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ALS Elliptical Wiggler

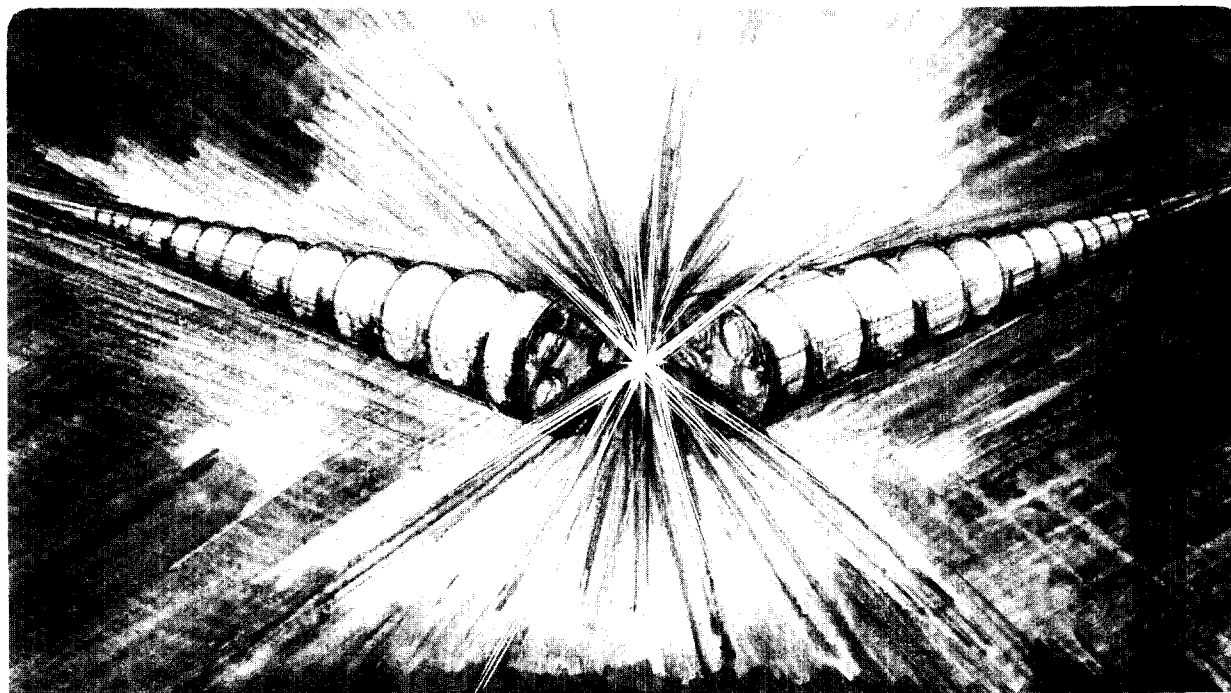
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Advanced Light Source Elliptical Wiggler

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Abstract

A 3.5 m long elliptical wiggler, optimized to produce elliptically polarized light in the 50 eV to 10 keV range, is currently under design and construction at the Advanced Light Source (ALS) at Lawrence Berkeley Laboratory. Calculations of spectral performance show that the flux of circularly polarized photons exceeds 10^{13} photons/sec over the 50 eV to 10 keV operating range for current of 0.4 amps and 1.5 GeV electron energy. This device features vertical and horizontal magnetic structures of 14 and $14\frac{1}{2}$ periods respectively. The period length is 20.0 cm. The vertical structure is a hybrid permanent magnet design with tapered pole tips that produce a peak field of 2.0 T. The horizontal structure is an iron core electromagnetic design, shifted longitudinally $\frac{1}{4}$ period, that is tucked between the upper and lower vertical magnetic structure sections. A maximum peak oscillating field of 0.095 T at a frequency up to 1 Hz will be achieved by excitation of the horizontal poles with a trapezoidal current waveform. The vacuum chamber is an unconventional design that is removable from the magnetic structure, after magnetic measurements, for UHV processing. The chamber is fabricated from non-magnetic stainless steel to minimize the effects of eddy currents. Device design is presented.

INTRODUCTION

An Elliptical Wiggler for producing elliptically polarized light at Lawrence Berkeley Laboratory's Advanced Light Source (ALS) is currently being designed. When installed in the ALS, requirements are to produce elliptically polarized light in the 50 eV to 10 keV spectral range with chirality switching of up to 1 Hz.¹ These requirements drive the photon beam parameters tabulated in Table I.

