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Design and possibilities of the materials science beamline at DELTA

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Synchrotron radiation is well suited for many experimental applications in materials science. Electron storage rings together with insertion devices are essential facilities to create brilliant X-ray beams in a wide spectral range essential for XAFS measurements. At the DELTA storage ring in Dortmund (Germany) we plan to build up a new materials science beamline for the photon energy range from 1 to 30 keV with the possibility to use circularly polarized photons. It is designed for the requirements of all XAFS methods, including time resolved QEXAFS-techniques down to ms time resolution and other experiments requiring a high intensity beam.

Keywords: XAFS, QEXAFS, beamline, circular polarization

1. The electron storage ring DELTA

DELTA (Dortmunder ELektronen Testspeicherring Anlage) is an 1.5 GeV electron storage ring with a perimeter of 115.2 m which will be operated as synchrotron radiation source. The DELTA project was founded in 1989 and its first components were commissioned at the end of 1994. Operating at 1.3 GeV up to 250 mA of stored current with a lifetime of 6-8 h have been realized so far. It is planned to reach 500 mA with an additional cavity. The ring is equipped with several insertion devices. An undulator is installed in order to perform FEL experiments. Besides a second undulator, a Superconducting Asymmetric Wiggler (SAW) will be installed at DELTA in the end of 1998 and used as radiation source for the experiments described here.

2. The superconducting asymmetric wiggler (SAW)

The SAW is a 20 pole helium cooled superconducting wiggler with a maximal magnetic field of 5.3 Tesla. It can be switched between a symmetric and an asymmetric operation mode. Its specialty is the asymmetric mode in which it generates a highly circular polarized X-ray beam. The radiation can be used in the energy range from 1 to 30 keV with a high intensity. The low energy of the stored electrons results in a moderately high heat load on the first optical component: On the first monochromator crystal a thermal load of maximal 400 W on a 80 mm² beam profile is expected. This heat load refers to the maximal electron current of 500 mA. The technical data of the SAW are summarized in Tab. 1.

Table 1:

Summary of the technical data of the superconducting asymmetric wiggler (SAW) at the 1.5 GeV electron storage ring DELTA (Dortmund, Germany) in the symmetric and the asymmetric mode.

	Symmetric mode	Asymmetric mode
Number of periods	10	5
Length of one period	144 mm	288 mm
Magnetic gap	18 mm	18 mm
Magnetic field	2.79 T	5.3 T
Critical energy	4.1 keV	8.2 keV
Wiggler parameter	37	149
Horizontal beam divergence	±13 mrad	±25 mrad
Vertical beam divergence	±0.34 mrad	±0.34 mrad

3. The planned Beamline

An overview of the beamline is shown in Fig. 1. The frontend inside the concrete shielding of the storage ring is connected to the ring vacuum. It includes an absorber, a fast beamshutter and radiation protection. Beam position monitors allow an exact characterization of the incident beam for diagnostics. The beamline is divided into several discrete ultrahigh vacuum sections by valves (V1-V7). The HV monochromator section is separated from the UHV sections by two Carbon-windows. After the concrete shielding the entrance slit system is installed in order to define the beam size for the optical components. For circular polarization the slit can also select an off plane beam.

The beamline will be equipped with two gold coated mirrors of 1 m length each working under grazing incidence; both can be vertically bent for focusing purposes. In addition, the mirrors with a cutoff energy E ≈ 12 keV serve for harmonic rejection. The beamline layout is based on concepts developed at the undulator beamline BW1 at HASYLAB (Hamburg, Germany) (Frahm *et. al.* (1995)).

The energy selection will be done using a fixed exit double crystal monochromator (30 mm beam offset). Though one single crystal pair is not well suited for the whole energy range from 1 to 30 keV, it is planned to install two different crystal pairs permanently (i.e. Si (111) and Si (311)) with the possibility of a remotely controlled crystal exchange. While using the plane Si (111) crystal pair, the mirrors serve for harmonic suppression and focusing of the beam. For energies above approx. 12 keV up to 30 keV, a Si (311) crystal pair will be used. The second monochromator crystal will allow sagittal focusing of the beam. For harmonic rejection the crystals can be detuned with respect to each other with piezo tilt stages. In addition, use of YB_{66} crystals is planned for the energy range 1-2 keV (Wong *et. al.* (1990)).

It is expected to have full operation and user access in the year 2001.

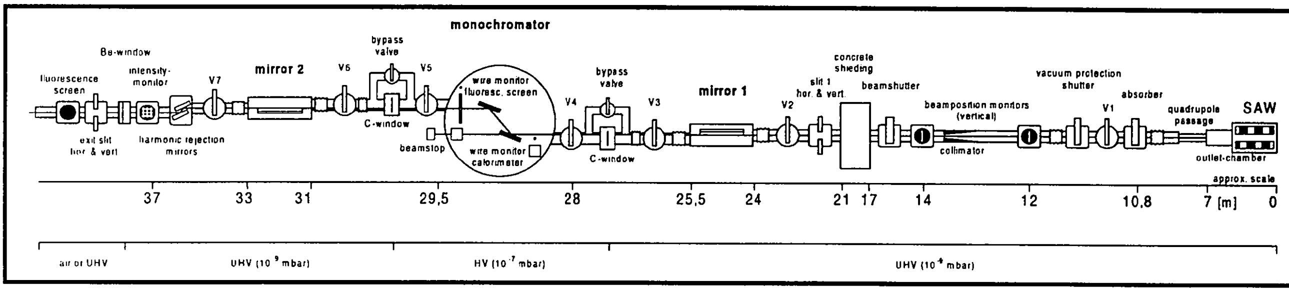

Fig. 1:

Setup of the beamline.

3.1 Monochromator

The main part of the beamline is the double crystal monochromator. The planned design consists of a two axis system. The monochromator is based on the design of the monochromator of the centre beamline at the SAW (Wollmann (1998)). The feature of remotely controlled crystal exchange will be added to this design and an improved first crystal cooling stage is planned. Conventional quick scanning EXAFS (QEXAFS, Frahm (1989)) data acquisition will be available as well as the new piezo QEXAFS technique: Piezo tilt tables on both crystals enable a time resolution in the millisecond range for a near edge spectrum (Bornebusch *et. al.* (1999)). In order to handle the heat load of 400 Watts on the first crystal, adaptive optics will be used. Finite element calculations have shown that otherwise, the first crystal is distorted too much and the beam has a decreased intensity and energy resolution (Wollmann (1998)). The technical data of the monochromator are summarized in Table 2.

Table 2:

Technical data of the planned double crystal monochromator of the material science beamline at the DELTA storage ring.

Energy range	1-30 keV	1-2 keV: YB_{66}
		2-12 keV: Si(111)
		8-30 keV: Si(311)
energy resolution $\Delta E/E$	10^{-4}	
beam offset	30 mm	

4. Possible XAFS experiments

With this beamline all XAFS methods can be realized. Both laterally resolved (XANES, EXAFS, SPEXAFS,...) and time resolved methods (QEXAFS and piezo-QEXAFS) are possible. The beamline is also designed for all diffraction techniques including DAFS and other applications where high intensity is essential (topography, tomography, standing waves,...). With the possibility to create circularly polarized photons experiments with magnetic materials (XMCD) can be made. Using the piezo-QEXAFS technique, also spatially resolved micro XANES measurements are feasible for the microscopic investigation of valence and coordination of specific elements.

5. Planned scientific Projects

- structural investigations of thin films and magnetic thin films, reactive sputter deposition
- phase transitions in thin films, monolayers and multilayers
- catalytic reactions at cryo-condensed metal films

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