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The 7T-MPW-EDDI beamline at BESSY II *

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Abstract: The materials science beamline EDDI is operated in the ***E***nergy ***D***ispersive ***DI***ffraction mode and provides hard synchrotron X-rays in an energy range between about 8 ... 150 keV for a multitude of experiments reaching from the in-situ study of thin film deposition over the investigation of liquid phase processes to the analysis of the residual stress distribution in complex components and technical parts. For high temperature experiments or measurements under external mechanical load various devices such as heating stations and a tensile/compression load test rig are available. Besides the sample environment for pure diffraction experiments a tomography/radiography setup is provided which allows for combined simultaneous diffraction plus imaging investigations.

1 Introduction

The EDDI beamline started user service in April 2005. It is operated in the energy-dispersive (ED) mode of diffraction employing the direct white photon beam provided by a superconducting 7T multipole wiggler. With an usable energy range of about 8 ... 150 keV it is first of all dedicated to the analysis of structural and property gradients in the near surface zone of polycrystalline materials, thin film systems and technical parts and components (Genzel et al., 2007). The main advantage of the ED diffraction mode compared with the angle-dispersive (AD) mode is that the former yields complete diffraction patterns (inclusive of the fluorescence lines originating from the elements the investigated material consists of) for fixed but arbitrary positions of both, sample and detector. Since each diffraction line E^{hkl} originates from another average information depth $\langle\tau^{hkl}\rangle$ the ED mode provides an additional parameter that can be used for the depth-resolved analysis of residual stresses, crystallographic texture and the materials microstructrure, respectively (Genzel et al., 2011; Apel et al., 2011). Together with high flux synchrotron radiation which facilitates time-resolved studies, the two features fixed scattering arrangement plus multitude of simultaneously recorded diffraction lines offer a variety of experimental possibilities in different fields of materials science.

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Fig. 1 shows the hutch of the EDDI experimental station which in contrast to most of the other facilities at BESSY II is *firmly connected* to the EDDI beamline (cf. chapter 4). The diffractometer system consists of two units in form of a X-cradle segment (5-axes positioner, mounted at the basic Θ-Θ-diffractometer) for light and small samples, and a 4-axes positioner for large and heavy samples. The two-detector setup at the back wall of the hutch allows for simultaneous data acquisition in two different measuring directions, i.e. orientations of the diffraction vector with respect to the sample reference system.

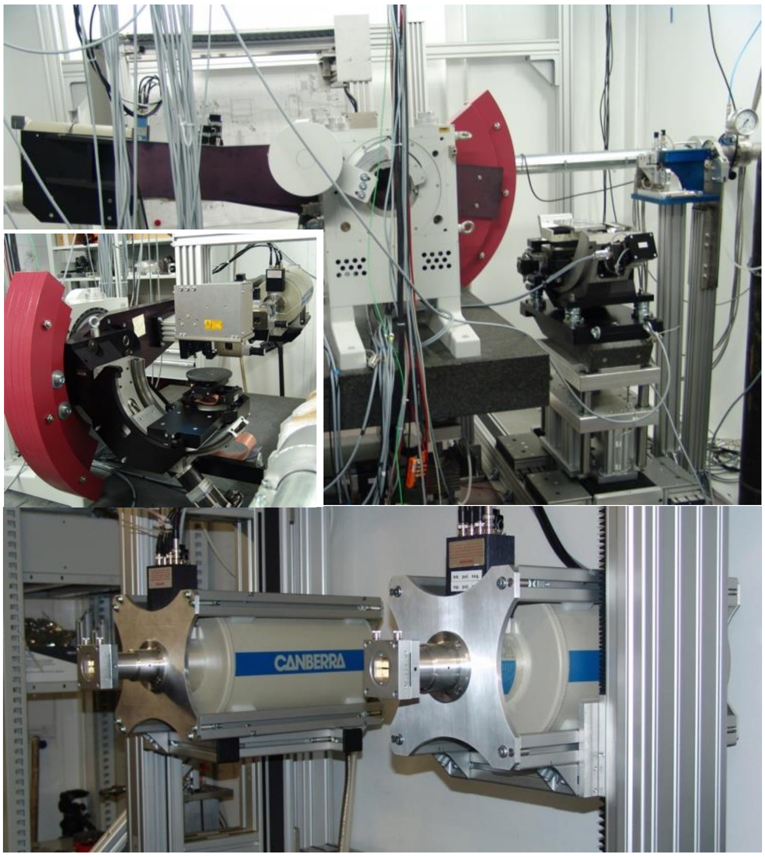

Figure 1: Top: Experimental hutch of the EDDI-beamline. The inset depicts the 5-axes positioning unit and the laser + CCD camera system for sample alignment. Bottom: The two-detector setup at the back wall of the hutch.

