FIRST RESULTS OF THE UE212 QUASIPERIODIC ELLIPTICAL ELECTROMAGNETIC UNDULATORS AT SLS

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Abstract

Two electromagnetic elliptical undulators (UE212) have been installed in series in the 11m long straight section 9L of the Swiss Light Source (SLS), serving as the radiation source for the Surface and Interface Spectroscopy (SIS) beamline in the energy range from 8 - 800 eV. The undulators are based on an ELETTRA design[1] and have been upgraded with an optional quasiperiodic modus achieved with two current circuits for the vertical coils. The units have been built at BINP, Novosibirsk, with vertical pole structures machined in single pieces over 4.55 m length with magnetically isolated horizontal poles to minimize crosstalk between the field components. The mechanical and magnetic properties will be presented and the effective suppression of the background in photoemission experiments resulting from the integer harmonic content is discussed. The flexibility of the quasiperiodicity – with the UE212 implemented for the first time in an electromagnetic undulator – together with a two monochromator setup allows for individual optimization to the experimental setup. An overview over the insertion devices at the SLS can be found in [3].

Figure 1: Side view of one UE212 section with the 4.55 m long single piece iron yoke/vertical pole structure and added horizontal poles. The inter coil connections for the two individual vertical power circuits are implemented on left or right side of each beam. The horizontal coils are attached all in series.

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1 THE UE212

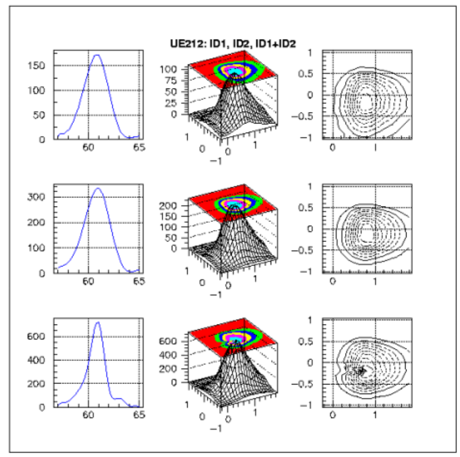

Figure 2: Measured spectra and intensity distribution for ID1, ID2 and both undulators together. The flux density differences between the spectra from the single undulators correspond to the different angular acceptance of the pin-hole (0.4×0.1 mrad).

The radiaton source for the SIS beamline should provide linear and circular polarized soft x-rays down to photon energies of about 10 eV combined with the wish of having a pure fundamental spectrum without harmonics. Because of the rather high photon energy of the SLS of 2.4 GeV and to keep the K-value reasonable a long period length of about 20 cm was needed. Therefore we adapted the design of the EEW[1], an electromagnet with alternating vertical and horizontal poles where the latter ones are in quadrupol configuration but wired as horizontal dipoles. The magnet structures as well as the support structure have been manufactured from BINP. Because helicity switching of the emitted light of the two undulators will take place only in the beamline with two static (DC) undulators and a chicane[2] which produces a parallel displacement of the electrons, BINP proposed to build bulk undulators with solid iron yokes including the vertical poles machined in single pieces over the full length. The separately machined horizontal poles have been fixed magnetically isolated

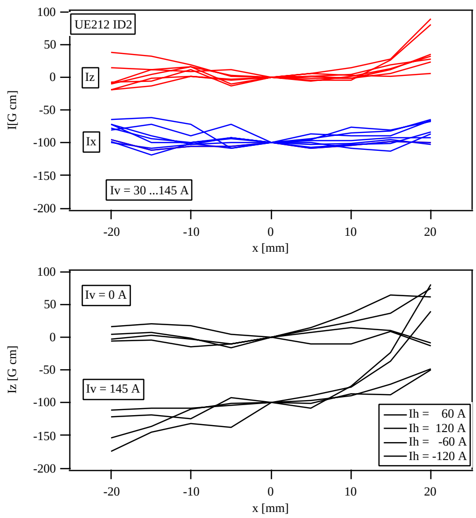

Figure 3: Top: Vertical and horizontal first field integrals in the region ± 20 mm horizontally, measured for the UE212-ID2 undulator for the vertical field in the range of 0.05 to 0.5 T (30 to 145 A). Bottom: Vertical field integrals for horizontal fields of ± 0.05 T and ± 0.1 T measured with zero and maximum vertical field. An arbitrary dipole offset is used to displace the graphs for clarity.

between the vertical ones as shown in figure 1. The machining process and design of the support structure resulted in very low tolerances as 30μm for the gap, 10μm for the pole length and 50μm for the periodicity. The multipoles respectively the transverse field integral distribution is within a band of 50 Gcm over ± 20 mm for the separated excitations shown in the top graph and in the bottom for $I_v = 0$ (see figure 3). In the circular mode a certain interference increases the field integrals at x-positions outside $x = 10$ mm. Up to now no lifetime or injection efficiency reduction has been observed. The tune shift is $\Delta Q_x = 0.0011$ and $\Delta Q_y = 0.0037$ for full vertical excitation.

The undulators are placed on a base frame which allows for positioning over the vacuum chamber with 16 (18) mm inside (outside) aperture. The vacuum chamber is made from bended 316LN stainless steel sheets of 2 mm thickness whereas the elliptically beam chamber is grinded to 1 mm wall thickness at pole positions. Stability is achieved by internal spacers placed 6 cm away from the nominal beam position in the shadow of the photon absorber. For an online control of the hysteresis effects Hall-probes from Sentron can be placed in the fringe field of the vertical and horizontal poles. They are housed ouside vacuum in a tube which can be positioned motor driven inside the antechamber as well as on the beam axis (if there is no electron beam). The control system will have the option to take the Hall-probe output into account [4]. Figure 2 shows the flux density versus energy and a pinhole scan in the frontend. At a photon energy of about 60 eV the two undulators are almost phase-matched. An active phase matching will be implemented in summer 2002 with the chicane dipole magnets. To take the spectra, both undulators were driven with the identical vertical current.

