Title
ALS Multiple Trim Magnets, or "Magic Fingers" for Insertion Device Field Integral Correction

Authors
Hoyer, E.
Marks, S.
Pipersky, Paul
et al.

Publication Date
1994-07-14

LBL-35865
UC-410

Lawrence Berkeley Laboratory

UNIVERSITY OF CALIFORNIA

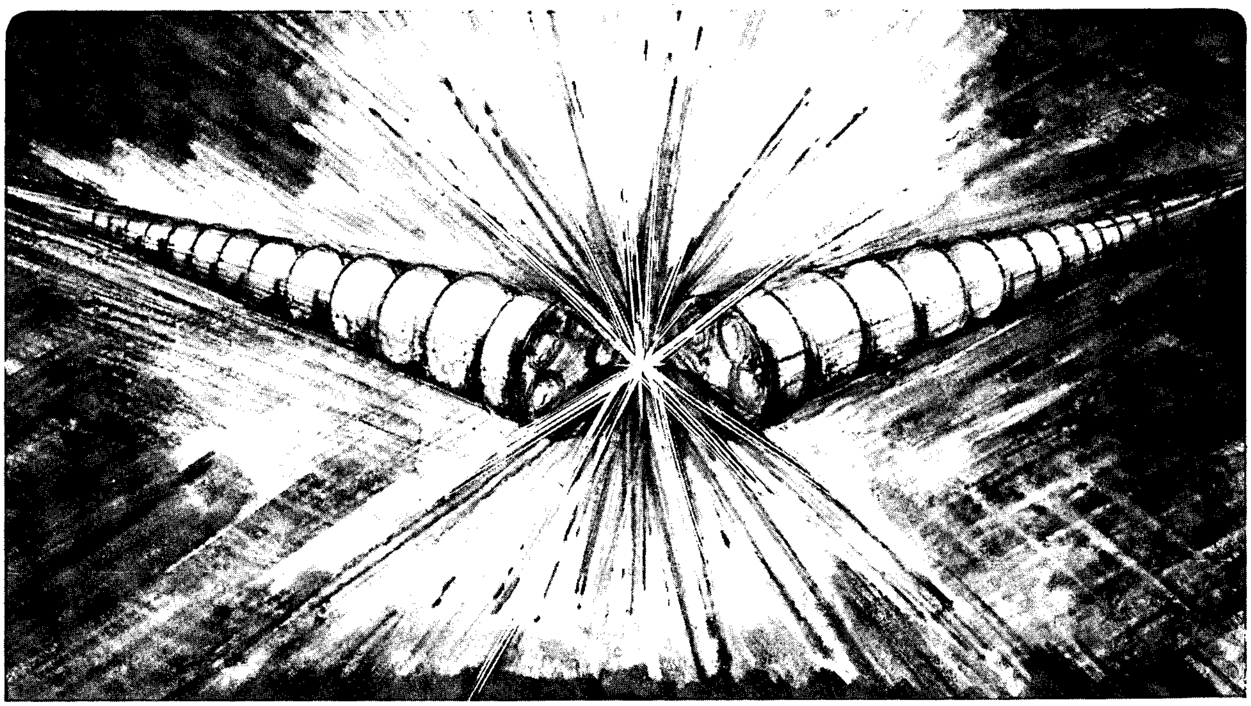
Accelerator & Fusion Research Division

Presented at the Fifth International Conference on Synchrotron Radiation Instrumentation, Woodbury, New York, July 18–22, 1994, and to be published in the Proceedings

ALS Multiple Trim Magnets, or "Magic Fingers", for Insertion Device Field Integral Correction

E. Hoyer, S. Marks, P. Pipersky, and R. Schlueter

July 1994



Prepared for the U.S. Department of Energy under Contract Number DE-AC03-76SF00098

LBL-35865
LSGN-188
UC-410

ALS MULTIPLE TRIM MAGNETS, OR "MAGIC FINGERS", FOR INSERTION DEVICE FIELD INTEGRAL CORRECTION*

E. Hoyer, S. Marks, P. Pipersky, and R. Schlueter

Advanced Light Source
Accelerator and Fusion Research Division
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720

July 1994

Paper presented at the 5th International Conference on Synchrotron Radiation Instrumentation, Woodbury, New York, July 18-22, 1994

*This work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division, of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

Multiple Trim Magnets , or "Magic Fingers", for Insertion Device Field Integral Correction

E. Hoyer, S. Marks, P. Pipersky, R. Schlueter

Advanced Light Source, Lawrence Berkeley Laboratory, University of California, Berkeley, CA 94720

* work was supported by the Director, Office of Energy Research, Office of Basic Energy Sciences, Materials Sciences Division of the U.S. Department of Energy, under Contract No. DE-AC03-76SF00098.

