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Performance of a helical undulator of the UVSOR

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A helical undulator was installed in the 0.75 GeV storage ring of the UVSOR facility of the Institute for Molecular Science. The undulator was designed to produce the fundamental of the circularly polarized undulator radiation in the energy range 2–43 eV, and the higher harmonics with elliptical polarization in the energy range up to 300 eV. Recently, the first spectrum from the undulator was observed. The performance of the undulator and the obtained spectrum are reported.

Keywords: helical undulators; UVSOR.

1. Introduction

Optical excitations with circularly-polarized light are useful for understanding the magnetic moments of electrons. The difference spectrum between absorption for right and left circularly polarized light is called circular dichroism. The circular dichroism method is one of the most powerful tools for the investigation of electronic structures, not only of magnetic materials but also of non-magnetic materials. On the other hand, spin-resolved photoelectron spectroscopy can provide information about momentum and spin of electrons. The combination of circularly polarized light and a spin-resolved photoelectron analyzer allows us to observe the electronic structures of materials with selected magnetic moments.

For the investigation of electronic structures of magnetic and non-magnetic materials by spin-resolved photoelectron spectroscopy, we have constructed a beamline, BL5A, in the 0.75 GeV electron storage ring, UVSOR, of the Institute for Molecular Science. The beamline consists of a helical undulator, a high-resolution monochromator and a spin- and angle-resolved photoelectron analyzer. The monochromator, named SGM-TRAIN (spherical grating monochromator with translational and rotational assembly including a normal incidence mount), is an improved version of a constant-deviation and constant-length monochromator (Kamada *et al.*, 1995, 1998). The spin- and angle-resolved photoelectron analyzer is of the low-energy diffuse scattering type (Takahashi *et al.*, 1996). This apparatus has already been completed and reported elsewhere. Recently, the first spectrum of circularly polarized light in the vacuum–ultra-violet region from the helical undulator was observed. In this paper the performance of the helical undulator and the observed spectrum are reported.

The UVSOR helical undulator is a modified version of a helical undulator, or an elliptical wiggler (Maréchal *et al.*, 1995), and an eight-figure undulator (Tanaka & Kitamura, 1996), which were designed for the 8 GeV storage ring, SPring-8. Since the energy of UVSOR is about one order less than that of SPring-8, special care was taken to optimize the magnetic fields. The peak energy of the fundamental radiation can be swept only by changing the undulator gap while keeping the degree of the circular polarization. The same type of helical undulator as UVSOR was installed in the 0.7 GeV storage ring, HiSOR, of Hiroshima University (Hiraya *et al.*, 1998).

2. Parameters

The helical undulator has three lanes in the upper and the lower magnet arrays, shown in Fig. 1. The undulator looks like a planar undulator. However, in the helical configuration the centre lane produces the vertical magnetic field and the side lanes produce the horizontal field. The vertical and horizontal magnetic fields were set to be almost equal to each other in an undulator gap of 30–150 mm. In the range of the undulator gap, the range of the deflection parameter, K, is 4.6–0.07. The fundamental emission peak is expected to cover the photon energy range 2–43 eV (Kimura *et al.*, 1996). The parameters of the helical undulator are shown in Table 1.

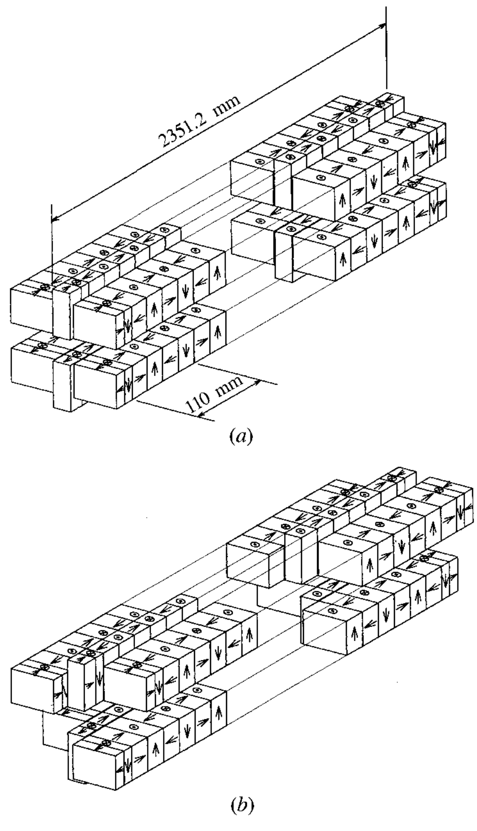

Figure 1
Schematic figure of the UVSOR helical undulator in the (*a*) planar and (*b*) helical configurations.

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The measured magnetic fields of three pairs of lanes, a centre pair and two kinds of diagonal pairs, at an undulator gap of 30 mm are shown in Fig. 2. The lower figure represents the three pairs of lanes. The amplitudes of the magnetic field of the undulator are all equal in a pair of lanes. The peak intensities of the magnetic fields are in good agreement with calculated data (Kimura *et al.*, 1996).

