J. Synchrotron Rad. (1998). **5**, 431–433

Development of an elliptical multipole wiggler at SPring-8

Xavier-Marie Maréchal,* Toru Hara, Toshiya Tanabe, Takashi Tanaka and Hideo Kitamura

JAERI-RIKEN SPring-8 Project Team, Kamigori-cho, Ako-gun, Hyogo 678-12, Japan. E-mail: marechal@spring8.or.jp

(*Received 4 August 1997; accepted 18 November 1997*)

An elliptical multipole wiggler (EMPW) based on a new concept has been installed on the SPring-8 storage ring. The EMPW, with a 120 mm period, has a critical energy of 50 keV at a gap of 20 mm. It will provide high-brilliance hard circularly polarized X-rays in the 100–300 keV range to the pilot beamline dedicated to materials science: the Compton scattering beamline. Field measurements, field integrals, the expected fluxes, polarization rates, power and power densities are presented for two operating gaps: 30 mm during commissioning, 20 mm later.

Keywords: elliptical wigglers; circular polarization.

1. Introduction

A new type of elliptical multipole wiggler (EMPW) (Maréchal *et al.*, 1995) has been analysed, corrected and installed on the SPring-8 storage ring (Fig. 1). This wiggler is the photon source for BL-08W, a beamline dedicated to materials science, whose applications will include magnetic Compton scattering, high-resolution Compton scattering and high-energy Bragg scattering (Sakurai, 1998). Operated at a gap of 30 mm in a first phase, the EMPW will later be used at a minimum gap of 20 mm, after installation of a new vacuum chamber.

The EMPW has a period of 120 mm and counts 37 periods. It is made of a high-magnetic-performance magnet, the NEOMAX-44H of Sumitomo Special Metals Co., which has a remanent field of 1.3 T and a coercive force of 17 kOe. The dimensions of the magnet are given Fig. 2. Note that the horizontal field is zeroed by moving the external magnet arrays in opposite directions. At a gap of 20 mm, the measured vertical and horizontal peak magnetic fields are 1.16 and 0.110 T, respectively. The corresponding vertical and horizontal deflection parameters, K_y and K_x, are 13 and 1.2, respectively. When measured at a gap of 30 mm, the fields in the vertical and horizontal planes (and the respective deflection parameters) are reduced to 0.88 and 0.095 (9.9 and 1.06), respectively: Fig. 3 shows the variation of the peak vertical and horizontal magnetic field as a function of the gap. The critical energy is also given for reference. The uniformity of the horizontal and vertical magnetic field in the orbit plane has also been measured. In a ±2 mm range around the EMPW axis (*i.e.* around the main axis of the electron trajectory), the field varies by less than 1% for the horizontal field and 0.1% for the vertical field. At the smaller gap of 20 mm, the uniformity of the horizontal field is slightly improved.

When installed on the storage ring, insertion devices should not generate any significant perturbation on the rest of the ring, or induce any loss of the electron beam. Ideally, insertion devices should be magnetically transparent to the electron beam. This should be true at any gap and, in our case, also at any phase. At SPring-8 the maximum field integral variation allowed is determined by the properties of the correction coils and the steering magnets installed around each insertion device. For the EMPW, the useful gap ranges from 20 mm to 290 mm, and the field integral variation should be less than 100 G cm for both the horizontal and the vertical plane. Fig. 4 shows the vertical and horizontal field integrals as a function of the magnetic gap, after correction. Field integrals were measured with flipping coils and

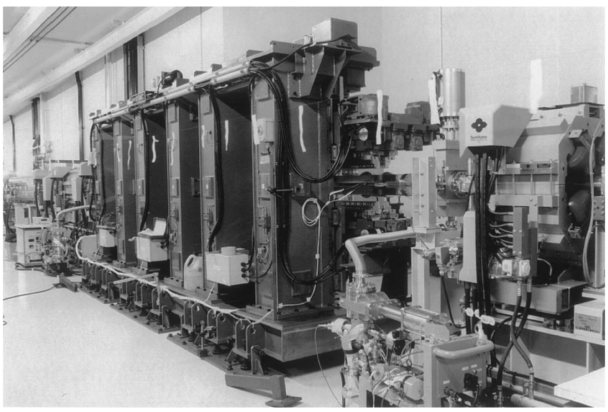

Figure 1
The EMPW installed on the SPring-8 storage ring.

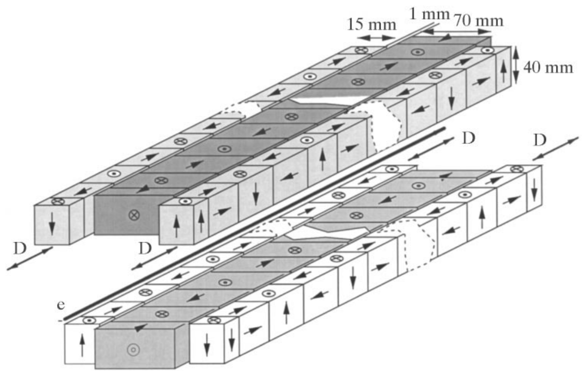

Figure 2
Schematic diagram of the EMPW design.

