

Construction of Very Short Period Undulators and the Photon Factory Upgrade

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To increase the number of the straight sections for the insertion devices, an up-grade project of the PF ring has been completed [1]. Due to this up-grade, four new straight sections of 1.4 m have been produced, and the existing ones have been nearly doubled in their length. These 1.4m long straight sections are designed to have small betatron functions, so that an in-vacuum type undulator with very short magnetic period and gap can be installed. In these years, on the other hand, we have been developing short period undulator magnets, and completed a short-period and small-gap undulator (SGU) in an in-vacuum configuration as a practical source of hard x ray region for protein crystallography in the 2.5 GeV Photon Factory storage ring.

Even using a beam energy of 2.5 GeV of the PF ring, it is possible to produce hard x-rays up to 15 keV if we select a very short period length of the undulator. However, this is only valid when the undulator can be set to the very small gap of the order of 5 mm or less to obtain enough field strength. This situation is accomplished by a combination of the in-vacuum undulator technology [2] and the advanced lattice design including small betatron functions [3].

The completed in-vacuum undulator SGU#17 had been installed at the straight section between the bending magnets B#16 and B#17 in the up-graded PF lattice and SGU#03 has been installed between B#02 and B#03. The vertical betatron function is designed to be 0.4m at the center of these sections to allow the minimum gap of 4.5 mm. In the construction of SGU#17, we employ a pure Halbach type magnet arrangement with a period length of 16mm in order to obtain the photon energy up to 15keV by using the lower (from 1st to 7th) harmonics of the undulator radiation. In case of SGU#03, we used a period length of 18 mm. Due to the allowable length at the installation sites we adopt a periodicity (N) of 29 for SGU#17, and N = 26 for SGU#03. As a magnet material we have selected Nd-Fe-B alloy with the remanent field of $B_r = 12.0$ kG and the coercivity of $iH_c = 28$ kOe (NEOMAX35VH manufactured by NEOMAX Co. Ltd). Magnet blocks are coated with TiN (5 μ m thick) for vacuum sealing. The magnet gap is ranging from 40 mm to 4.5 mm (the deflection parameter, K ranging up to 1.27). In order to avoid several problems due to Ohmic and parasitic mode losses, we cover the opposed faces of the magnet arrays with thin metal foils. This foil (60 μ m thick) made of oxygen-free copper is plated with Ni (25 μ m thick) for magnetic sustainment of this foil on the magnet face. We also put a contactor composed of a foil of Be-Cu (180 μ m thick), which flexibly connects the end of the magnet array to the Q duct of the PF ring.

Field adjustments have been made on the basis of the precise field measurements using Hall probes which are oriented in y- and x- directions. We have adjusted the undulator field by optimizing a kick angle of the electron at each pole finally to have an ideal sinusoidal orbit.

The quality of the undulator fields are kept satisfactory in the allowed range of the gap, whereas the field adjustment was done at the gap of 5 mm. We also have satisfactory results on the kicks at the undulator's entrance and exit that violate parallelism between the electron orbit and the undulator. We find that both an absolute value of the kicks and their relative changes are negligibly small. The effects of the field errors to each harmonic can be described by a ratio of the real brilliance to the ideal case. The real brilliance is calculated in case of a single electron using the measured field data, whereas the ideal one is done for the ideal field. In case of SGU#17, the brilliance ratio is as high as 94% for fifth harmonic as a result of fine field adjustments.

Commissioning of the beamline and characterization of the x-rays from SGU#17 is now under way. Detailed reports on the characterization will be presented in the forum.

References

1. Photon Factory Activity Report 2004 #21.
2. S.Yamamoto et al., Construction of two new in-vacuum type tapered undulator for the PF-AR, The Proc. of the 8th int. conf. on synchrotron radiation instrum., AIP Conf. Proc. 705, 211-214 (2004).
3. Photon Factory Activity Report 2003 #20.