The radiography/tomography + diffraction measurement option available at EDDI is shown in Fig. 2. After being partially absorbed by the sample the directly transmitted beam is converted into visible light by a LuAG scintillator and then mirrored into the optical system of a fast CMOS camera. The part of the beam being diffracted by the sample passes the light conversion components without being absorbed and is recorded by a Ge solid state detector. This setup enables to perform fast in-situ imaging (radiography/tomography) and diffraction analysis simultaneously at one and the same sample and therefore, to track phase transformations and (micro)structure evolution during dynamic processes such as metal foaming (García-Moreno et al., 2013).

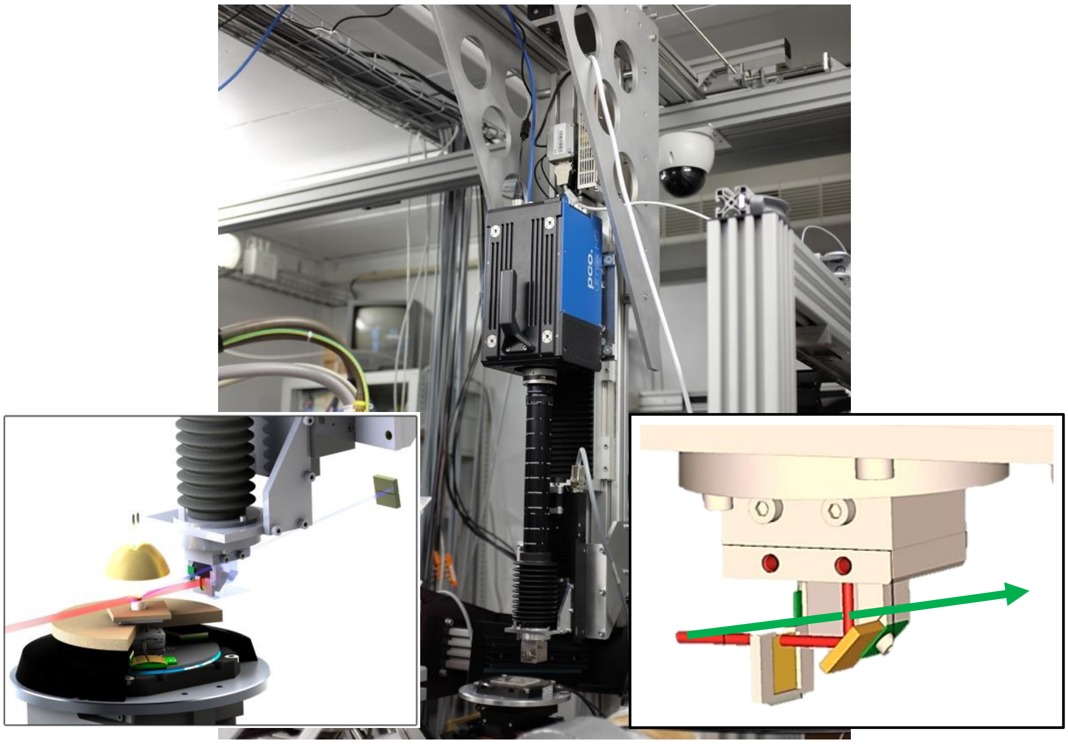

Figure 2: The radiography/tomography + diffraction setup. The left inset depicts the rotation table, the right inset schematically shows the X-ray path of the transmitted (red) and the diffracted (green) beam, respectively (García-Moreno et al., 2013).

2 Instrument Applications

Due to the features of ED diffraction mentioned above and the very flexible setup EDDI is a multi-purpose instrument applicable in various fields of materials science. Typical applications are:

- Phase analysis (qualitative and quantitative)
- Residual stress analysis
- Texture analysis
- Microstructure analysis (domain sizes and microstrain)
- In situ investigations (e. g. under high temperature or external load)
- High spatially resolved measurements (slit widths up to appr. 10 µm possible)
- Simultaneous measurements with two detectors
- Simultaneous radioscopy/tomography and diffraction

3 Source

The insertion device is a superconducting 7T multipole wiggler with the parameters summarized in Table 1. The wigglers critical energy is 13.5 keV at 1.7 GeV. Fig. 3 shows its energy spectrum recorded directly without as well as with different attenuators in the beam by means of a Germanium solid state detector (Canberra).

