **Beam position**
- **Spectrum**
- **Intensity**

LUXOR HAS THE CAPABILITY IN DESIGN AND REALIZATION OF INSTRUMENTS FOR PHOTON BEAM DIAGNOSTICS.

Spectrum measurement

- *The spectrometer that is used at present at DESY for TTF-2 characterization during the commissioning phase, can be refurbished and used also for the characterization of FEL emission in the 5-45 nm spectral region.*
- *An on-line single-shot spectrometer for the soft X-ray region can be designed*

Monitoring the FEL pulse intensity
Gas ionization detector (DESY)



Online monitor of single-pulse FEL intensity

+ transparent
+ wide dynamic range
+ independent from beam position
+ 6 nm < λ < 93 nm
+ absolute calibration (~10%)

Single photoionisation:

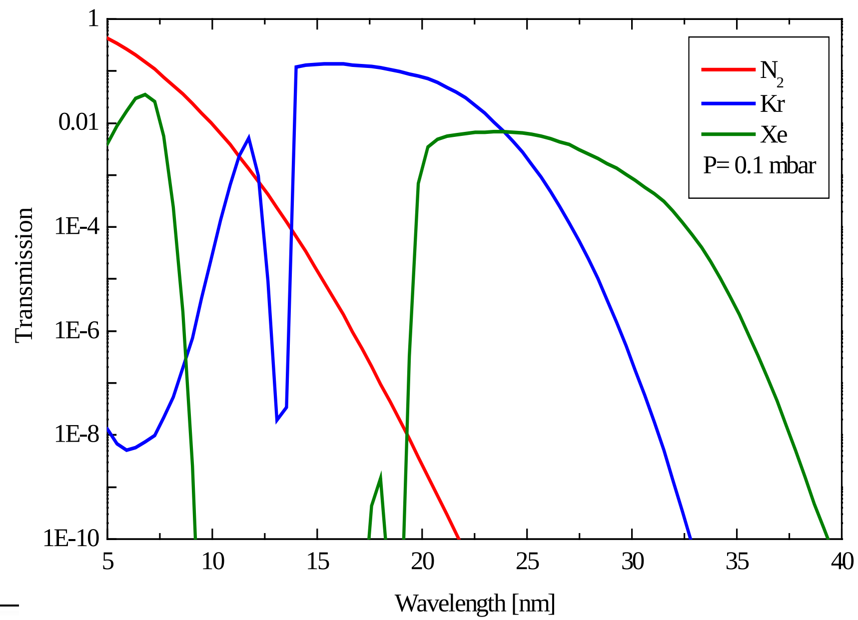
$$N = N_{ph} \times n \times s \times l$$

N = number of electrons or ions
N_{ph} = number of photons
n = target density
s = photoionisation cross section
l = length of interaction volume

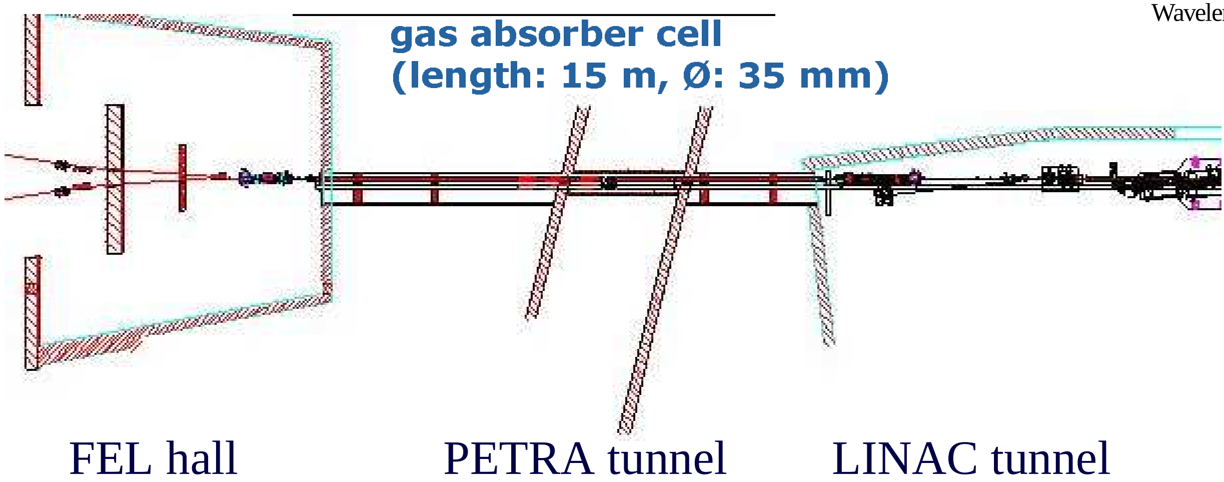
Controlled attenuation of FEL radiation
Gas aborber (DESY)

