



# The FemtoSpeX facility at BESSY II

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**Abstract:** The FemtoSpeX facility of the BESSY II storage ring is dedicated to ultrafast optical-pump and soft x-ray probe experiments. Experimental end-stations for experiments in transmission, reflection, and diffraction geometry are available.

## 1 Introduction

The FemtoSpeX facility of BESSY II is optimized for time-resolved experiments using polarized soft x-ray pulses (Bergeard et al., 2014; Boeglin et al., 2010; Eschenlohr et al., 2013; Holldack et al., 2010; Izquierdo et al., 2014; Radu et al., 2011; Stamm et al., 2007; Trabant, C. et al., 2013; Wietstruk et al., 2011). It consists of a high-transmission monochromator, a fs pump laser system including harmonic generation and dedicated end stations for transmission, reflection and diffraction experiments. Magnetic fields up to 0.5 T for transmission and 0.2 T for other geometries are available. A new end station with higher magnetic fields in all geometries is in preparation. For a detailed description see Holldack et al. (2014). An overview of the facility is given in Fig. 1.

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## 2 Monochromator

The reflection zone-plate-monochromator (ZPM) beamline at the insertion device UE56-1 has been particularly designed and optimized with high transmission optics (Holldack et al., 2014) to compensate for the relatively low flux of  $1 \times 10^6$  ph/sec/0.1%BW of the Femtoslicing source (Khan et al., 2006). The optical layout is depicted in Fig. 2 (left). A reflection zone plate comprises focusing as well as energy dispersion for a particular design photon energy. To cover the absorption edges of the mostly studied elements between 410 to 1333 eV, a four inch substrate hosts nine zone plate lenses (Fig. 2 right) that cover selected photon energies within that range. The images on top of the zone-plate photograph show the intensity distributions in the focus after each lens (Brzhezinskaya et al., 2013; Holldack et al., 2014). The optics is tailored to minimize pulse elongation and preserve the polarization properties of the elliptical light from the undulator.

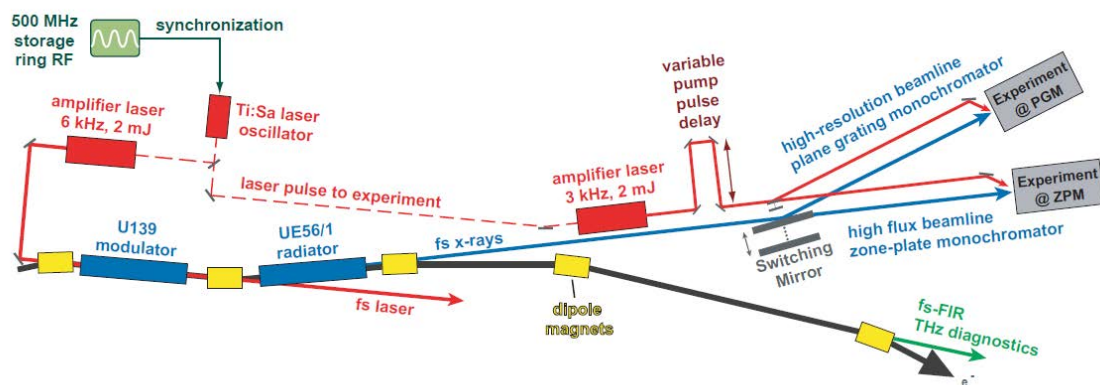


Figure 1: Optical layout of the full optical pump-soft-x-ray probe setup at the FemtoSpeX facility at the BESSY II storage ring (Holldack et al., 2014). The horizontal dimension of the entire setup is ca. 50 m. Synchronized to the 500 MHz master-oscillator driving the rf-cavities of the storage ring, a Ti:Sa oscillator seeds the two regenerative amplifiers that are located in different laser hutches. As a monochromator, either the high resolution Plane Grating Monochromator (PGM) or the high flux Zone Plate Monochromator (ZPM) can be selected by setting a switching mirror to the corresponding position.