Abstract

Multiple Trim Magnets (MTMs), also known as "Magic Fingers", is an arrangement of magnets for reducing integrated magnetic field errors in insertion devices. The idea is to use transverse arrays of permanent magnets, hence the name "Multiple Trim Magnets", above and below the midplane, to correct both normal and skew longitudinal magnetic field integral errors in a device. MTMs are typically installed at the ends of an ID. Adjustments are made by changing either the size, position or orientation of each trim magnet. Application of the MTMs to the ALS undulators reduced both the normal and skew longitudinal field integral errors, over the entire 20 mm by 60 mm "good field region", of the beam aperture by as much as an order of magnitude. The requirements included corrections of field and gradients outside the multipole convergence radius. Additionally, these trim magnet arrays provided correction of the linear component of the integrated field gradients for particles with trajectories not parallel to the nominal beam axis. The MTM concept, design, construction, tests that demonstrated feasibility and magnetic field integral reduction of ALS undulators are presented.

Background

Qualification magnetic measurements on the first two ALS undulators, IDA-U5.0, and IDB-U5.0 showed excellent on-axis field quality; the random magnetic field errors were less than 0.23% over its 4.5 m long hybrid type periodic structure.[1] Estimated spectral performance with this field showed that the loss in amplitude of the 5th harmonic of the photon spectral output to be less than 30%. However, the higher order field integral errors were high within the 20 mm by 60 mm beam apertures, shown in Figs. 5 and 6. Analysis of the data showed that the dominant errors were coming from the permanent magnet blocks; the cumulative error increased as one traversed along the longitudinal axis of the insertion device. To correct these higher order field integral errors of the as-built devices to acceptable levels, Multiple Trim Magnets (MTMs) or "Magic Fingers", as they are commonly known, were conceived and developed. [2]

Concept

Higher order field errors arise primarily from the small minor component magnetic field errors in the permanent magnet blocks between adjacent poles of the hybrid structure, producing small field integral errors in the magnetic gap.[3] In longitudinally traversing the insertion device these small integral errors are additive. The correction scheme assumes that all these small integral errors can be added and are equivalent to a single field integral error produced by a single magnetic field component between two adjacent poles. This assumption is valid for beam optics when the betatron wavelength of the accelerator or storage ring is much longer than the optical element, i.e,. the undulator. To correct for this single magnetic field component, an equal strength magnetic field component of the opposite sign is put in the integral path to null that field integral. This idea works for both normal and skew fields.

To provide the correction magnetic field components, transverse arrays of permanent magnets are used above and below the midplane to correct both normal and skew longitudinal magnetic field integrals in a device. MTMs are typically installed at the ends of an ID. Adjustments are made by changing either the size, position or orientation of each trim magnet. By placing the full correction at either end, correction is made for electron paths parallel to the axis. Splitting the correction between the two ends additionally zeroes the linear component of integral errors for electron paths that are not parallel to the axis.[4] The successful implementation of this idea to reduce both normal and skew higher order field integral errors of the U5.0 Undulators follows.

Design and Construction

A preliminary determination of the size and position of the trim magnets to correct the higher order vertical field errors on the U5.0 Undulators was made with a series of PANDIRA 2-D computer runs to provide trim magnet vertical field integral contribution information for the U5.0 Undulator minimum gap geometry.[5] From these computer runs, graphs were generated which provide a first order estimation of the achievable vertical field integrals based on trim magnet thickness, length and setback information assuming infinite width. The geometry for the computer runs is shown in Fig. 1.

The width of the trim magnets in the horizontal direction was set based on the smoothness of the higher order vertical field integrals at various operating gaps. Nine trim magnets were selected to span the three block permanent magnet array of the U5.0 half-period pole assembly in the horizontal direction. This gives an 11 mm trim magnet width.