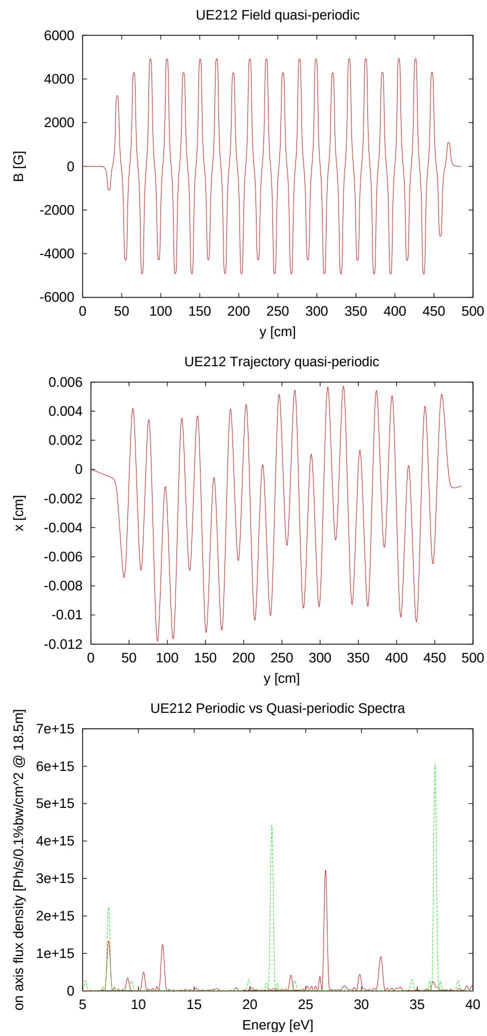

Figure 4: Measured quasiperiodic field (119 A / 145 A) and calculated trajectory and spectra for UE212-ID1. The fundamental intensity decreases slightly, but the 3rd and 5th harmonic (22.5 eV and 37 eV) are shifted from integer to rational multiples.

2 HARMONIC SUPPRESSION

For reduction of the harmonic content in the spectra, the undulators can be operated in a quasi-periodic mode [5] using field amplitude modulation. The vertical coils are feeded by two individual power supplies, following the fibonacci row:

$$x_i = i - \left[\frac{i \tan\alpha}{1+\tan\alpha} + 1\right]$$

where the brackets mean the integer value. The rule is to attach a pair of coils (on the upper and lower beam) either to circuit 1 or 2 when $y_i = i - x_i$ is 0 or 1. For a quasi-periodic crystal α has to be irrational, but for the few period undulator it is smeared out and $\alpha = 0.15$ was choosen which results to the field distribution, trajectory and on axis spectra in figure 4. In the last poles the excitation series has been changed *by hand* in order to have zero 2nd field integral (offset) at the exit. The matching periods are excluded from the quasiperiodic changes. In figure 5 a Photoemission Spectrum above the Fermi-edge E_f on a silver surface is shown, taken with UE212-ID1 at a photon energy of 23 eV ($I = 70$ A in periodic mode). The quasi-periodic electromagnet has the unique possibility to vary the current ratio in order to minimize either the 2nd or the 3rd harmonic. Here the spectrum was taken with the grazing incidence monochromator (PGM) and the lowest background is achieved by minimizing the 3rd harmonic. The quasi-periodic specta are taken for the currents $I_1 = 60$ A and I_2 =71 to 74 A. With the optional normal incidence monochromator (NIM) of the SIS beamline, which suppresses effectively photon energies above 30 eV it is a good strategy to minimize instead the 2nd harmonic. And of course, the quasi-periodicity is reversible.

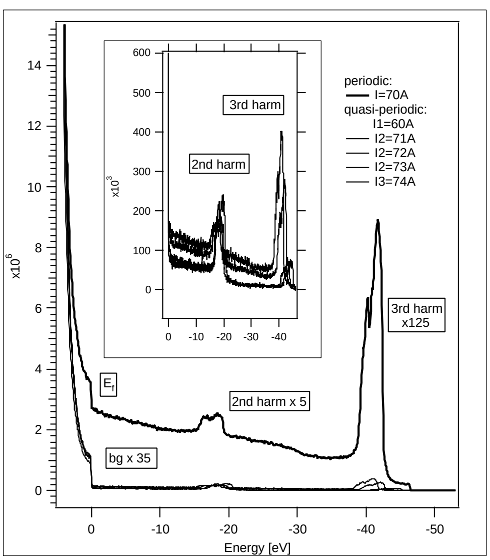

Figure 5: Photemission Spectrum measured at the SIS beamline with periodic and quasi-periodic UE212-ID1 with different current ratios and PGM configuration. The background above the Fermi edge is decreased by a factor of 35 and the 3rd harmonic is decreased by a factor of 125. Note, the 3rd harmonic appears also in 3rd order in the photoemission spectrum. The small picture zooms in the quasiperiodic harmonics (see vertical scale) and shows the intensity changes between the 2nd and 3rd harmonic when changing the current ratio I_1/I_2.

Further studies to suppress the harmonics with the NIM monochromator and with both undulators will follow, but already the first spectra taken show the potential and the flexibility of the quasiperiodic electromagnetic undulators UE212 for the SIS beamline.

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