The Synchrotron Infrared Activities at BESSY

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Abstract. The new multipurpose infrared (IR) beamline at the electron storage ring BESSY II provides highly brilliant infrared radiation for structural and time resolved studies in the biological and material science. With this facility new research possibilities at BESSY are made available to the scientific community.

Key words: infrared spectroscopy, infrared synchrotron radiation, THz radiation

1. Introduction

Synchrotron radiation is a unique source of infrared radiation that is being increasingly exploited at storage rings around the world. Recently, the highly brilliant VUV and soft X-ray source BESSY II was augmented by a large acceptance infrared beamline [1]. This beamline was proposed by the ‘Infrared Initiative Synchrotron Radiation’ (IRIS) [2] a consortium of scientific groups working in the fields of biological and material science.

The new infrared facility at BESSY is now utilized for microspectroscopic investigations of biological systems and for the investigations on the structural and functional interactions of proteins including time dependent studies. In addition, vibrational, structural, and electronic properties of surfaces and thin layers are studied using infrared ellipsometry. The beamline is equipped with two Fourier transform infrared (FT IR) spectrometers, an infrared microscope and an infrared ellipsometer. In a later stage of the project an ultra-high vacuum chamber will be installed for surface science experiments.

The infrared beamline provides highly brilliant synchrotron radiation from the near to the far infrared wavelength region. The paper reports the design and the performance of the beamline. User operation of this infrared facility started in the second half of 2002 and planned experiments are presented. Recently at BESSY, the conditions for generating steady state coherent synchrotron radiation (CSR) in the far infrared (FIR) wavelength region have been established [3]. First brilliance measurements of the CSR are presented revealing the electron storage ring as a powerful THz source.

Figure 1. Layout of the beamline. The experimental stations are placed on the concrete roof of the radiation shielding tunnel. The infrared ellipsometer attached to the Bruker spectrometer is not shown in the graphic.

2. Beamline Design and Experimental Stations

The mechanical and optical layout of the beamline [4] is shown in Figure 1. The front end extracts infrared radiation from a dipole magnet with a horizontal acceptance of ± 30 mrad and a vertical acceptance of ± 20 mrad. The first extracting mirror, a plane mirror placed at a distance of 900 mm from the source, is split into two halves to prevent heat damage by permitting the high energy fan of the radiation to pass through to an additional absorber. The infrared radiation is brought to the experimental stations by an anamorphic mirror system. A diamond window, which is transparent from the visible to the far infrared, separates the ultra high vacuum environment of the storage ring from the fore-vacuum of the experimental stations.

The beamline is equipped with two FT IR spectrometers, a vacuum spectrometer Bruker IFS 66v/S and a Thermo Nicolet Nexus 870, covering the spectral range from the near to the far infrared with corresponding beam-splitters and detectors. Both spectrometers have step-scan capabilities for time resolved investigations. For microspectroscopic investigations in the mid infrared a Continuum infrared microscope is attached to the Nexus 870. An infrared ellipsometer has been developed [5] taking advantage of the brilliance of the infrared synchro-

tron radiation. It operates in two modes allowing the investigation of the polarization dependent reflection of either small samples with sample areas of less a square millimeter or of samples with moderate sample areas but with a high angle accuracy.

3. Planned Experiments

First user operation of the infrared facility started in the second half of 2002. For this first half-year-period of operation nine scientific proposals have been awarded beamtime, with scientific objectives spanning from planetary science to prion and cancer research. Among the planned experiments are: infrared microscopy on central nervous system tissue and on cancerous tissues, investigation of the interactions of rhodopsin, investigation of OH in anhydrous minerals, optical properties of superconducting materials, anisotropic thin films, adsorbates on semiconductor surfaces and terrestrial analog minerals. Challenging results have already been obtained by spatially resolved chemical mapping of colon mucosa tissues and by microspectroscopic investigations of hydrous micro-inclusions in omphacite.

4. Implications for THz Spectroscopy

Infrared steady state CSR is produced in a 'low alpha' optics mode of the synchrotron light source BESSY II [3]. Here, the length of the stored electron bunches is deliberately shortened, becoming comparable to the wavelength of the radiation. The electron bunches behave like large, single macro-particles and the emitted electromagnetic waves from each electron of the bunch add up coherently, leading to a dramatic increase of the radiation power. Recently at the infrared beamline at BESSY II, the conditions for generating infrared CSR have been investigated and a power increase of up to 100,000 compared to the normal, incoherent synchrotron radiation in the range of $10\text{--}60\text{ cm}^{-1}$ ($0.3\text{--}1.8\text{ THz}$) has been recorded [6].

The brilliance of the coherent FIR synchrotron radiation source was examined by recording the flux through different sized circular apertures placed in the Bruker 66v/S sample compartment. The ratio of the coherent flux and the flux of an internal Hg arc lamp of the FT IR spectrometer measured under same conditions is shown in Figure 2. At 20 cm^{-1} and for the synchrotron parameters involved in these measurements one obtains 1000 times more flux on a sample of 2 mm diameter than from the internal source. The brilliance of the CSR source is ideally suited for spectroscopic applications with a very low optical throughput, e.g., for the spectroscopic investigation of samples with a sample area in the range of the diffraction limit.

Figure 2. Ratio of the spectrum of the coherent FIR synchrotron source and the spectrum of the internal Hg arc lamp for a circular aperture of a diameter of 2 mm. Note that by changing the storage ring parameters (e.g., by increasing the stored current) the flux of the emitted coherent FIR radiation is dramatically enhanced which in turn results in a corresponding increase of the ratio.

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