On the ALS undulators, the multiple trim magnet assemblies are installed between the field clamps and the last poles at both ends of the undulator, above and below the midplane for a total

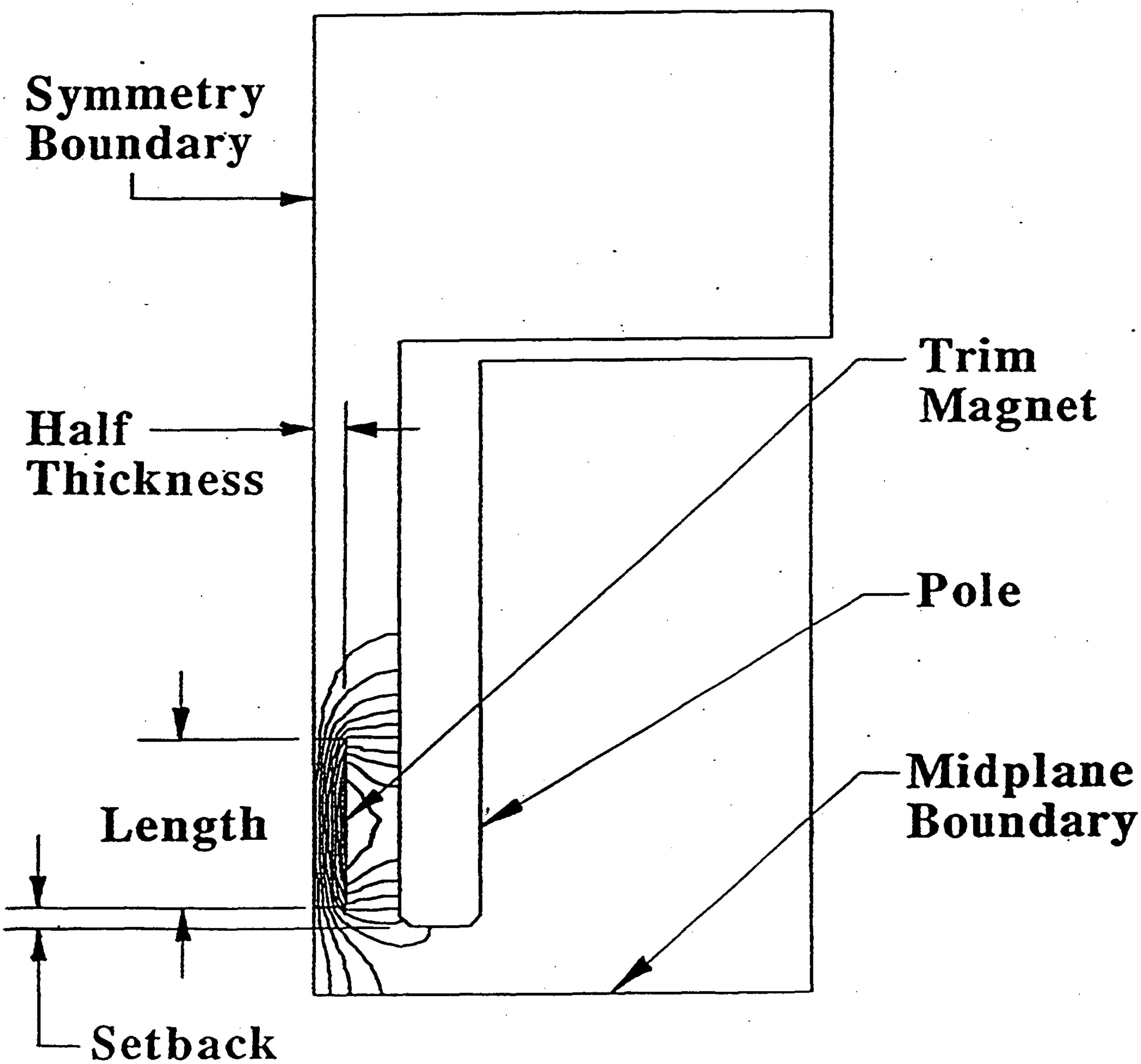


Fig. 1 2-D Flux plot of a trim magnet in U5.0 Undulator geometry.

of four assemblies. The mechanical implementation of the multiple trim magnets into the undulator is shown in Fig. 2. The cartridge base holds the vertical adjusting screws for the nine trim magnets and is bolted to the field clamp. Each trim magnet is bonded to a holder which is threaded and engages an adjusting screw that is attached and free to turn on the cartridge. Trim magnets installed and adjusted on the IDB-U5.0 Undulator are shown in Fig. 3.

Tests

Using the IDB-U5.0 installation, shown in Fig. 3, tests were carried out using a pair of trim magnets centered on the upstream end of the device to determine the longitudinal field integral response for both normal and skew fields.

The measured normal magnetic field response for a pair of vertically oriented blocks, installed between the half strength pole and field clamp, is shown in Fig. 4. The blocks are 4 mm in thickness by 17 mm in length by 11 mm in width. Graphs are shown for 14, 23, and 47 mm gaps, and for 2 mm and 6 mm setbacks. The setback is the vertical offset, away from the midplane, relative to the pole tip.