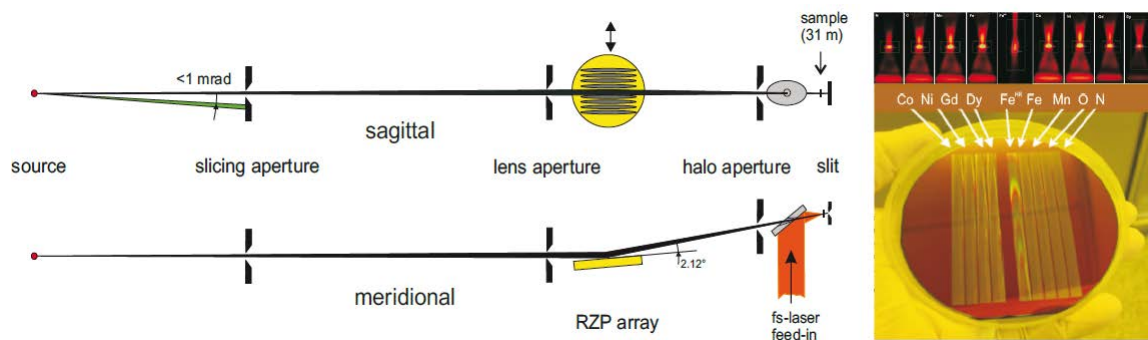


Figure 2: Optical layout (left) of the high transmission ( $T \sim 0.2$ ) ZPM (Brzhezinskaya et al., 2013; Holldack et al., 2014).

### 3 Pump laser system

To allow for resonant pumping at high repetition rates, the laser system consists of two coupled Ti:Sa amplifiers (Legend Elite Duo, company: COHERENT) driven by a single oscillator (Micra, COHERENT). The amplifiers typically run at 6 and 3 kHz for the slicing- and the pump excitation, respectively, and at pulse energies of 1.8 mJ. "Slicing" of stored electron bunches is achieved by laser pulses from the first amplifier resulting in  $\sim 100$  fs x-ray pulses while the second amplifier yields pulses of  $\sim 40$  fs duration at 800 nm and as well at the second and third harmonic (400 nm and 266 nm, respectively) for the "pump" excitation of the sample. The pulse energies are sufficient to operate an optical parametric amplifier (OPA, Opera Solo, COHERENT) providing variable pump wavelengths for sample excitation from the UV (240 nm) to the mid infrared ( $6\mu\text{m}$ ) wavelength range, with wave-length-dependent pulse energies. A special laser feed-in is used to couple in the pump-laser beam in to the ZPM beamline in a collinear geometry or under a small angle of  $1.5^\circ$ .

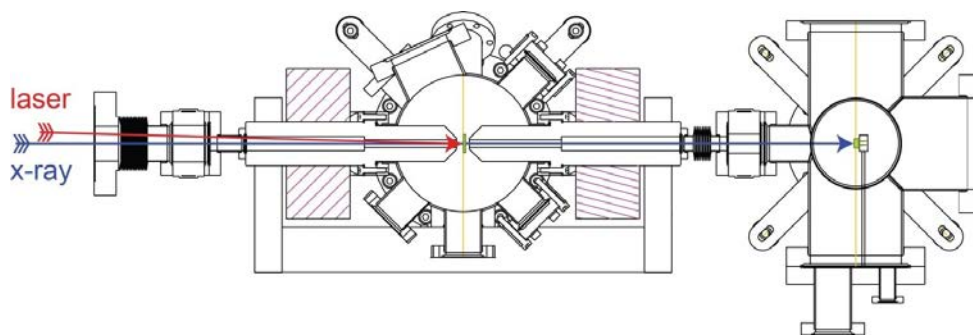


Figure 3: Layout of the fs XMCD/XAS chamber (FemtoSpeX Magnetism).