The mechanical configuration of the Hybrid-Electromagnet Elliptical Wiggler is shown in Figs. 1 and 2. The vertical magnetic field is generated with a variable gap hybrid-permanent magnetic structure; the horizontal magnetic field comes from an iron core electromagnetic structure.² The support structure and drive system configurations are similar to those of the ALS undulators.³ The vacuum chamber configuration features a beam tube with multiple pumping ports that are connected to a pumping chamber.

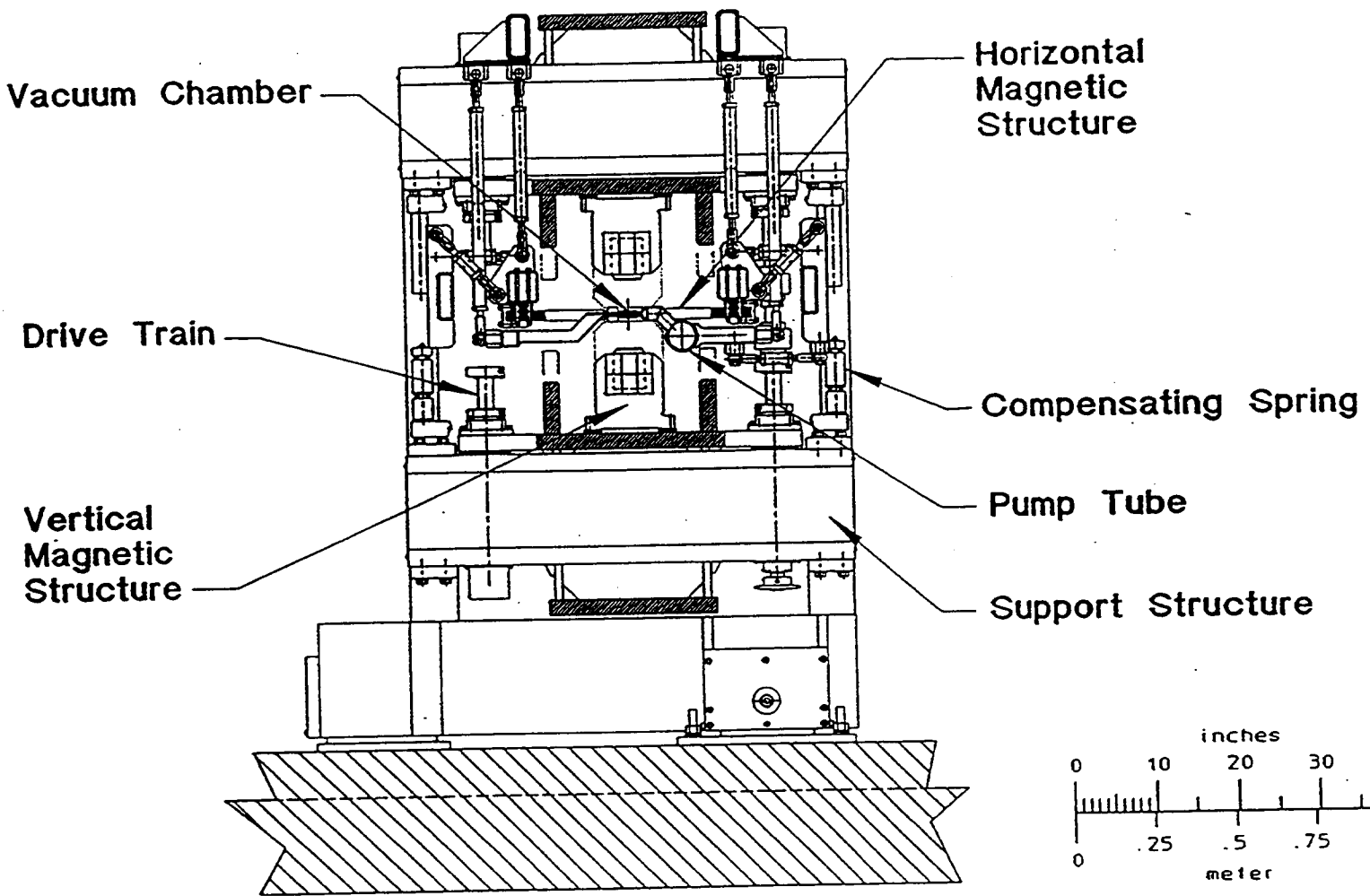