PANDIRA generated design curves (2-D) were in good agreement with the measured net trim magnet normal field integral response for a configuration of several trim magnets side by side that provide a 2-D field distribution at the center of the array. Trim magnet response to setback variation also agrees with design calculations. Thus, the design curves, confirmed by measurements, provide a guide for initially setting trim magnets and for subsequent iterations to minimize the longitudinal normal magnetic field integrals.

Typically, the measured uncorrected normal magnetic field integrals of the undulator and the trim magnet normal magnetic field integrals have a very similar gap dependency so when corrections are made at one gap they are quite good over a range of gaps.

A companion set of curves were generated for the skew magnetic field integral responses. Here the measurements were carried out also with a pair of opposing trim magnets, placed symmetrically above and below the midplane between the poles. Whereas the normal response function is a local dipole, the skew response is a local gradient. The strength of the gradient decreases rapidly with increased setback.

In summary, for normal magnetic field integral corrections the easy-axis of the trim magnets above and below the midplane are aligned with each other and for the skew magnetic field integral corrections, the easy-axis of the trim magnets above and below the midplane oppose each other.

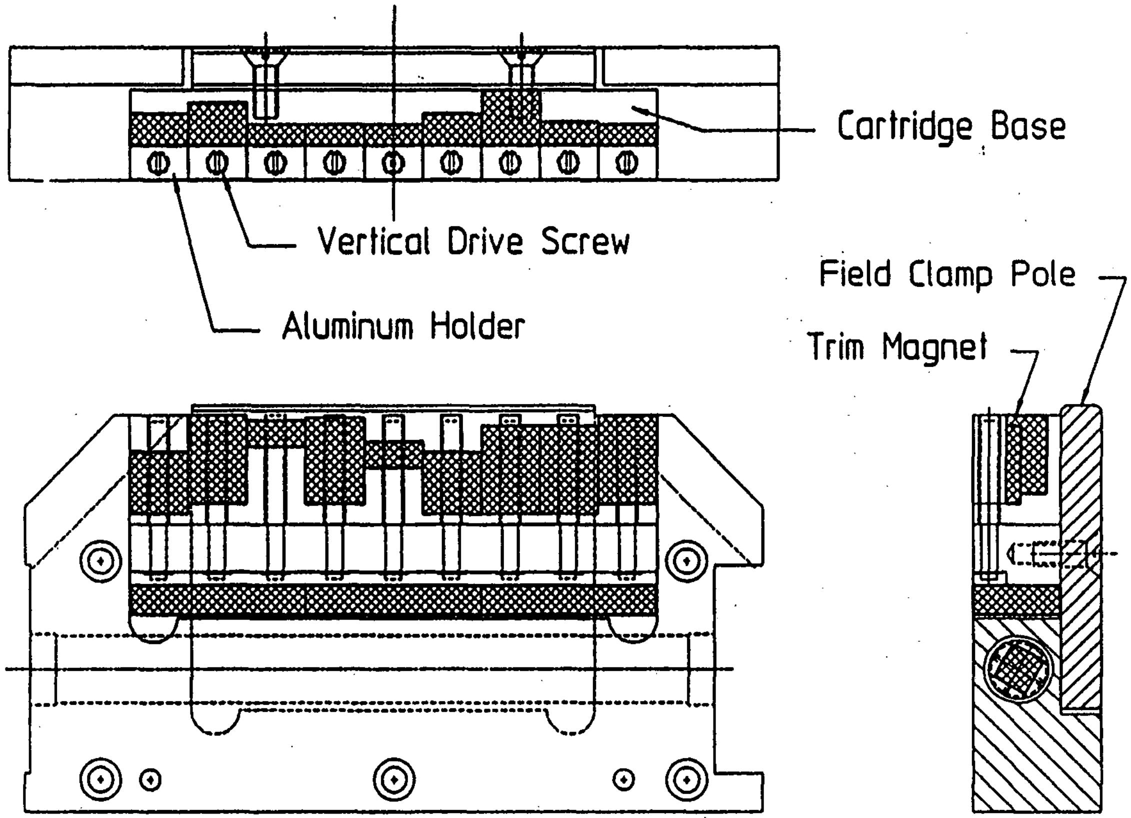


Fig. 2 Multiple Trim Magnet and Cartridge Base Installation at Field Clamp Pole.

