3 USER TECHNICAL SUPPORT

3.1 Insertion Devices

A total of 25 IDs is presently installed in the storage ring (see Table 3.1). Almost all are hybrid permanent-magnet undulators. One is a hybrid permanent-magnet wiggler with an 8.5-cm period, and one is an electromagnetic wiggler. The most recent additions are 3.3-cm-period undulators for two new beamlines and one new 2.7-cm-period undulator added to an existing beamline. A circularly polarizing undulator is in the final stages of magnetic tuning. More details of the new devices are given below. In the future, it is expected that users will request undulators with period lengths different from these to suit their particular needs. A superconducting device is also planned.

In addition to tuning devices for the APS storage ring, nine 3.3-cm-period undulators have been measured and tuned for the APS FEL project. Details of the APS FEL project will be given in a separate publication.

At the APS, the straight sections in the storage ring have a length of 5.0 m, thus permitting the installation of two undulators of maximum length 2.4 m. In sector 4, two undulators with periods of 3.3 cm and 12.8 cm provide coverage of the energy range from 0.5 to 50 keV. These undulators have been installed in a dogleg configuration with dipole permanent magnets before, between, and after the magnets to horizontally separate the radiation fans by 270 µrad. The hard x-ray range is covered using the APS

Table 3.1. Type and number of IDs installed in the storage ring.

Type	Number
3.3-cm-period undulator	19
5.5-cm-period undulator	1
2.7-cm-period undulaor	2
1.8-cm-period undulator	1
8.5-cm-period wiggler	1
Elliptical multipole wiggler	1

standard undulator A and a custom-built 12.8-cm-period circularly polarizing undulator (see next section) is used for the intermediate energy x-ray range. An 8 mm beam separation in the first optics enclosure at approximately 30 meters from the center of the straight section is achieved.

The 2-m-long, 2.7-cm-period undulator, originally designed as a prototype for the FEL project, has now been modified and tuned for installation in the APS storage ring. It was installed in addition to the 2.4-m-long, 2.7-cm-period undulator already in sector 3, bringing the combined length of undulators in that sector to 4.4 m (all with 2.7 cm period). Unlike the other standard devices, this device was fully designed (including the support structure and the gap motion mechanism) and fabricated at the APS. Only the initial measurement and sorting of magnet blocks were done at STI Optronics. A minimum gap of 8.5 cm is achievable for both IDs. The gap can be adjusted and tapered independently for each ID.

3.1.1 Circularly Polarized Undulator

A circularly polarized undulator (CPU) was fabricated at the Budker Institute of Nuclear Physics (BINP, Novosibirsk, Russia) and delivered to the APS. The magnetic measurement and tuning of the CPU (Fig. 3.1) is being done at the APS. Although the tuning has not yet been completed, some intermediate results are given here.

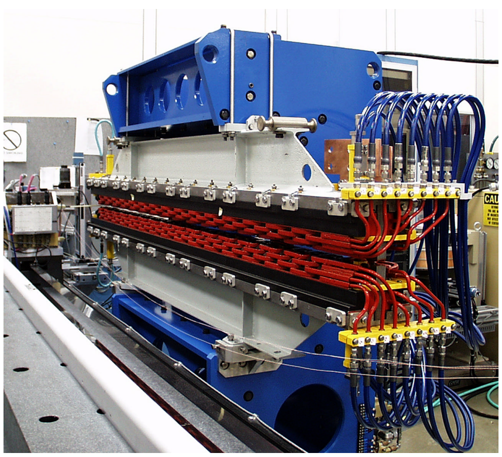

Fig. 3.1. View of the CPU on the measurement bench.

After the first measurement, several problems were recognized that need to be solved before installation. One problem was the finding that the achievable horizontal field at the maximum coil current of 1400 A was slightly smaller than the vertical field (0.24 T) at the maximum vertical coil current (400 A). In order to solve this problem, the vertical gap of the horizontal poles was reduced by applying shims at the bottom of the poles. The second major problem was the existence of multipole field integral components. Almost all normal and skew multipole components did not meet the requirement. To solve this problem, additional trim coils to correct skew quadrupole, skew octupole, and normal quadrupole integrated field components were designed, fabricated, and installed. Figures 3.2 and 3.3 show the skew quadrupole corrector coil and the skew octupole corrector coil, respectively.

Especially challenging was the correction of skew quadrupole and skew octupole components that were 30 times and 10 times bigger than requirements, respectively. Pure skew quadrupole and skew octupole correction lens are not possible to use due to the aperture restrictions. A combination of a planar skew octupole lens and a skew quadrupole lens allowed us to meet the requirements for both skew components simultaneously.

Figures 3.4 and 3.5 show the vertical coil current dependence of quadrupole and octupole components, respectively, in the circular polarization mode. The handedness of circular polarization is changed by changing the polarity of the vertical coil current since the horizontal coil current is always set to positive values.

