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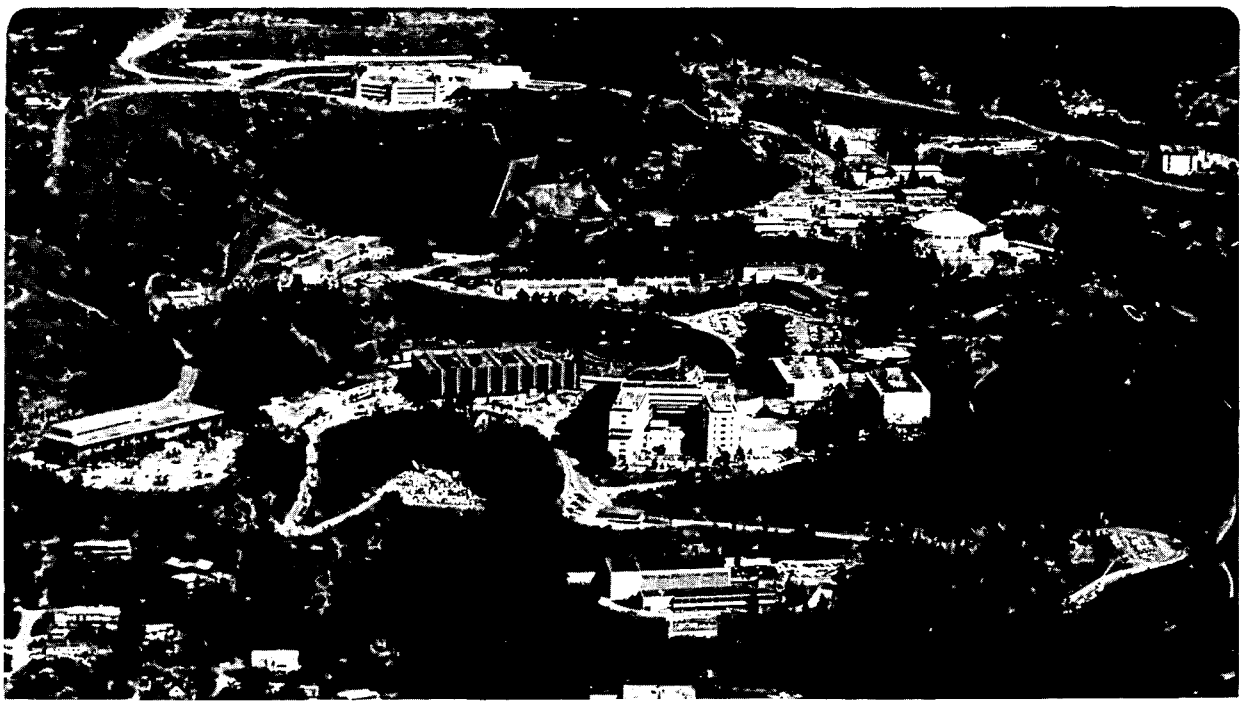

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LAWRENCE BERKELEY LABORATORY - UNIVERSITY OF CALIFORNIA
ENGINEERING NOTE

CODE	SERIAL	PAGE
MME Book No. 626	LBID-517 MT 304	1 OF 7

AUTHOR	DEPARTMENT	LOCATION	DATE
Donald H. Nelson	Electronics Engineering	B25A-124	August 6, 1981

PROGRAM — PROJECT — JOB
LBL-SSRL Undulator

TITLE
July 1981 Magnetic Measurements

Introduction

Herman Winick requested assistance from LBL in making additional magnetic field measurements of the LBL-SSRL undulator.[1] Observations of resonances in the beams which pass through the undulator have led to the preliminary conclusion that the undulator field contains an octupole component in quadruture to the dipole (fundamental) component.[2] The magnitude of the suspected octupole may be described as an integrated effect at 1 cm of 6.1 Gauss-meters, i.e., $\int_{-\infty}^{\infty} B_y dx \Big|^{*}_{y=1\,\mathrm{cm},\, z=0} =$ 610 Gcm.