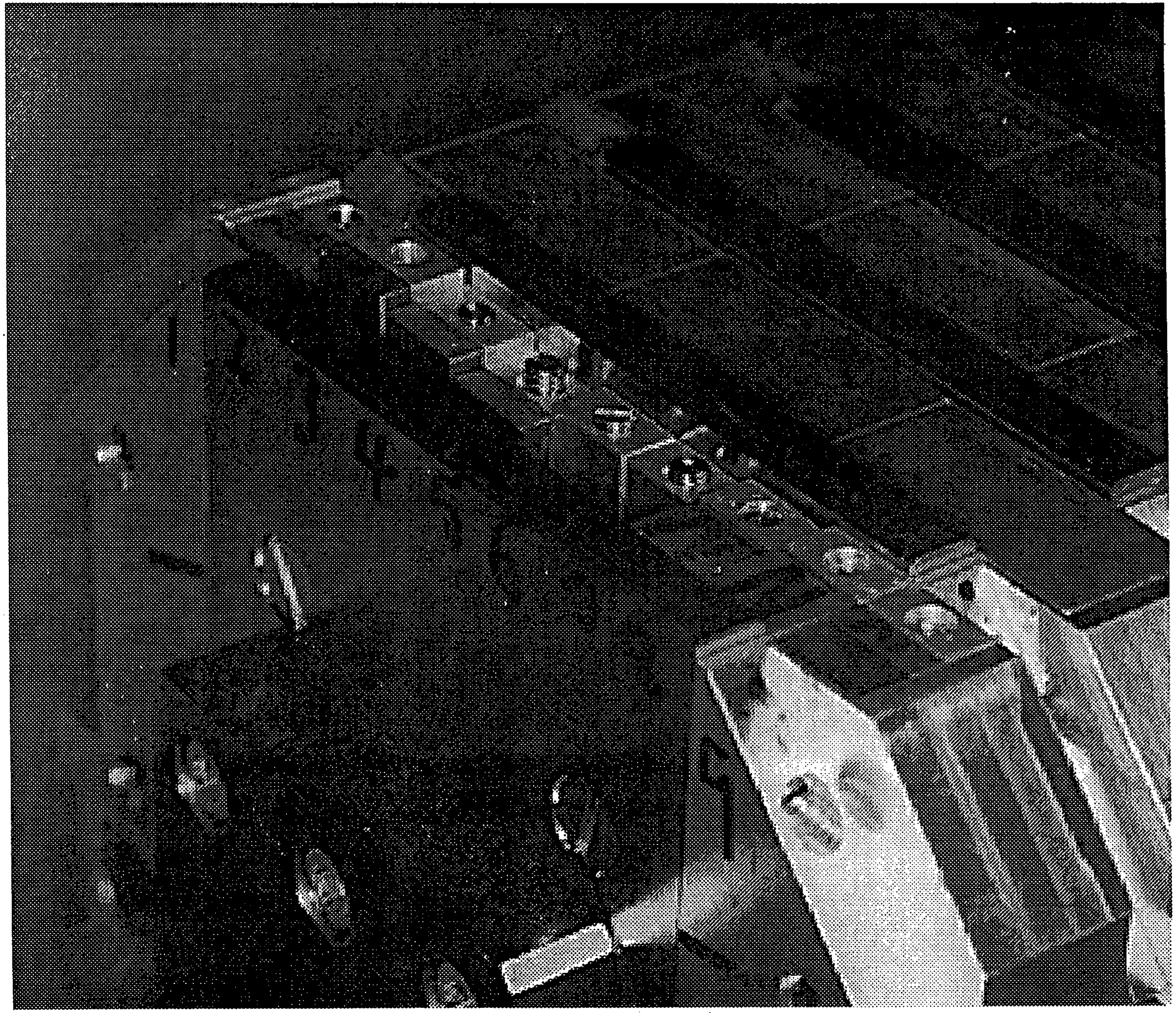


Fig. 3 Multiple trim magnets installed in IDB - U5.0 Undulator

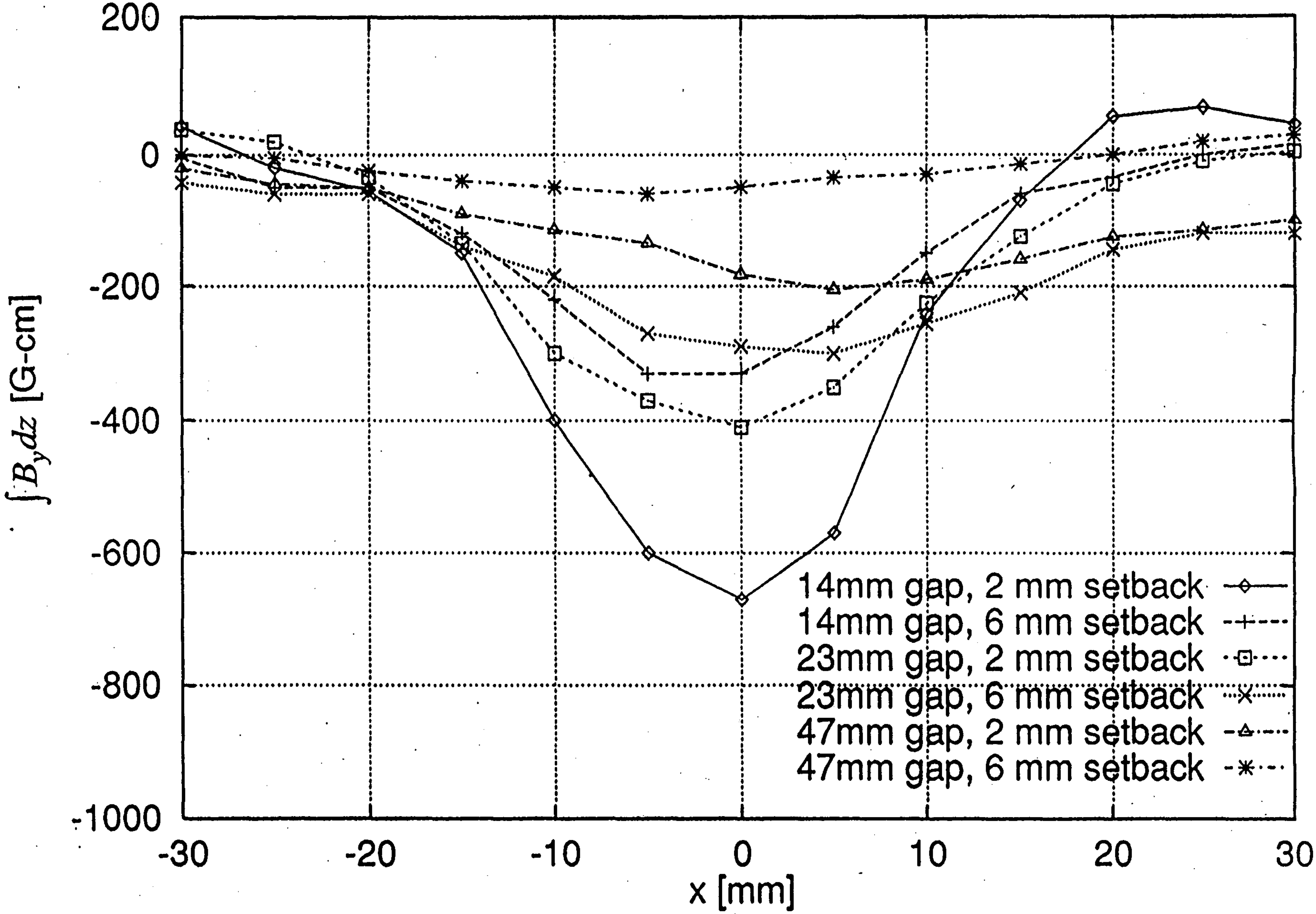


Fig. 4 Normal magnetic field integral response for a trim magnet pair in a U5.0 Undulator

Magnetic Field Integral Improvement with MTM

The procedure for correcting the normal magnetic field integrals is to use the design curves for the first iteration. The design curves are only a guide, based on 2-D configurations, but the actual fields are more 3-D. In subsequent iterations the design curves are used in conjunction with measured incremental changes in the field integrals. For the skew fields, the measured magnet response curves are used.

MTMs were installed at the ends of the devices. The correction at each end contains half of the total normal and skew corrections, i.e., the MTMs were configured so that the normal and skew corrections were superimposed. Since field perturbations superimpose linearly, the correction scheme can be used to make combined corrections to both normal and skew fields in the same array. In reducing the magnetic field integrals, typically the normal magnetic field integrals were minimized first followed by the reduction of the skew magnetic field integrals.

The corrected normal magnetic field integrals are shown in Fig. 5. The total range in integrals at the 14 mm gap over the 6 cm wide aperture for the IDA-U5.0 Undulator was reduced from 3200 G cm to 200 G cm, better than an order of magnitude reduction in normal magnetic field integral. The integrals at the other gaps were also reduced . This demonstrates that this scheme is very effective in reducing normal magnetic field integrals in hybrid structures. The remaining dipole field at the smallest gap is nulled with the adjacent corrector magnets.

Similarly, in Fig 6, the corrected skew field integral variations are shown after the normal field integrals were minimized. Again, at the 14 mm gap over the 6 mm wide aperture, the integral range was reduced from 2700 G cm to 600 G cm, a factor 5 reduction. Adjusting the trim magnets for skew field integral corrections is more difficult because both magnitude and slope must be taken into consideration when setting the trim magnet adjustments; hence, more iterations are generally required. The results demonstrate that skew field integrals can also be substantially minimized with multiple trim magnet arrays in hybrid structures.