- **Controlled attenuation of FEL beam in the region 6-40 nm**
- **Attenuation of 10^{-6} (depends on gas)**
- **Preserves beam attributes (coherence, statistics, spectrum, etc.)**

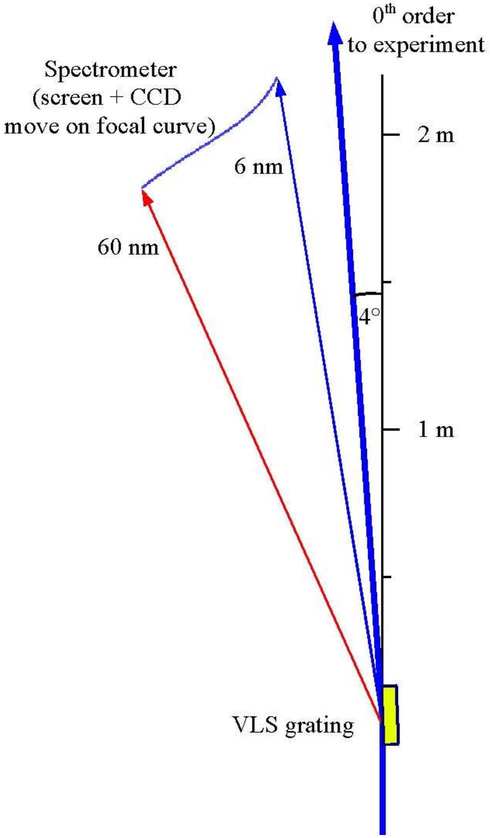
transmission of gas absorber

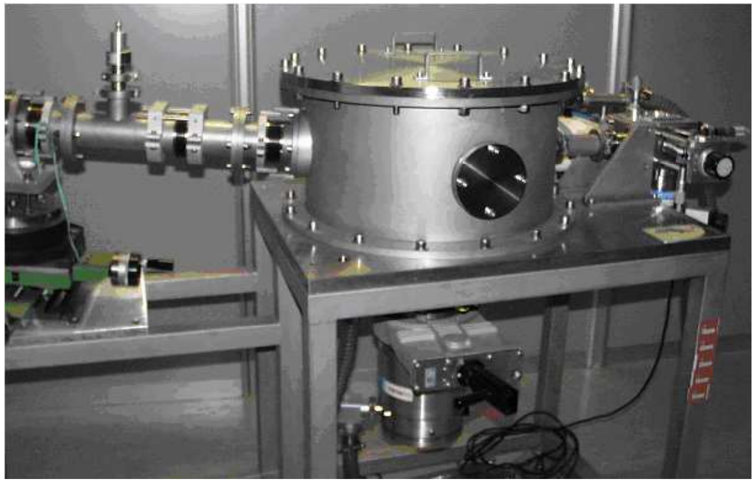


gas absorber cell
(length: 15 m, Ø: 35 mm)



Monitoring the FEL spectrum (Hasylab-LUXOR)
On-line spectrometer for single pulses





On-line monitoring
Grating spectrometer
with maximum zero order efficiency

Off-line monitoring
Grating spectrometer

PROPOSAL FOR OPTICS DEVELOPMENT (1/2)

REALIZATION OF AN UV BEAM-SPLITTER FOR ULTRASHORT PULSES

Many experiments require the **splitting of the FEL beam**. One of the viable solutions for the intense EUV FEL beam is the use of **grazing-incidence gratings**.

LUXOR is interested in the detailed study and realization of a **beam-splitter for ultrashort pulses with gratings in compensated configuration**.

The beam-splitter will be realized on a lab board with **two plane grazing-incidence gratings** and **three plane mirrors** mounted on manual translators and rotators. It will be operated with ***UV radiation (200-300 nm region)***.

The system input is an ultrashort UV pulse (<=100 fs), the output two parallel ultrashort beams with variable delay.

PROPOSAL FOR OPTICS DEVELOPMENT (2/2)

PARTNERS, ROLES AND TIME SCHEDULE

LUXOR (INFM, Padova) - ULTRAS (INFM, Milano)

Tasks

LUXOR: Optical design and system realization.

ULTRAS: UV ultrashort source (e.g. low-order harmonic generation from Ti:Sa laser), UV auto-correlator for the measurement of the pulse duration, measurement of the time delay between the two pulses.

LUXOR/ULTRAS: Test of optical performance with the ultrashort UV laser beam.

Request	40-50 kE
Time schedule	<=1 year

REALIZATION OF THE SPECTROMETER FOR SPARC

A normal-incidence spectrometer can be designed and realised by LUXOR for the monitoring of SPARC in the 40-600 nm region.

Characteristics

- large spectral region of operation (40-600 nm with three gratings)
- high spectral resolution ($\lambda/\Delta\lambda > 7000$)
- EUV-enhanced CCD detector for simultaneous acquisition of the spectrum
- the absolute calibration of each element can be performed at LUXOR ($\Rightarrow$ number of emitted photons)