A trim coil for compensating the normal quadrupole component is integrated in the

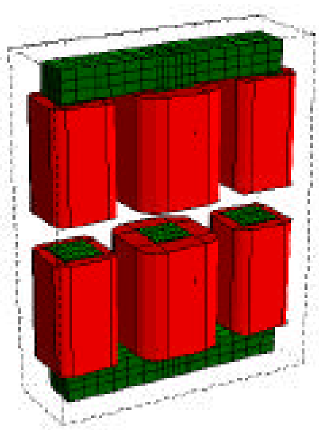

Fig. 3.2. Skew quadrupole corrector coil.

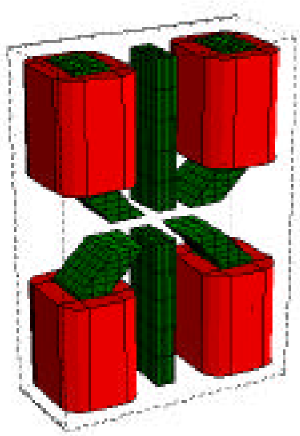

Fig. 3.3. Skew octupole corrector coil.

CPU. The vertical coil current dependence of normal quadrupole is shown in Fig. 3.6.

The CPU is capable of switching the polarity of the magnetic field in the frequency range from zero to 10 Hz. In order to implement this feature, trim coils were added to produce vertical and horizontal dipole magnetic fields at each end of the undulator. An arbitrary function

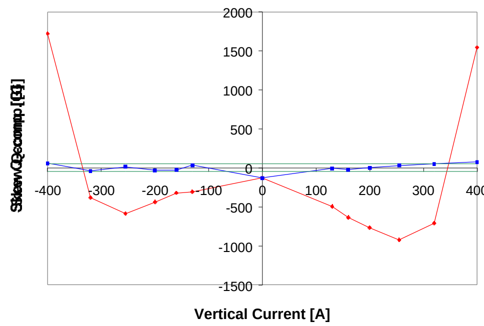

Fig. 3.4. Vertical current dependence of skew quadrupole component. Red corresponds to the field components before correction. Blue corresponds to those after correction. Green lines stand for the tolerance of the ring.

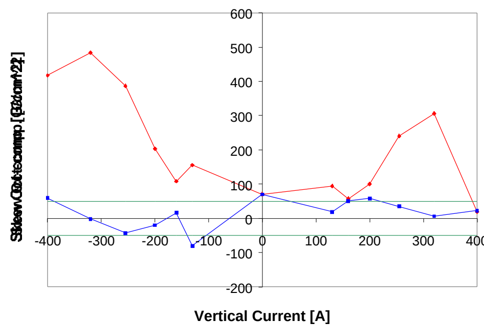

Fig. 3.5. Vertical current dependence of skew octupole component. Red corresponds to the field components before correction. Blue corresponds to those after correction. Green lines stand for the tolerance of the ring

generator with four separate channels was designed and fabricated to provide current to the coils. These coils will compensate for vertical and horizontal, first and second field integrals during the switching time from one polarity of the main magnetic field to the other.

Compensation of the dipole field components was performed for all field regions. Figure 3.7 shows examples of transient field compensation. The vertical switched from positive to negative at the frequency of 5 Hz in this figure. The top half in Fig. 3.7 shows the compensation for the first half period only, and the bottom half shows the compensation result for both first and second half periods. As the result of compensation, the field integral variation is within ± 50 G-cm for all field ranges.

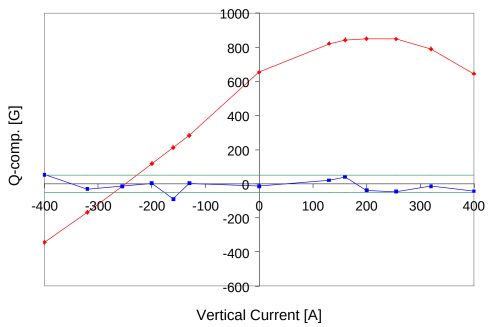

Fig. 3.6. Vertical current dependence of normal quadrupole component. Red corresponds to the field components before correction. Blue corresponds to those after correction. Green lines stand for the tolerance of the ring.

3.1.2 Fabrication of a New Gap Separation Mechanism for Insertion Devices

Four undulators utilizing the APS-designed ID gap separation mechanism have been completed and installed in the storage ring (sectors, 3, 4, 14, and 34), and components to assemble three more have been procured. A photo of the mechanism is shown in Fig. 3.8. The new design improves ID gap positioning accuracy while reducing mechanical complexity and reducing cost. The design uses four drive motors, one for each end of each jaw, which operate independently—thereby simplifying the mechanical drive trains while allowing fine adjustments to the parallelism of the jaws. The load-bearing support is assembled from stress-relieved welded structural steel beams. The system was designed to be compatible with the existing undulator A magnet assemblies and to allow a minimum gap under load of 10.0 mm.