3. Obtained spectrum

The observed spectrum at an undulator gap of 100 mm is shown in the upper part of Fig. 3. The fundamental radiation was observed at a photon energy of 37 eV, and the second and the third harmonics were also observed. In the case of the on-axis spectrum from the circularly polarized undulator radiation, the higher-order components should not appear. In our experimental set-up for the performance test, however, not only the on-axis component but also the off-axis component of the undulator radiation were detected. Therefore, the higher harmonics were observed in the spectrum.

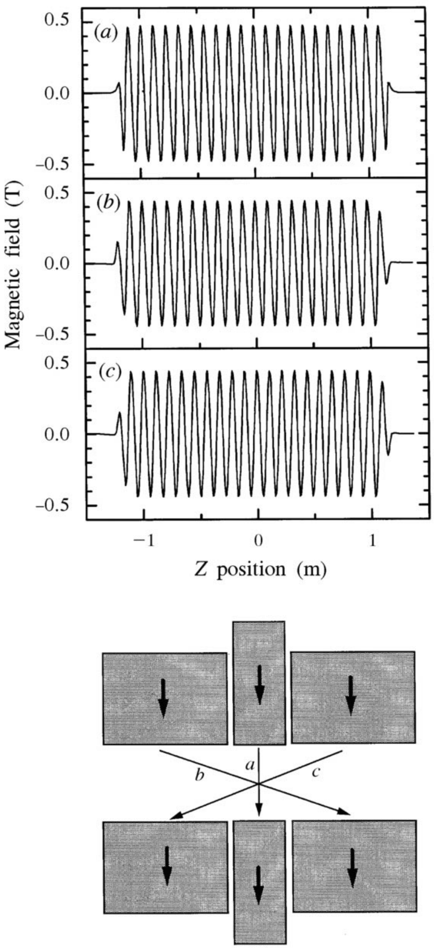

Figure 2
Measured magnetic fields of three pairs of lanes, a centre pair and two diagonal pairs, at an undulator gap of 30 mm. The lower figure represents the three pairs of magnets.

Table 1
Parameters of the helical undulator of UVSOR.

Number of periods	21
Period length, λ_u	110 mm
Total length	2351.2 mm
Permanent magnet	NdFeB
Remanent field, B_r	1.3 T
Width of magnet pole for vertical field	21 mm
Width of magnet pole for horizontal field	50 mm × 2
Undulator gap	30–150 mm
Magnetic field in helical mode	0.007–0.45 T
Deflection parameter, $K_{x,y}$, in helical mode	0.07–4.6
Scan range of fundamental in helical mode	2–43 eV
Magnetic field in planar mode	0.015–0.83 T
Deflection parameter, K, in planar mode	0.15–8.5
Scan range of fundamental in planar mode	1.2–43 eV

Note that the observed spectrum was obtained by using the rearranged magnet array of the helical optical klystron for a helical free-electron laser. In the optical klystron configuration the centre three periods of the magnet arrays are rearranged (Hama, 1996). By using the optical klystron, the shortest free-electron-laser wavelength of 239 nm was achieved (Kimura *et al.*, 1997). As shown in Fig. 3, the interferogram appears in the fundamental radiation because of the use of the magnet array of the optical klystron. The interferogram is due to the interference of radiation from the former nine periods with that from the latter nine periods.

The analytical calculation results of the undulator spectrum with three different numbers of periods (seven, eight and nine) are plotted in the lower part of Fig. 3. The best-fit spectrum of the analytical calculation was obtained with eight periods, despite the nine periods of the undulator, and an acceptance angle of 0.4 mrad. The result means that the undulator radiation consists of the emissions from each centre eight periods of the former and the latter magnet arrays. According to the calculation of the electron-beam trajectory, the trajectories at the first and the last

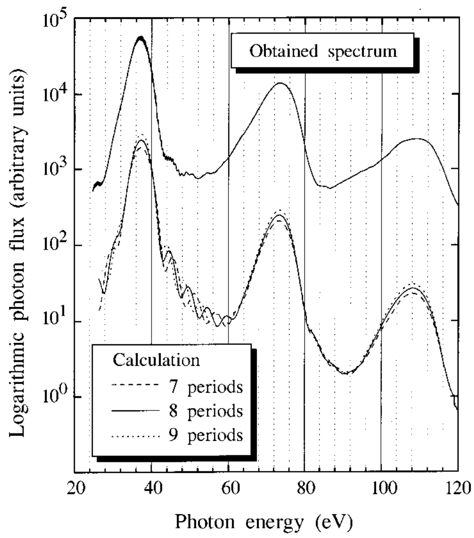

Figure 3
Obtained (upper) and calculated (lower) spectra from the undulator at an undulator gap of 100 mm. The analytical calculation was performed by using an acceptance angle of 0.4 mrad and seven, eight and nine periods of the magnet array. Note that the intensities of the calculated spectra are shifted from the measured one to make the figure simpler to read.

periods are far from on-axis. Therefore, the emission from the half of the first and the half of the last periods is not considered to interfere with the emission from the other periods. The value of 0.4 mrad is consistent with the maximum of the angular distribution of an undulator with eight periods.

4. Conclusions

A helical undulator was installed in the 0.75 GeV storage ring, UVSOR, of the Institute for Molecular Science and the first spectrum was observed. The spectrum was explained by using an acceptance angle of 0.4 mrad and eight periods of the magnet array.

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