Conclusion

MTM arrays provide a convenient and effective mechanism for correcting normal and skew integral errors. Corrections are effective over a range of operating gaps. MTM arrays can be added and adjusted after the assembly and measurements of the rest of the magnetic structure are complete.

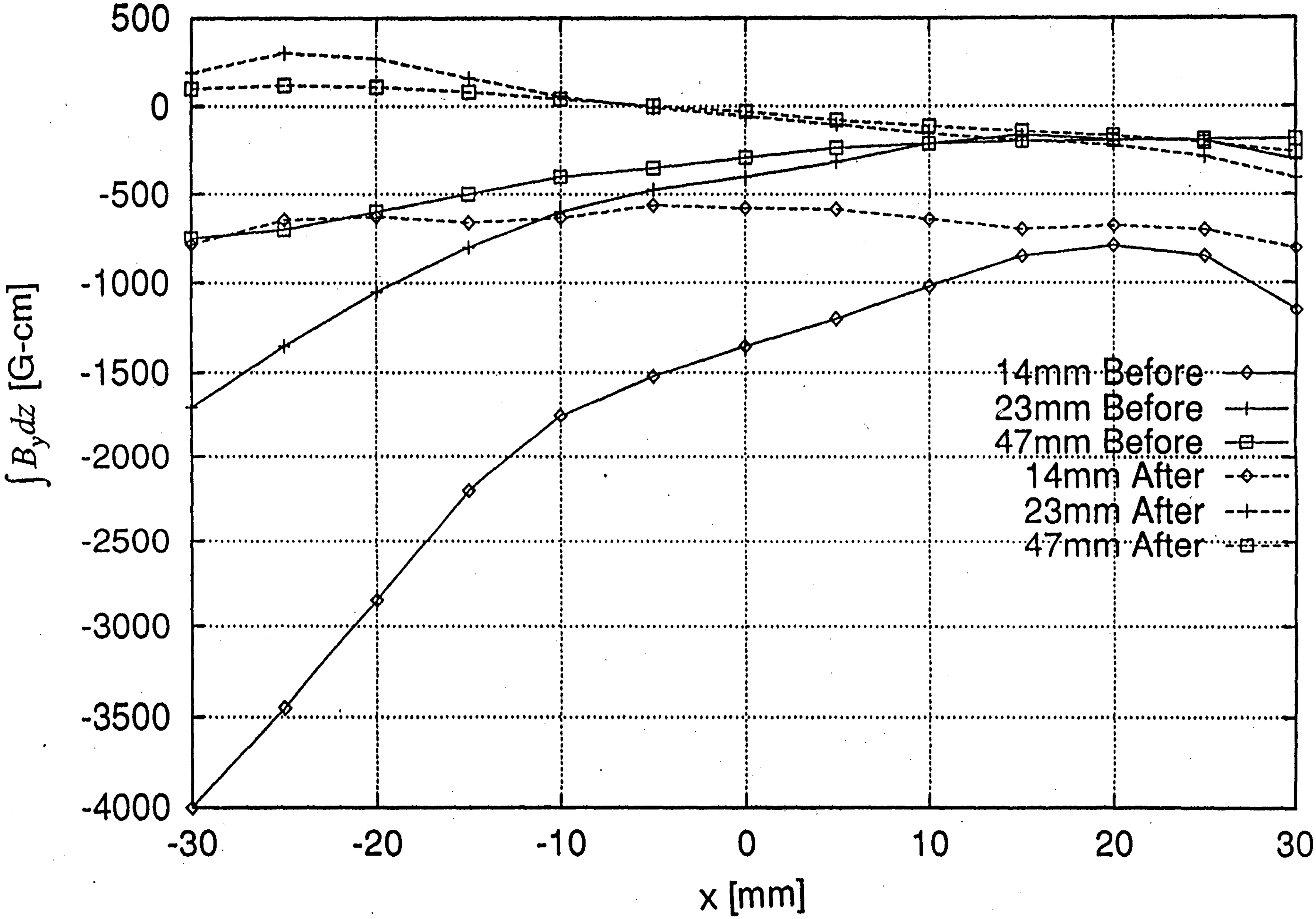


Fig. 5 IDA-U5.0 Undulator - Uncorrected and corrected normal magnetic field integrals