Fig. 1 Side Sectional View-Electromagnet Elliptical Wiggler

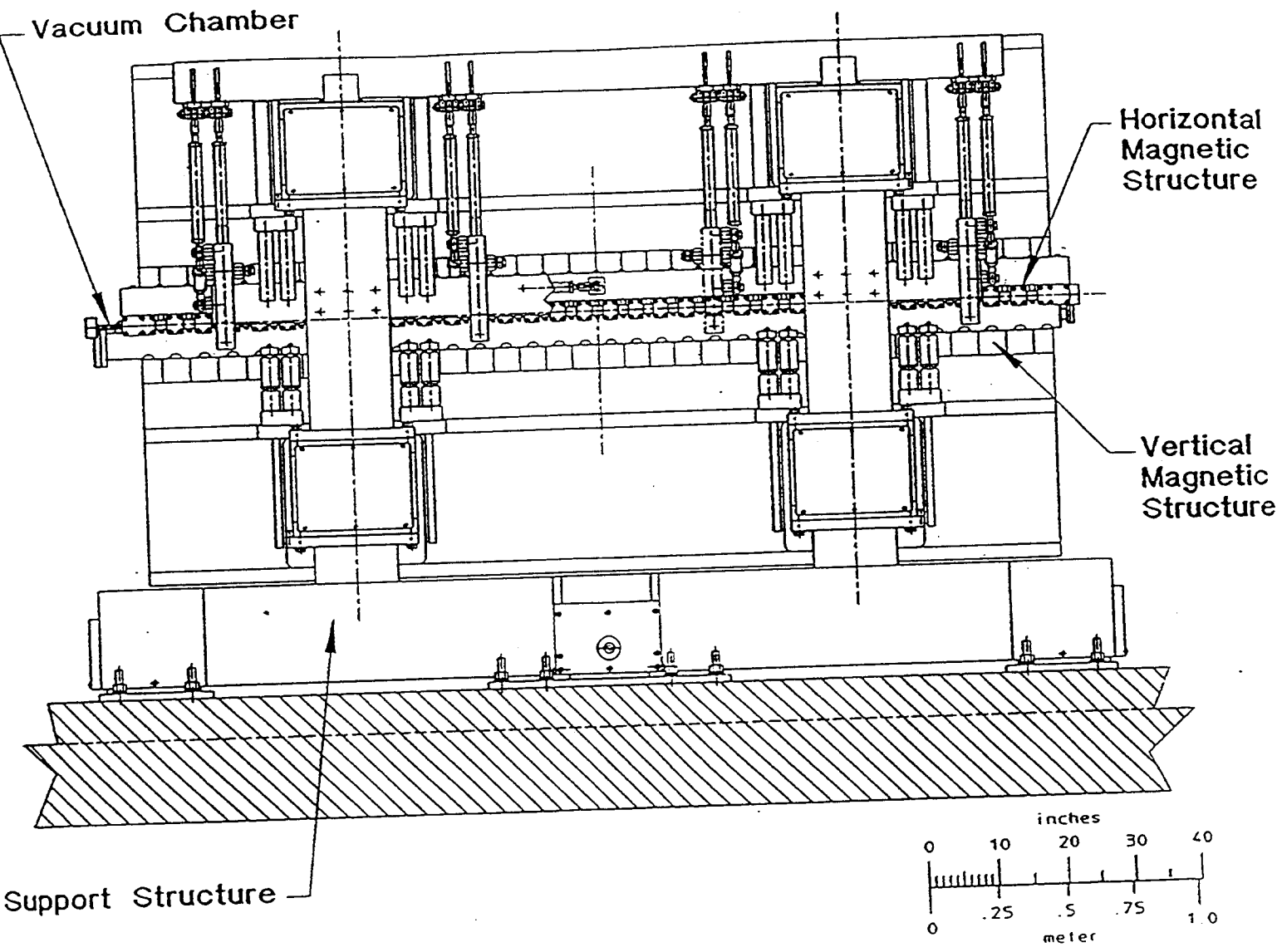


Fig. 2 Elevation View-Electromagnet Elliptical Wiggler

Spectral calculations indicate that the device will produce a polarization figure of merit, defined as flux times degree of circular polarization squared, of greater than 10^{14} photons/sec/0.1%BW at photon energies up to 5 keV and greater than 10^{13} photons/sec/0.1%BW for photon energies between 5-10 keV, for a 5 mrad horizontal aperture fan with the ALS operating at 1.5 GeV and 400 mA.⁴