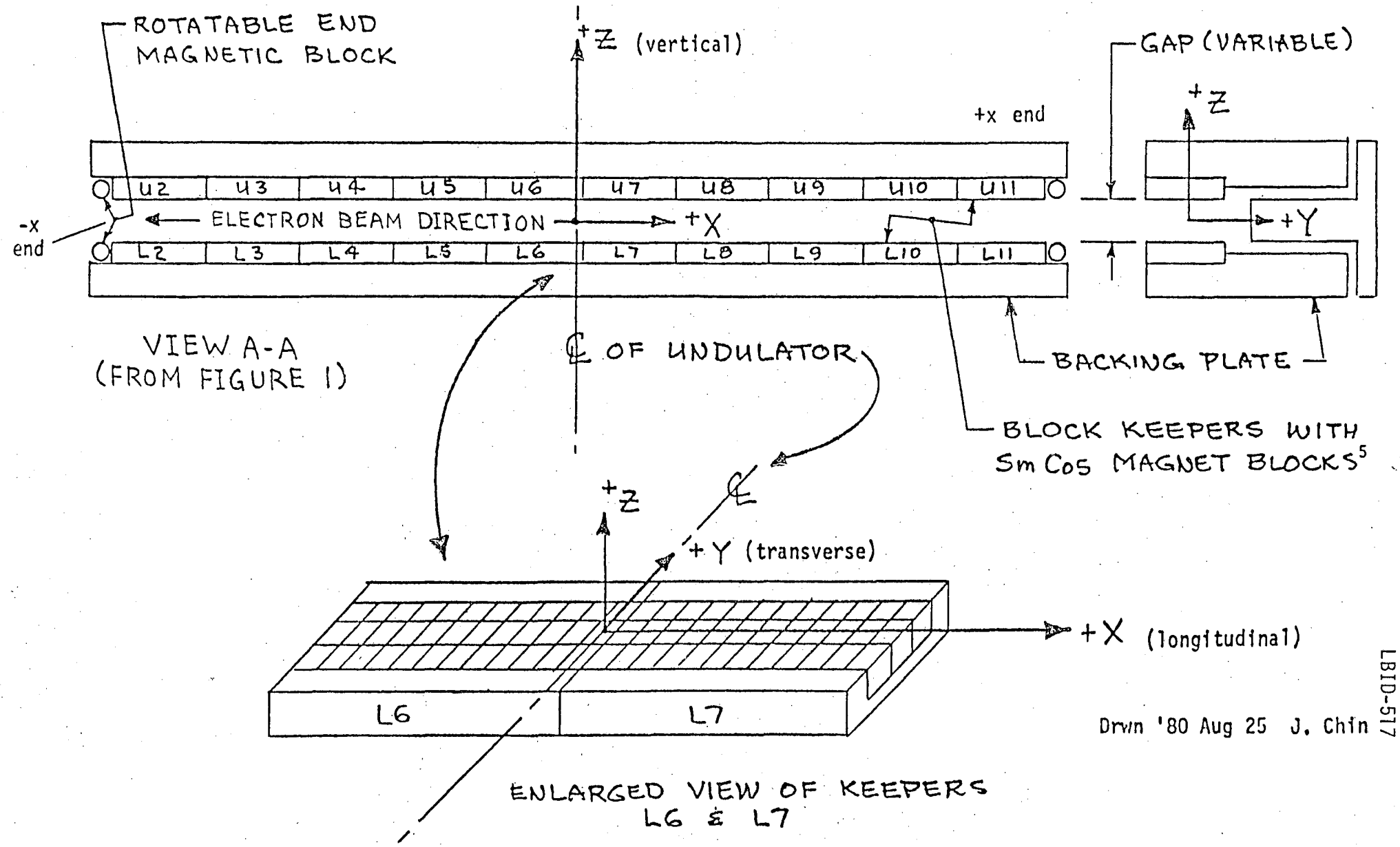
Primary Measurement Results

On July 30 and 31, 1981, Ed Cyr and Don Nelson measured the quantity $\Delta B_y \big|_{y=1.2\,\mathrm{cm},\, z=0}$ at 113 x-locations (quarter periods starting at x = 0) where $\Delta B_y = B_y\,(1.2\text{ cm}) - B_y\,(-1.2\text{ cm})$.

Using an HP 97 program, I numerically integrated these data and concluded the following:

1. $\int_{-85.3}^{85.3} \Delta B_y dx \big|_{y=1.2\,\mathrm{cm},\, z=0} = 500 \pm 50$ (Gcm) (ΔB_y is defined above.)
2. Assuming y-symmetry,
$$\int_{-85.3}^{85.3} B_y dx \big|_{y=1.2,\, z=0} = 250 \pm 25 \text{ (Gcm)} .$$
3. Assuming B_y is due entirely to an octupole component in the field integral,
$$\int_{-85.3}^{85.3} B_y dx \big|_{y=1.0,\, z=0} = \frac{1}{(1.2)^3} \int_{-85.3}^{85.3} B_y dx \big|_{y=1.2,\, z=0} = \frac{250}{1.73}$$
$\simeq 150 \pm 15$ (Gcm).
4. This integral is $\sim$1/4 the suspected integral.
5. We discovered no significant localized field that would explain the observed "resonance".

*Figure 1, a schematic representation of the undulator (Figure 2 of MT 292), shows the coordinate system of measurements.