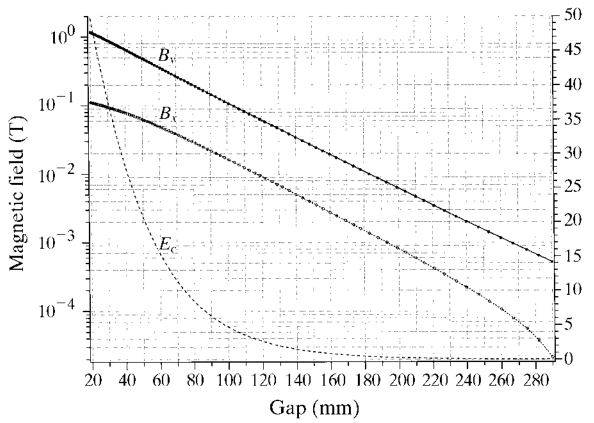

Figure 3
Variation of the horizontal (B_x) and vertical (B_y) peak magnetic fields and critical photon energy (E_c) as measured for different magnetic gaps.

also determined from the integrated value of the magnetic field. Both agree quite well, except for the horizontal field at a small gap. The large remaining field integral at the fully opened gap might be explained by the still non-zero value of the peak field (7 G measured at 290 mm) and the length of the device (4.5 m). As explained previously, field integrals will be compensated by coils and steering magnets.

The field integrals and their derivatives should be kept to a minimum, not only on the wiggler axis but also in a wide range around it, since they depend on the transverse coordinates. Fig. 5 shows the variation of the horizontal and vertical field integrals along the horizontal axis, for a gap of 20–200 mm.

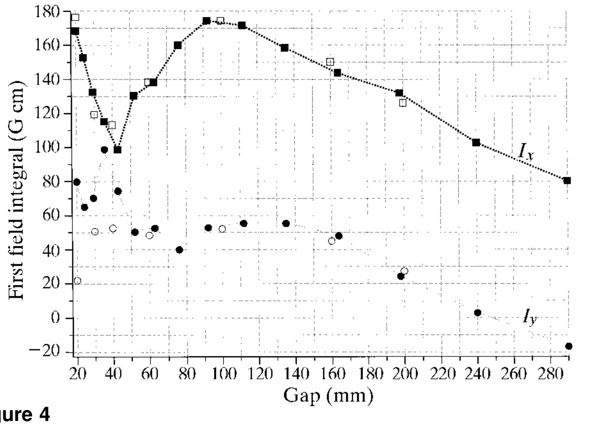

Figure 4
Vertical and horizontal field integrals (I_y and I_x) as a function of the magnetic gap, after correction. The filled markers are for the values integrated from the magnetic field. Hollow markers are for the values measured by a flipping coil.

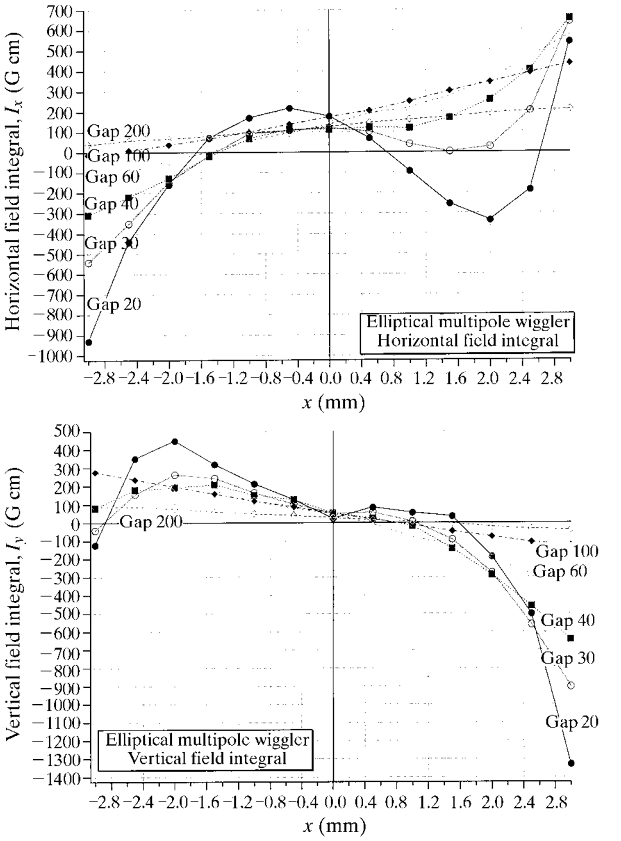

Figure 5
Vertical and horizontal field integrals measured along the horizontal axis, in the middle plane, and for different magnetic gaps.