Table I. Elliptical Wiggler Photon Beam Parameters

Maximum Usable Energy	12 keV
Horizontal Field Cycling Frequency	1 Hz max.
Max. Horizontal Deflection Para. ($K_{y\text{eff}}$)	25.95
Max. Vertical Deflection Para. ($K_{x\text{eff}}$)	1.5
Max. Horz. Opening Angle (@1.5 GeV)	+/-8.82 mrad
Max. Vert. Orbit Angles (@ 1.5 GeV)	+/-0.510 mrad
Wiggler Period Length	20 cm
Number of Periods, Vertical Structure	14

PRINCIPLE OF OPERATION

To describe the operation of the elliptical wiggler, it is useful to note that radiation from each individual pole of a conventional wiggler behaves qualitatively like that from a bend magnet. On the horizontal midplane the flux is linearly polarized; i.e., the degree of circular polarization is zero. As the observer moves vertically off-axis, the absolute value of the degree of circular polarization increases. The degree of circular polarization above the midplane is of opposite handedness as that below the midplane. This provides the basis for the off-midplane observation of circularly polarized flux from bend magnets; however, the radiation from a series of wiggler poles, viewed off-axis, exhibits no net circular polarization, since it consists of the radiation from poles of alternating polarity, which produce radiation of alternating chirality. Circularly polarized flux can be produced on the midplane, however, through the use of a periodic horizontal magnetic field, shifted spatially 90° relative to the vertical field. The horizontal field deflects the electron beam vertically so that as it passes through the vertical field it provides an effect on axis which is equivalent to viewing the radiation from successive poles first from above the midplane and then from below. This is schematically illustrated in Fig. 3.

VERTICAL MAGNETIC STRUCTURE

The vertical magnetic field structure consists of a periodic structure with 14 periods. The ends are modified to satisfy entrance and exit requirements. To achieve the 2.0 T peak field, the hybrid-permanent magnet design utilizes Nd-Fe-B magnetic material and vanadium permendur poles, whose tips are tapered in both the transverse and longitudinal directions. Views of the