Type	Supercoducting 7T MPW
Location	5.2
Periods/Pols	17 n

Table 1: Parameters of 7T-MPW

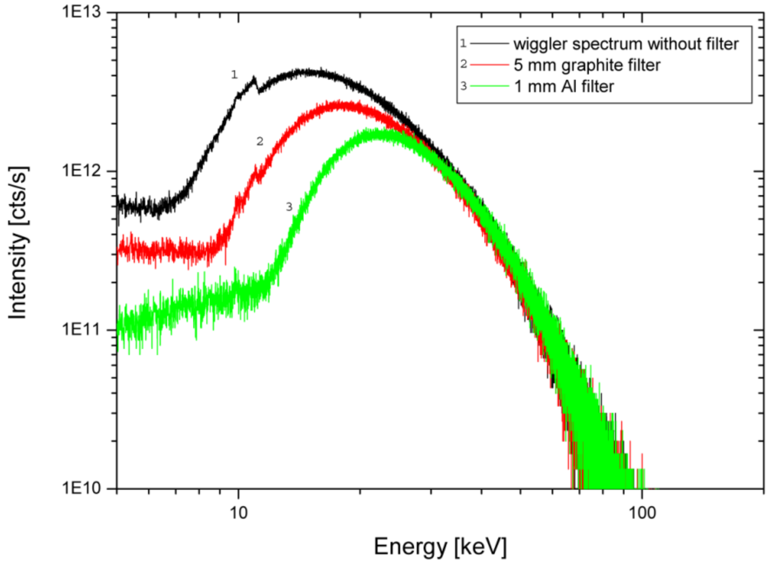

Figure 3: Wiggler spectrum recorded at the EDDI beamline.

4 Optical Design

The overall beamline layout is shown in Fig. 4. Because the beamline is exclusively designed for ED diffraction, direct use is made of the white beam as emitted by the wiggler. The only optical elements are an absorber mask and two slit systems at different positions of the beamline, which are needed to reduce the beam cross-section. Additionally, two filter systems equipped with attenuators of different material and thickness are available to suppress low energy photons in order to prevent sample heating. The samples can be mounted on different positioning units, data acquisition can be performed either using one detector in pure vertical scattering geometry (standard setup) or by means of a two-detector setup (cf. Fig. 1)

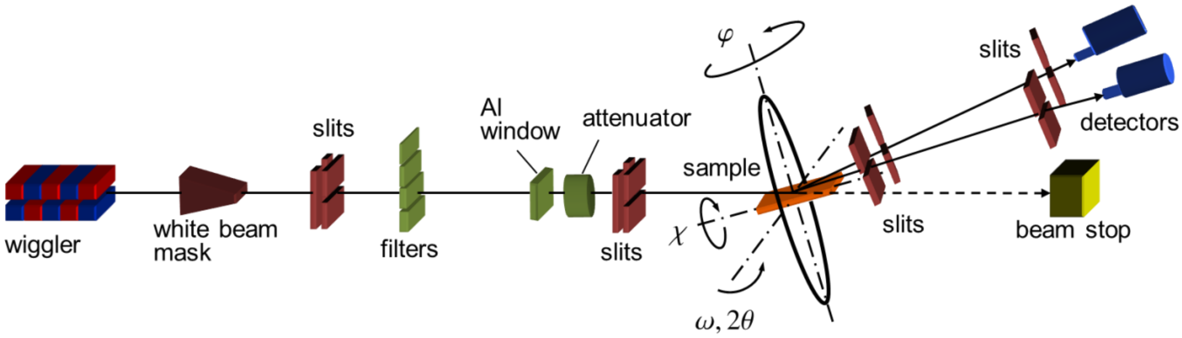

Figure 4: Optical layout of beamline 7T-MPW-EDDI.

5 Technical Data

Location	5.2
Source	7T-MPW
Monochromator	Direct beam (white beam)
Energy range	5 - 150 keV
Energy resolution	Ge solid state detector (Canberra): 160 eV (at 10 keV) and 420 eV (at 100 keV)
Flux	$3 \cdot 10^{12}$ (at 10 keV) and $1 \cdot 10^{10}$ (at 100 keV) (photons/s at 300 mA through a pinhole of 1x1mm^2)
Polarization	Horizontal
Divergence horizontal	± 1.2 mrad
Divergence vertical	± 0.5 mrad With a double slit system (30μm) Δθ ≈ 0.003° mrad
Focus size (hor. x vert.)	Focussed beam not possible Cross-section: max. 4 x 4 mm^2, usually 0.5 x 0.5 mm^2
Distance Focus / last valve	Focussed beam not possible Distance sample/last valve: 6000 mm
Height Focus / floor level	1400 mm
Free photon beam available	Yes
Fixed end station	Yes
Experiment in vacuum	No
Temperature range	Room temperature ... 1100°C (furnace)
Detector	Two Ge solid state detectors (Canberra) resolution: 160 eV (at 10 keV) and 420 eV (at 100 keV)
Manipulators	- 5-axes Eulerian cradle (for samples up to 1 - 2 kg) - 4-axes Eularian cradle (for samples up to 50 kg) - Hexapod (PI GmbH) - Tensile-compressive loading device (Walter+Bai) up to ±20 kN - Furnace (Anton-Paar DHS 1100) between 25°C and 1100°C - Two detector setup possible - Other sample environments and user sample environments possible
Radiography/Tomography	High-speed CMOS camera (PCO DIMAX) LuAg:Ce Scintillator, white beam optic 4 mm × 4 mm field of view 2 mm pixel size 1000 Hz radiography 4 Hz tomography Furnace (heating lamps or resistive plates) up to 700 °C

Table 2: Technical data of Beamline 7T-MPW-EDDI.

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