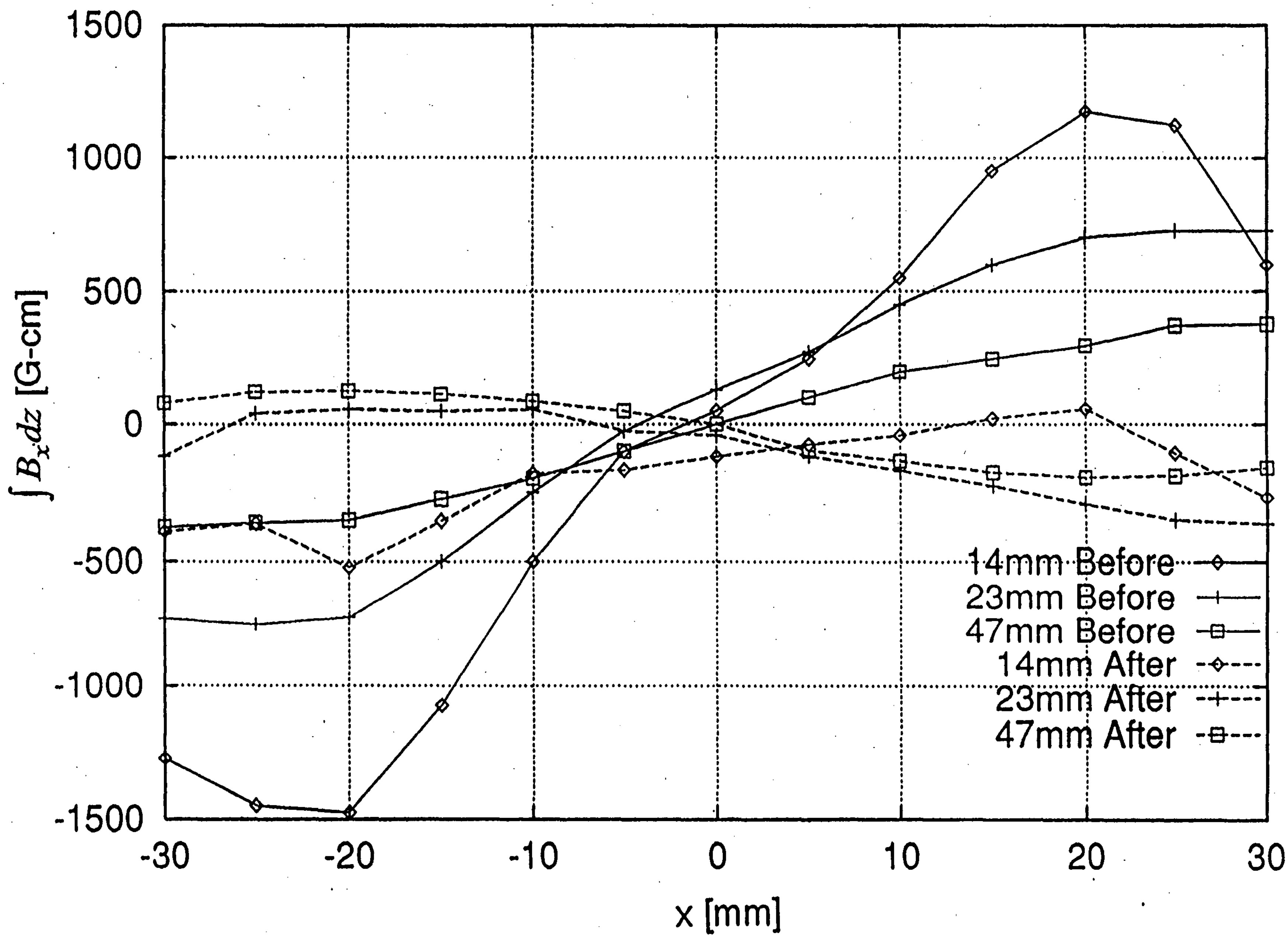


Fig. 6 IDA-U5.0 Undulator - Uncorrected and corrected skew magnetic field integrals

References

1. E. Hoyer, et al., "Undulators for the Advanced Light Source", SRI 94, (July 1994).

2. E. Hoyer, "Multiple Trim Magnets", LBL Engr. Note M7354, (May 1993).

3. D. Humphries, P. Kownacki, S. Marks, R. Schlueter, M. Goetz, "A Multipole Objective Magnet Sorting Algorithim for the Advanced Light Source Insertion Devices", SRI 94, (July 1994).

4. S. Marks, et al., "Analysis of Insertion Devices Measurements for the ALS", SPIE 93, (July 1993).

5. K. Halbach et al., developed PANDIRA, an improved version of POISSON, which allows solution of permanent magnet and residual field problems; POISSON is an improved version of TRIM (A. Winslow, J. Computer Phy. 1, 149,1967).