Vertical Magnetic Field Poles

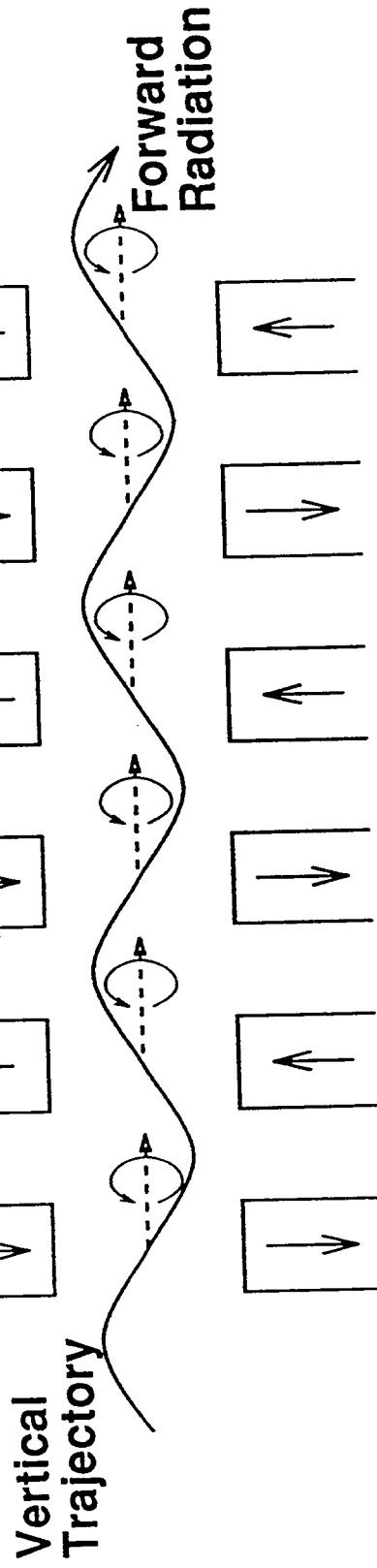


Fig 3. Elliptical Wiggler Schematic of Operation

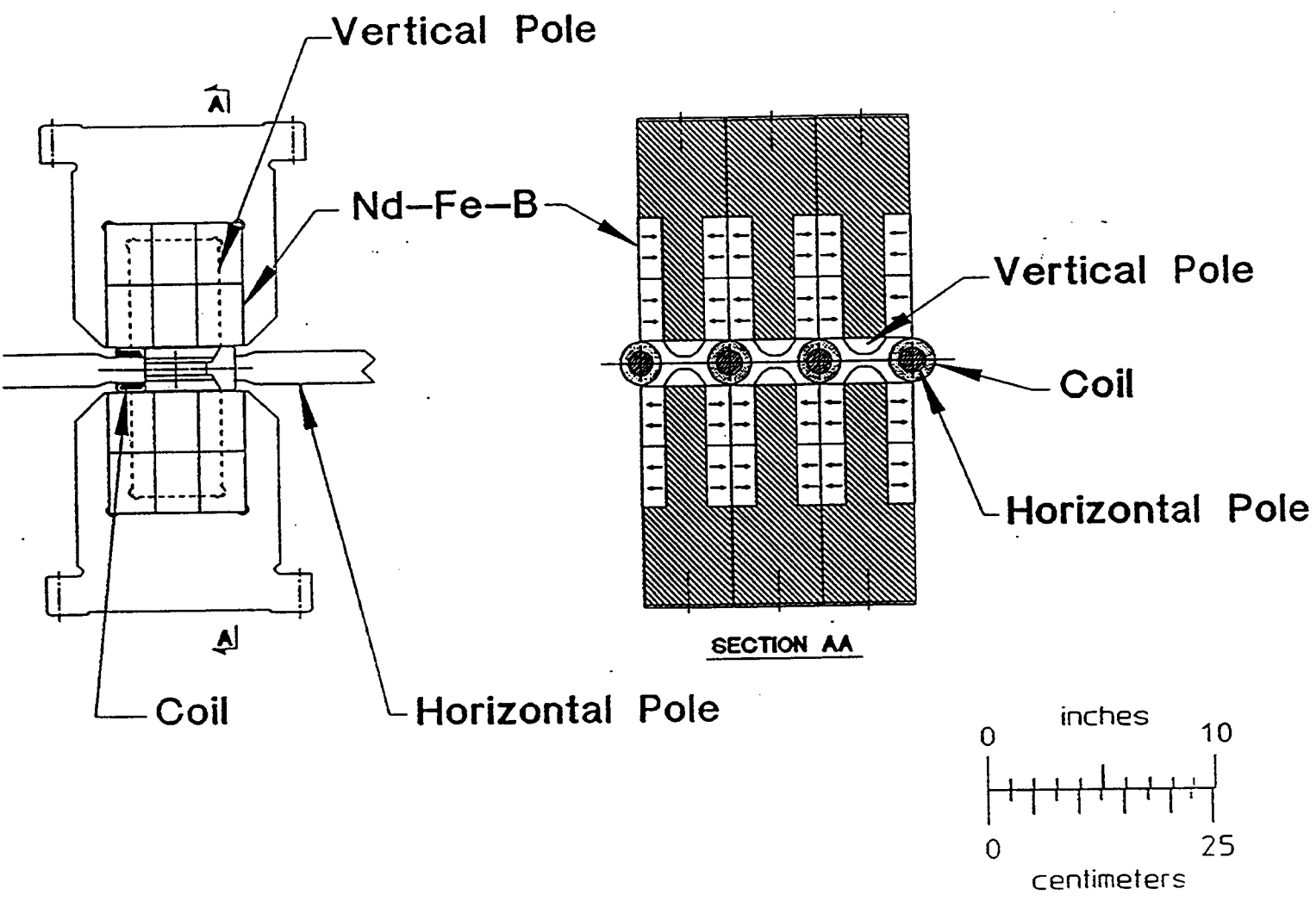


Fig. 4 Elliptical Wiggler Magnetic. Structure Design

vertical magnetic structure are shown in Fig. 4. The design requires that the Nd-Fe-B material be recessed to allow the horizontal magnetic field structure to be brought as close to the vacuum chamber as possible. Vertical magnetic structure parameters are given in Table II.