2. Performance of the EMPW

The performance of the EMPW has been determined from the measured fields and optical characteristics of the SPring-8 electron beam, namely energy of 8 GeV, current of 100 mA, emittance of 5.5 nm rad on a low-β section (β_x = 0.951 m, β_y = 5.5 m). The critical energy of the wiggler is 50 keV at a 20 mm gap (37.5 keV at a 30 mm gap) and the total power generated reaches 24.4 kW (13.7 kW). When the horizontal field is set to be zero, the power density is at its maximum on the wiggler axis: 191 kW mrad^{-2} (143 kW mrad^{-2} at a gap of 30 mm).

Fig. 6 shows the typical brightness and polarization rates obtained at the minimum gap of 20 mm, computed for a filament electron beam on the wiggler axis: in the 100–150 keV range, up to 2×10^{17}–7×10^{16} photons s^{-1} (0.1% bandwidth)$^{-1}$ mrad^{-2} with a circular polarization rate of 0.85. As the energy increases the brightness decreases: at 300 keV one expects 4×10^{15} photons s^{-1} (0.1% bandwidth)$^{-1}$ mrad^{-2} with a circular polarization rate of 60%. Higher polarization rates can be obtained but at the expense of brightness. Indeed, on axis, polarization rates are a function only of the horizontal deflection parameter K_x on the one hand and the energy to a critical energy ratio E/E_c on the other hand: the lower the K_x value, the higher

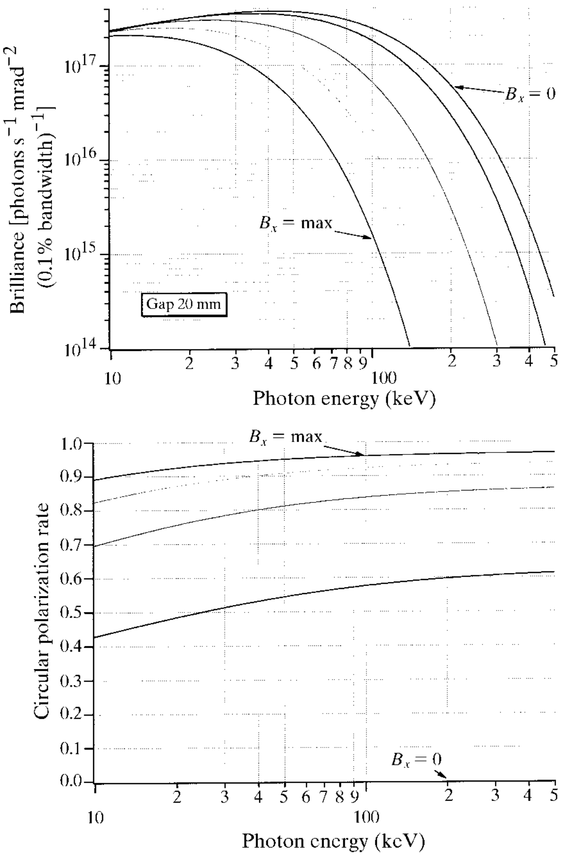

Figure 6
Brightness and circular polarization rates computed on the EMPW axis, for different values of the horizontal field at a gap of 20 mm, *i.e.* 95%, 81%, 59% and 31% of the maximum value.

the flux but the lower the circular polarization rate. Also, for a given K_x, the higher the E/E_c value, the higher the circular polarization rate.

However, it has been noted before that the EMPW performances, brilliance and polarization rates are degraded by the electron beam finite emittance, and the effect of the vertical angular divergence has been studied by various authors (Kitamura & Yamamoto, 1992; Maréchal, 1994). The circular polarization rate is reduced by the effect of vertical angular divergence: when the divergence increases, circular polarization is lost in favour of linear polarization and depolarization. For the same photon energy, low circular polarization rates (small values of the horizontal deflection parameter K_x) are more sensitive to the effect of angular divergence. Moreover, this effect is much stronger at high energies: operating the EMPW at SPring-8 with a low coupling (thus a small vertical angular divergence) will preserve the quality of the radiation, not only the circular polarization rate but also the figure of merit (Maréchal, 1994). For example, in the 100–150 keV range, the circular polarization rate will decrease from 0.85 to 0.80 for 2% coupling (0.72 for 20% coupling). At higher energies the loss is much more important, and at 300 keV the polarization rates will be 56% (2% coupling) and 34% (20% coupling).

3. Conclusions

The SPring-8 EMPW has been installed on the Compton scattering beamline. Magnetic measurements showed that steering magnets will be needed to operate the EMPW without affecting the electron beam. However, high fluxes of circularized photons are expected in the targeted photon energy range.

References

Kitamura, H. & Yamamoto, S. (1992). *Rev. Sci. Instrum.* **63**(1), 1104–1109.

Maréchal, X.-M. (1994). SPring-8 Engineering Note. SPring-8, Kamigori-cho, Ako-gun, Hyogo 678–12, Japan.

Maréchal, X.-M., Tanaka, T. & Kitamura, H. (1995). *Rev. Sci. Instrum.* **66**(2), 1937–1939.

Sakurai, Y. (1998). *J. Synchrotron Rad.* **5**, 208–214.