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UNDULATOR

FIGURE 1

6. To verify that the field integral has the property of an octupole, additional measurements may be made with different coil spacing(s). If $\int B_y dx$ varies as y^3, the integral is octupole in nature.

Additional Measurements

Ed Cyr and Don Nelson also measured $B_y(x, y = 0, z = 0)$ at 114 equally spaced locations ($\{-85.3\} \leq x \leq 86.8$ cm, $\Delta x = 1.525$ cm). Based on these (Hall Probe) data, I drew the following conclusion:

The average of the 114 measurements of B_y $(y = 0)$ (after corrections for a constant Hall probe tilt error of $2.3° \pm 0.3°$) is 0.25 Gauss with a standard deviation (due mainly to irregularities inherent in the magnet assembly) between 15 and 25 Gauss.

At the request of Herman Winick, we loaned the Hall Effect Gaussmeter to SSRL. Mike Cox of SSRL measured and recorded magnetic induction at the center of the surface of the 714* stationary magnets. For the peak/valley magnets, he measured B_z with the transverse probe flat on the center of each magnet. For the magnets between the peak/valley magnets, he measured B_x with the transverse probe rotated 90° clockwise and mounted on a fixture for angular stability.

Measurement Procedure

Figure 2 shows the test equipment used for our tests. Table I lists specific equipment. For measuring ΔB_y, we modified a fixture used for the earlier measurements added cylindrical pegs to accurately space the coils in y and shims to place the coils at z = 0.

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*See Figure 1, 2 x 36 x 10 - 6 = 714 (Keeper Sections L2 and U2 each contain 33 magnets. All others contain 36 magnets.)

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SUBJECT: LBL-SSRL Undulator
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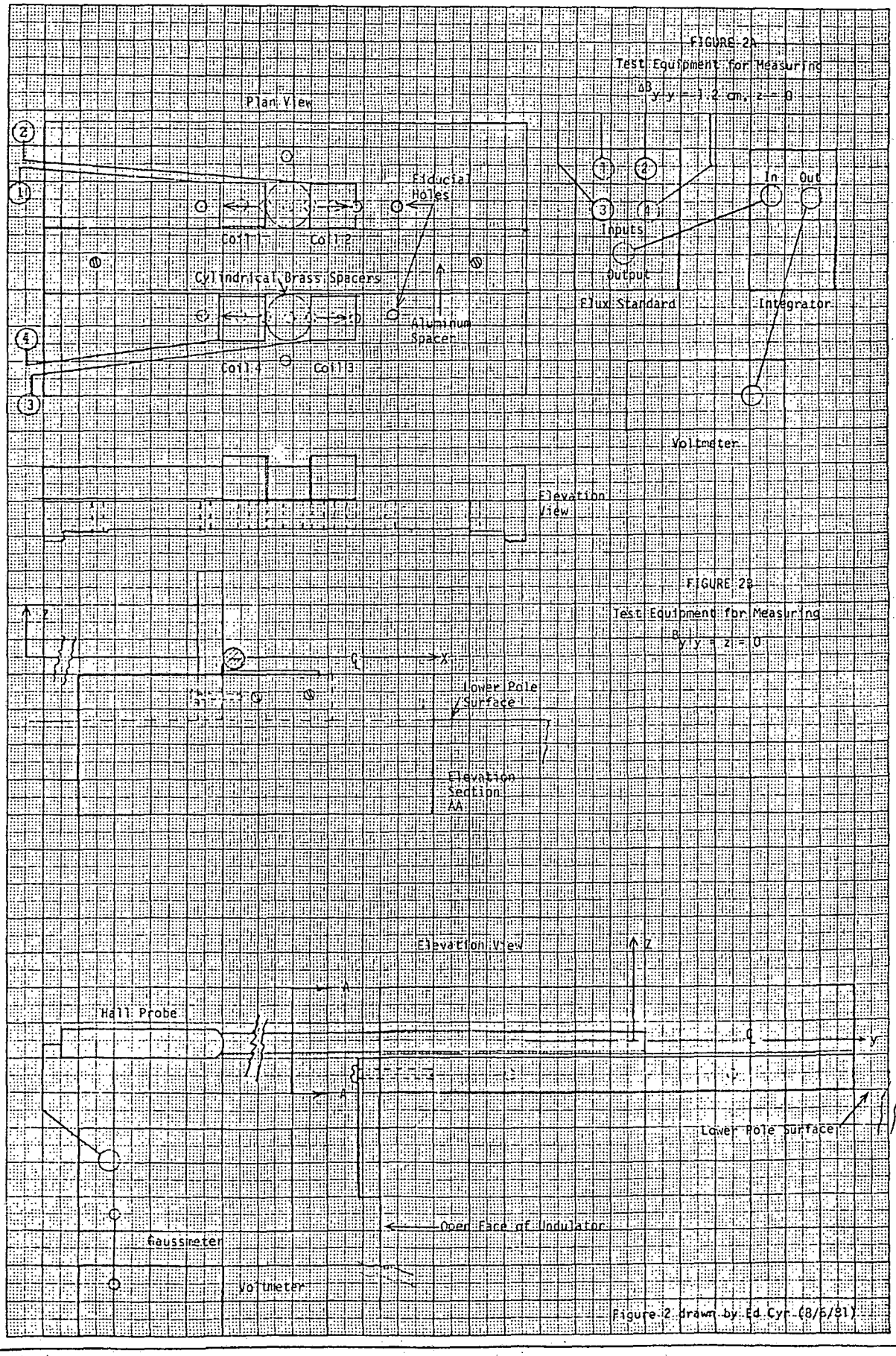

