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SOME NEW IDEAS ABOUT UNDULATORS

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SOME NEW IDEAS ABOUT UNDULATORS

Talk presented at the International Conference
on Insertion Devices for Synchrotron Sources

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Abstract

There are still no helical undulators that satisfy all major requirements. A new helical undulator is described that has at least some of the properties that were not obtainable until now. It can be used in a synchrotron storage ring, is completely accessible from both sides, light with both helicities can be produced, the helical field can be made quite strong, and the period length can be adjusted over a small range.-Similarly, there have been some efforts lately to develop undulators with very short periods. It is shown how a hybrid undulator with a period of the order 1 mm can be constructed.

1) A Helical Undulator

Figure 1a shows schematically the field line pattern in an undulator (U) with the usual midplane symmetry. Figure 1b shows the symmetry of the fields used in the U described here. Figure 2 shows a plan view of the U, with the z axis representing the average direction of the beam, and the periodic pattern of lines showing schematically the "poles" of the U. This U could be implemented either as a hybrid U (Reference 1) or an U that uses only current sheet equivalent material (CSEM), equivalent to the U described in Reference 2. Since a hybrid performance design for this symmetry has not yet been done, we use the appropriately modified equations of Reference 2. With $k = 2\pi/\lambda$, it follows from Figure 2 that

$$\lambda_o/\lambda_u = k_u/k_o = \cos\delta \tag{1}$$

and transcription of the field equations in Reference 2 gives for x = 0:

$$B_z = -B_o \cdot \cos\delta \cdot \cosh k_o y \cdot \sin k_u z \tag{2}$$

$$B_x = B_o \cdot \sin\delta \cdot \cosh k_o y \cdot \sin k_u z \tag{3}$$

$$B_y = B_o \cdot \sinh k_o y \cdot \cos k_u z \tag{3.2}$$

$$B_o = 2 \cdot B_r \cdot \frac{\sin \varepsilon\pi/M'}{\pi/M'} (1 - e^{-k_o L}). \tag{4}$$

B_r represents the remanent field of the CSEM, M' the number of blocks per period in one half of the U, (usually $M' = 4$),

ε = block width * M'/λ_o, and L the height of the blocks.

The field component B_z has very little effect on the trajectory of the electrons and can be ignored for the purposes of this paper.

Comparing Equation (3.1) to Equation (3.2) shows that at y_1, determined by

$$\tanh k_0 y_1 = \sin \delta, \tag{5.1}$$

or equivalently

$$\cosh k_0 y_1 \cdot \cos \delta = 1, \tag{5.2}$$

one finds helical fields, and it is easy to see that these helical fields dominate the equation of motion of the electrons. A detailed analysis of the trajectories has not yet been done, but the following points are important and readily seen.

1) It is advisable to use this U only with beams that have small dimensions in the y direction, i.e. the helical fields are useful only for a small emittance beam in a synchrotron storage ring.

2) Helicity can be changed by either moving the beam (by energizing a pair of dipoles at each end of the U) or the U so that the beam experiences the helical fields at $\pm y_1$.

3) Since one is using the fields off the midplane, it is important that the field is not contaminated strongly by higher harmonics. It would probably be wise to use $\varepsilon = 4/5$, so that the first non-zero harmonic is the ninth (see Reference 2). If one uses $M' = 4$ and $L = \lambda_0/4$, B_0 becomes

$$B_0 = 1.19\ B_r. \tag{6}$$

4) In contrast to a conventional U, where violation of midplane symmetry produces error fields that are essentially parallel to the trajectories, error fields due to violation of midplane symmetry in this U are essentially perpendicular to the trajectories. For that reason, midplane symmetry should be much better measured and controlled than in conventional U's.

5) It follows directly that this U produces at $y = 0$ linearly polarized light, with the plane of polarization rotated by 90° relative to the light produced by a conventional U.

6) The period λ_u of the U can be changed by rotating the U about the y axis.

Closing the description of this U, I want to stress that this is only a preliminary exploration of a new concept that might lead (with some additional analysis and optimization) to a useful device, or at least might point the way to other insertion devices that take, more cleverly, advantage of the properties of the magnetic fields in a magnet with the symmetry properties that this U has.

2) Construction Procedure for a Short Period Hybrid Undulator

Despite renewed interest in very short period U's, nobody seems to consider the hybrid U (Reference 1) seriously. The reason is probably the necessity of having to handle very thin, and therefore fragile, sheets of material, combined with the fact that the magnetic forces caused by the CSEM can be quite large. It is therefore worthwhile to describe a construction procedure that avoids the problems associated with the magnetic forces.

Figure 3 shows on top a part of the periodic hybrid U structure, and at the bottom the basic construction module, consisting of two half-width sheets of soft iron glued to a full-width sheet of CSEM. To assemble such a sandwich, one would use oriented but unmagnetized CSEM, thus avoiding the magnetic force problem. Putting these modulus into a non-metallic fixture for magnetization again avoids the magnetic force problem.