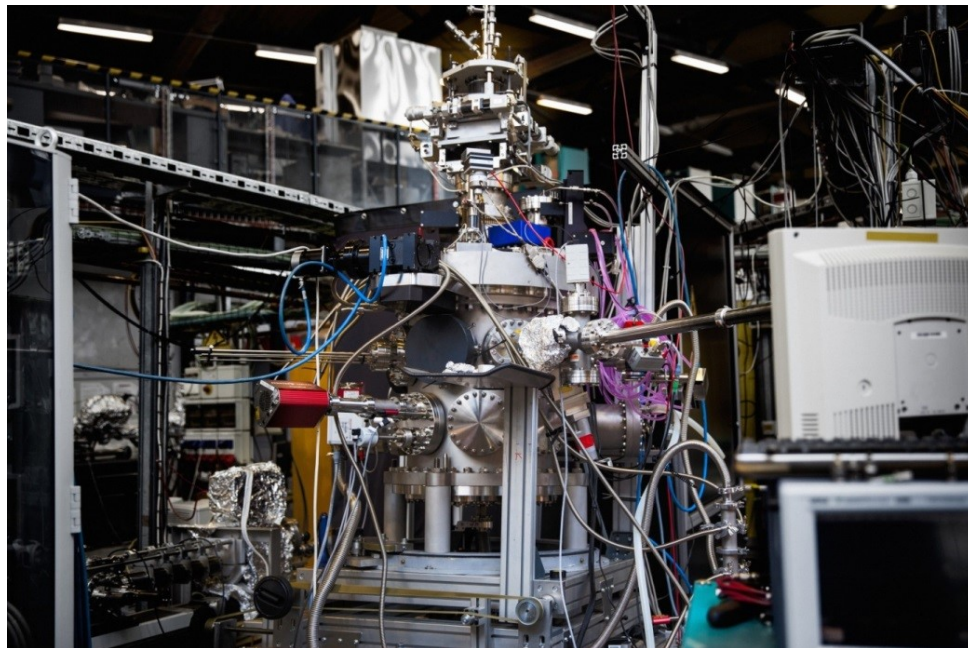


Figure 4: View of the FEMTOSPEX Scattering station.

## 4 FemtoSpeX Magnetism (transmission) station

The experimental setup for laser pump – X-ray probe on magnetic samples consists of a measurement chamber housing the magnet (up to 0.5 T parallel to the x-ray beam) and transmission sample, and the detector chamber with a fast avalanche photodiode (APD). An Al foil mounted between the chambers prevents laser light to enter the detection chamber with the APD. A load-lock allows for fast sample transfer. The layout of the instrument can be seen in Fig. 3. Technical data are summarized in Table 3.

## 5 FemtoSpeX Scattering station

A two circle UHV diffractometer is available for diffraction (Hollmack et al., 2010; Trabant, C. et al., 2013) or reflectivity (Izquierdo et al., 2014) studies. Sample and detector angles can be varied independently. Magnetic fields up to 0.2 T in variable direction are available. Scattered photons are detected with avalanche photodiodes (APDs). The APDs are screened from light of the pump-laser by Al membranes and a light tight housing. Low noise amplification (up to 60dB by Hamamatsu and Kuhne preamplifiers) allows besides analog pulse detection for time-correlated single-photon pulse counting. Generally signals as low as  $\sim 5$  photons/sec from the sample can be detected. A photograph of the station is depicted in Fig. 4, technical data are summarized in Table 4.

## 6 Source

The insertion device is the elliptical undulator UE56-1 with the following parameters:

Type	APPLE2
Location	H11
Periode length	56 mm
Period number	30
Minimal Energy at 1,7 GeV	58.5 eV
Minimal Gap	16.6 mm
Polarisation	linear horizontal, linear vertical, elliptical, circular

Table 1: Parameters of insertion device UE56-1.

## 7 Technical data

Source	Insertion device: UE56-1
Monochromator	Reflection Zone Plate Monochromator (RZPM)
Photon energy range	410 - 1330 eV
Photon energy resolution	500 (2000)
Photon flux (slicing mode)	$1 \cdot 10^6$ ph/sec/0.1%BW@6kHz (100 fs pulses)
Divergence (horizontal, vertical)	0.2 mrad, 0.1 mrad
Focus size (hor. x vert.)	100 $\mu$ m x 40 $\mu$ m (slit)
Distance focus - last valve	800 mm
Free photon beam	No
Fixed end station	Yes

Table 2: Technical data of the Beamline UE56-1 ZPM.

Experiment in vacuum	Yes
Temperature range	30 - 450 K (low-T), 130 - 750 K (variable T)
Detector	GaAs Photodiode, gated Avalanche Photodiode (1 ns)
Manipulators	Low-Temperature (He) cryostat, variable temperature cryostat
Magneticfield (longitudinal)	0.5 Tesla
Magneticfield (transverse)	0.04 Tesla

Table 3: Technical parameters of the FEMTOSPEX transmission station.

Experiment in vacuum	Yes
Temperature range	6 - 400 K
Detector	Photon detection (see detection special features below)
Manipulators	x/y/z; two cycle goniometer
Sample environment	<ul style="list-style-type: none"> <li>•In-situ sample cleaving available</li> <li>•Sample transfer system available</li> <li>•Measurements at cryogenic temperatures possible</li> </ul>
Magnetic field	0.2 T (variable direction)
Detection special features	<ul style="list-style-type: none"> <li>•fs-laser synchronized gated detection (Avalanche Photo Diode)</li> <li>•Single photon counting detection for low intensity measurements</li> <li>•Laser light screened detection (&gt;10<sup>12</sup> attenuation)</li> </ul>
Diffractometer features	<ul style="list-style-type: none"> <li>•Motor controlled two-circle</li> <li>•Variable detector resolution</li> </ul>
UHV	< 10 <sup>-9</sup> mbar (turbo-molecular pump, LN-cooling trap)
Miscellaneous	Laser safety protected viewports

Table 4: Technical parameters FEMTOSPEX Scattering station.





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