Figure 2 drawn by Ed Cyr (8/6/81)

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Device	Description	Identification
Coil 1	12 mm Cube nA = 0.530 (m^2)	B-147 (LBL, MME)
Coil 2	nA = 0.537 (m^2)	B-150 (LBL, MME)
Coil 3	nA = 0.535 (m^2)	B-148 (LBL, MME)
Coil 4	nA = 0.519 (m^2)	B-139 (LBL, MME)
Flux Standard	MME SLFS 40	$\emptyset_{SLFS\ 40.5}$ = 0.5487 Wb
Integrator	MME Model 71	S/N 1 R = 46.4 kΩ C = 1.0 μF Div = 360
Voltmeter	Fluke Model No. 8000 A Multimeter	SSRL Property No. 007
Gaussmeter	F.W. Bell Model 620	DOE No. 501586
Probe	Axial Probe Model HAB4-2508	S/N 141861
Voltmeter	(Same as Above)	
Probe (Loaned to M. Cox)	Transverse Model HTR40608	S/N 129152

TABLE I Test Equipment

At the suggestion of Dr. Klaus Halbach, we took advantage of the odd symmetry (in y) of the octupole in eliminating variable tilt error as a significant error (due to the dipole which exhibits even symmetry). Had time permitted, we may have fabricated integral coils 6.1 cm long (in x) to cancel periodic (in x) field components, thereby providing double cancellation of the dipole and other components with even symmetry.

To measure ΔB_y (x), we first placed the coils (mounted on the fixture) in a mu-metal shield (used as a zero-field reference) and reset the integrator. We then placed the fixture at a desired (x) position as determined by a pair of meter sticks mounted on the undulator (with double-backed tape). The flux standard provided a calibration of the measurement system. The data were recorded by hand.

For measuring B_y (x = 0), Mike Cox provided us with a fixture which (1) positioned (the active portion of) the axial probe at y = z = 0, and (2) constrained the cylindrical probe to be parallel to the lower magnet surface and perpendicular to the outside surface of the undulator (the surface just below the lower pole surface).

Mike made a similar fixture for positioning a transverse probe on the center of each magnet's exposed surface. On August 5th, Mike reported "those measurements have been completed and a copy of the results has been sent to Klaus Halbach. There were no major surprises."

Discussion - Future Measurements

LBL's Magnetic Measurements Engineering has the immediate capability to measure both ${}_0\int^{122}\Delta B_y|_{y=0.6,\,z=0}\,dx$ and ${}_{-122}\int^{0}\Delta B_y dx$ directly with an existing gradient/integral coil (L-25A & B). A mounting fixture that would allow this coil to be positioned in either half of the magnet and rotated about its long axis would facilitate these measurements and in order to rotate the coil pair inside the undulator, the undulator gap would have to be opened to a dimension greater than 3.6 cm.

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Klaus Halbach pointed out that a pair of line integral coils 6.1 cm long could be fabricated. Then the sum of exactly 31 measurements of $\int_{x_0 - 3.05}^{x_0 + 3.05} \Delta B_y dx$ at appropriate values of x_0 would directly determine the integral $\int_{-94.55}^{94.55} \Delta B_y dx$ while canceling periodic signals (in x).

Future measurements could be made with a multipole array so the spacial harmonics of the field integral could be determined directly. (Except for designing and fabricating (1) an appropriate coil array and (2) the hardware for rotating the array on the longitudinal center line of the undulator) Magnetic Measurements Engineering will have the facility to make automated measurements of this type by October 1, 1981.

References

1. Nelson, D.H. and Green, M.I., "Stanford Synchrotron Research Laboratory LBL-SSRL Undulator Results of 1980 Magnetic Measurements", LBL Engineering Note - MT 292, LBID-324, December 15, 1980.

2. Morton, P., "Measurements in SPEAR With Undulator in Place", SPEAR-223, July, 1981.

Distribution

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