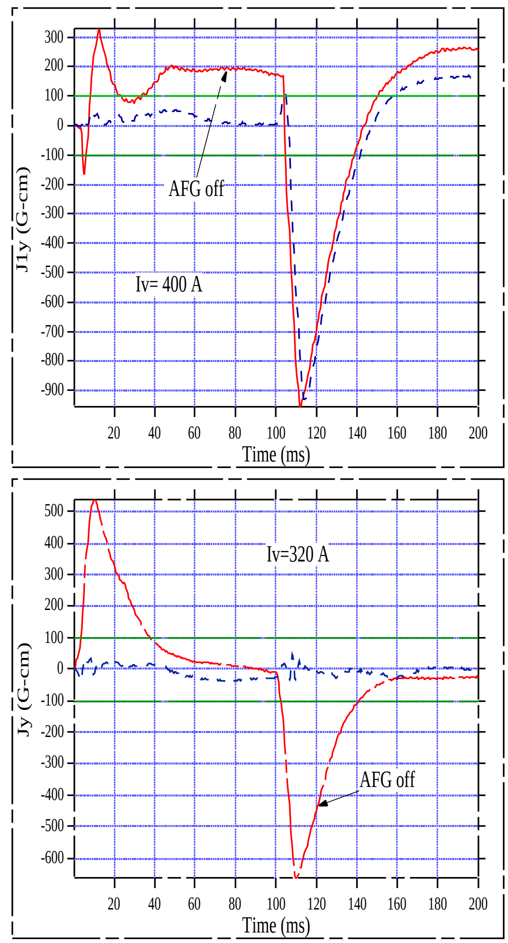

Fig. 3.7. Examples of variation of field integral. Red curves correspond to the field integral before compensation; blue curves correspond to those after compensation by using the arbitrary function generator. Green lines stand for the tolerance of the ring.

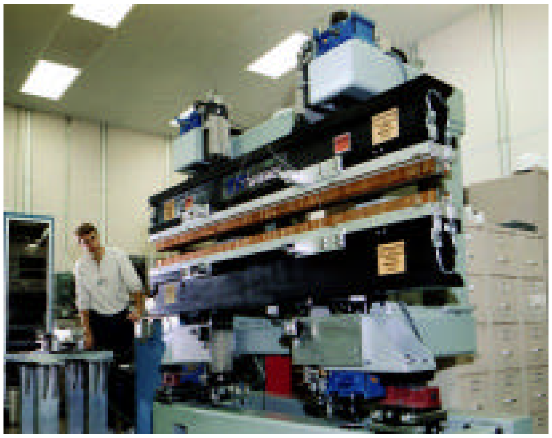

Fig. 3.8. New gap separation mechanism being tested in the magnetic measurement facility.

3.1.3 Insertion Device Vacuum Chamber Development and Fabrication

Vacuum chambers with 8 mm apertures have been installed in 24 of the 35 sectors available for ID beamlines. Construction of new 8-mm-aperture chambers continues; six of the ten chambers being built have already been welded. A 5-meter-long, 5-mm-aperture ID vacuum chamber, in addition to the 5 mm chamber installed in sector 3, has been fabricated and is now installed in sector 4. The 5-mm-aperture vacuum chamber allows the minimum gap to be decreased to 8.5 mm, which enhances the performance of both the 2.7-cm-period device in sector 3 and now the 12.8-cm-period device in sector 4.

3.1.3.1 BESSY insertion device vacuum chamber fabrication

For several years, the ID group of XFD has collaborated with the staff of the BESSY, located in Berlin, Germany, to design and fabricate ID vacuum chambers for the BESSY II project. These chambers used the innovative technology developed by the APS for small aperture vacuum chambers. Previously, nine chambers were fabricated for this facility. XFD is now working on a project to build four additional chambers

3.1.3.2 DESY FEL vacuum chamber fabrication

The Deutsches Elektronen-Synchrotron (DESY), located in Hamburg, Germany, is building a vacuum-ultraviolet (VUV) FEL based on the TESLA Test Facility linear accelerator. The APS is an official partner in this project. Towards this objective, XFD designed and fabricated the small-aperture extruded-aluminum vacuum chambers that are used for the FEL undulators. Seven 9.5-mm-aperature chambers, each 4.516 m long, were built. This project was completed in the summer of 1999, and initial FEL tests were performed at DESY during the fall and winter of 1999.

3.1.3.3 SLS insertion device vacuum chamber design and fabrication

The XFD is collaborating with the Paul Scherer Institute to design and fabricate four insertion device vacuum chambers based on the APS extruded-aluminum design for the SLS. Three of the chambers will be 2.1 m long and will use the APS 12 mm, 8 mm, and 5 mm aperture extrusions, and one chamber will be 5.15 m long and will use the 11 mm extrusion developed for BESSY. Modifications of the rf transitions and welding joints have been developed to match the requirements of the SLS ring. The BESSY-type chamber will also have additional beam position monitors and new pumping ports and end boxes. SLS will fabricate the supports according to the APS design.