The total force between the two modules that make a complete period is repulsive. If one glues lightly (to avoid lateral mechanical instability) each module temporarily to an appropriately shaped fixture, and then glues the two modules permanently together, one can produce a full period section without fear of breakage. Using essentially the same method, one can then proceed and make longer and longer sections.

As the next step, the four sides of each full length array would be ground flat. The magnetic field of each half of the U would then be measured, and magnetic tuning would be done if needed. Two possible magnetic tuning methods come to mind immediately: either localized removal of soft iron or CSEM by grinding, or attachment of local soft iron shunts with appropriate air gaps.

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REFERENCES

1) K. Halbach, Journal de Physique 44, C1-211 (1983)

2) K. Halbach, Nuclear Instruments and Methods 187, 109 (1981)

Figure 1. Undulator Field Symmetries

Figure 2. Plan View of Undulator

Figure 3. Construction Module of Short Period Undulator

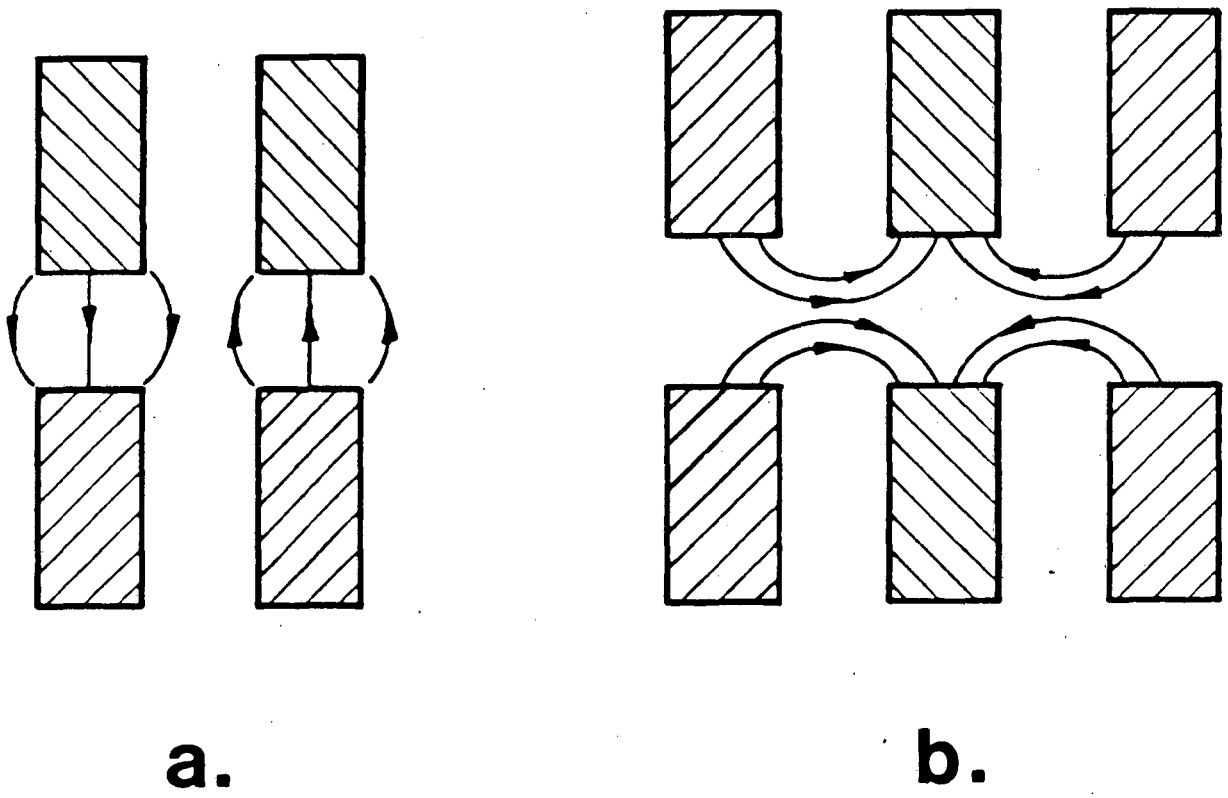

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Fig. 1

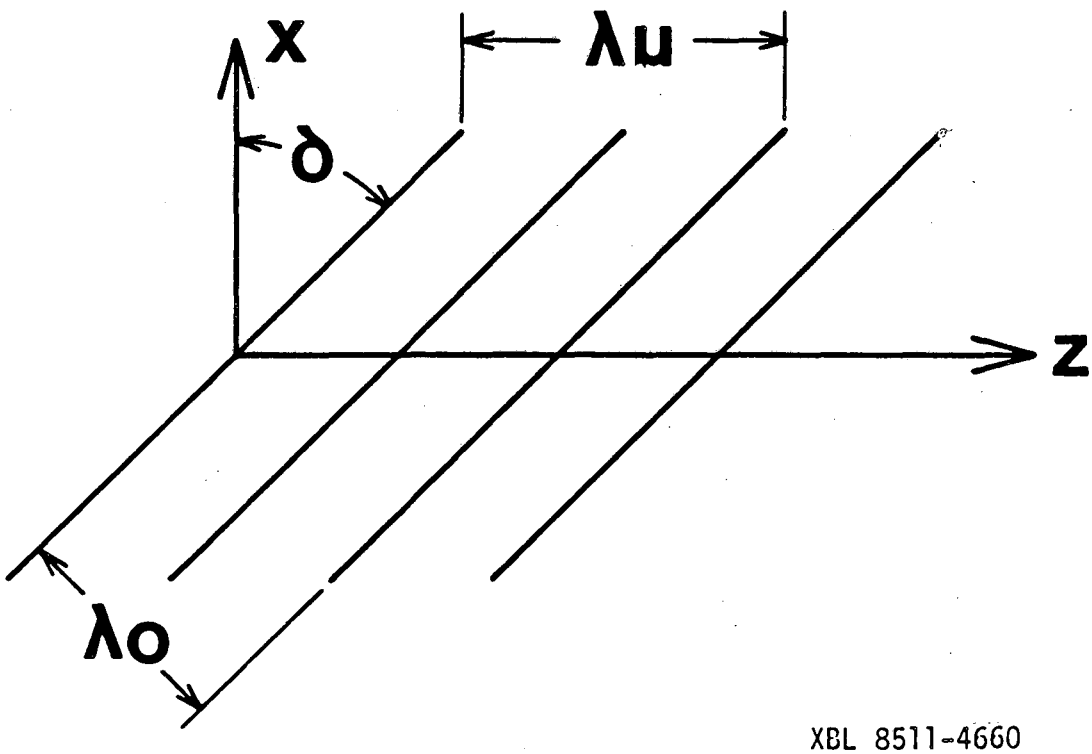

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Fig. 2

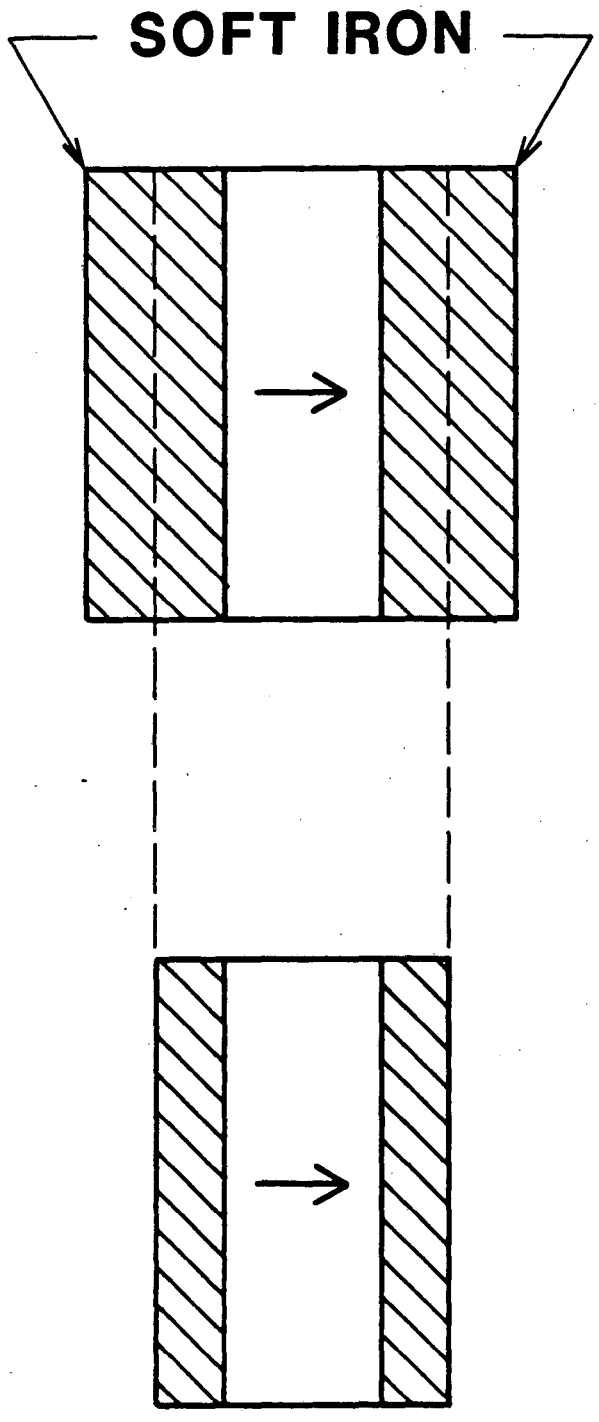

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Fig. 3

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