The basic building block for the periodic vertical magnetic structure is the half-period pole assembly. This unit consists of an aluminum keeper, a pole that is pinned in the keeper and 12 Nd-Fe-B blocks that are bonded to both the pole and keeper. The half-period pole assemblies are in turn mounted on two backing beams and the pole surfaces are aligned to within 25 microns with respect to each other on each backing beam.

The entrance and exit vertical magnetic structures are configured so that the electron beam axis of the periodic motion changes minimally when the magnetic field strength is varied. To achieve this requirement, the normalized pole potential sequence for the entrance structure over the range of gaps is 0 (field clamp), $1/4$, $-3/4$, 1, -1, etc., and reversed in position and sign for the exit structure. The appropriate pole potentials are achieved by modifying the amount of permanent magnet material at the ends and fine tuning with electromagnetic coils.

To achieve the stringent accelerator field specifications, the integrated field integral errors will be minimized by precise alignment of the magnetic structure and by arranging the locations of the permanent magnet blocks such that the effect of the block minor magnetic moments, which produce higher order field components in the beam aperture, is minimized.⁵ Final trimming of the field integrals will be with the end coils to correct the dipole field integral and with multiple trim magnets, installed in the end structures, to correct the higher order field integral errors.⁶

Table II. Vertical Magnetic Structure Parameters

Magnetic Gap	1.4 cm-22.0 cm
Peak Field	2.0 T-0.025 T
Maximum Pole Field	2.23 T
Pole Width	10.0 cm
Pole Thickness	4.6 cm
Pole Height	13.4 cm
Nd-Fe-B Operating Point	0.52

HORIZONTAL MAGNETIC STRUCTURE

The horizontal magnetic structure has the same period length as the vertical magnetic structure but is longitudinally phase shifted $1/4$ period relative to the vertical magnetic structure. To achieve the 0.095 T peak field, the poles and coils of the horizontal magnetic field structure are tucked between the upper and lower vertical magnetic field structures as shown in Fig 4. The magnetic field distribution includes $14\frac{1}{2}$ periods and the ends are modified to achieve the same normalized potential structure as that for the vertical field. At both wiggler ends, the horizontal

structure extends $1/4$ period past the vertical structure so as to avoid linear polarization contamination of the circularly polarized photon beam.

The horizontal structure cores are laminated from 0.64 mm thick M-36 electrical steel and powered by water-cooled electrical coils. A system of struts is used for support and adjustment of the horizontal magnetic structure. Coil excitation is with a bipolar, regulated power supply that will provide a trapezoidal wave form for frequencies from DC up to 1 Hz. Horizontal field parameters are given in Table III.

Table III. Horizontal Magnetic Field Parameters

Peak Horizontal Field	0.0947 T
Peak Pole Flux Density	1.96 T
Conductor	1/8OD x 1/16ID Cu
Number of Turns/Coil	12
Current	500 A
Total Voltage	76.9 V
Total Power	37.5 kW
Total Flowrate	9.1 gpm
Coil Temperature Rise	11.2° C

SUPPORT/DRIVE/CONTROL SYSTEM

The support and drive system is shown in Fig 1. It includes the support structure that provides the framework for holding the magnetic structures and the drive system that opens and closes the vertical magnetic structure gap. The support structure design is similar to the ALS undulator support structures, but has been shortened by about 1 m and widened about 20 cm to accommodate the horizontal structure. Gap motion is achieved with a stepper-motor, gear box and roller chain drive with coupled left-hand and right-hand 2 mm pitch Transrol roller screws that are attached to the upper and lower backing beams. The drive system is identical to the ALS undulator system except that the tolerances on the drive roller screws have been relaxed.

The magnetic gap control system is the standard ALS Insertion Device Control System. It includes a Compumotor system with a Model 500 indexer, Model PK130M motor driver, and a Model ARC absolute rotary encoder.

VACUUM SYSTEM

The elliptical wiggler vacuum chamber is a welded stainless steel assembly that includes a beam chamber, 18 pump-out tubes and a pump tube as shown in Fig. 5.⁷ The beam chamber aperture, with internal dimensions of 1.0 cm by 6.1 cm, is adequate for dynamic aperture requirements. With this beam aperture, a minimum vertical gap of 1.4 cm and a horizontal magnetic gap of 7.2 cm are achievable. The chamber has a rectangular water cooling channel on

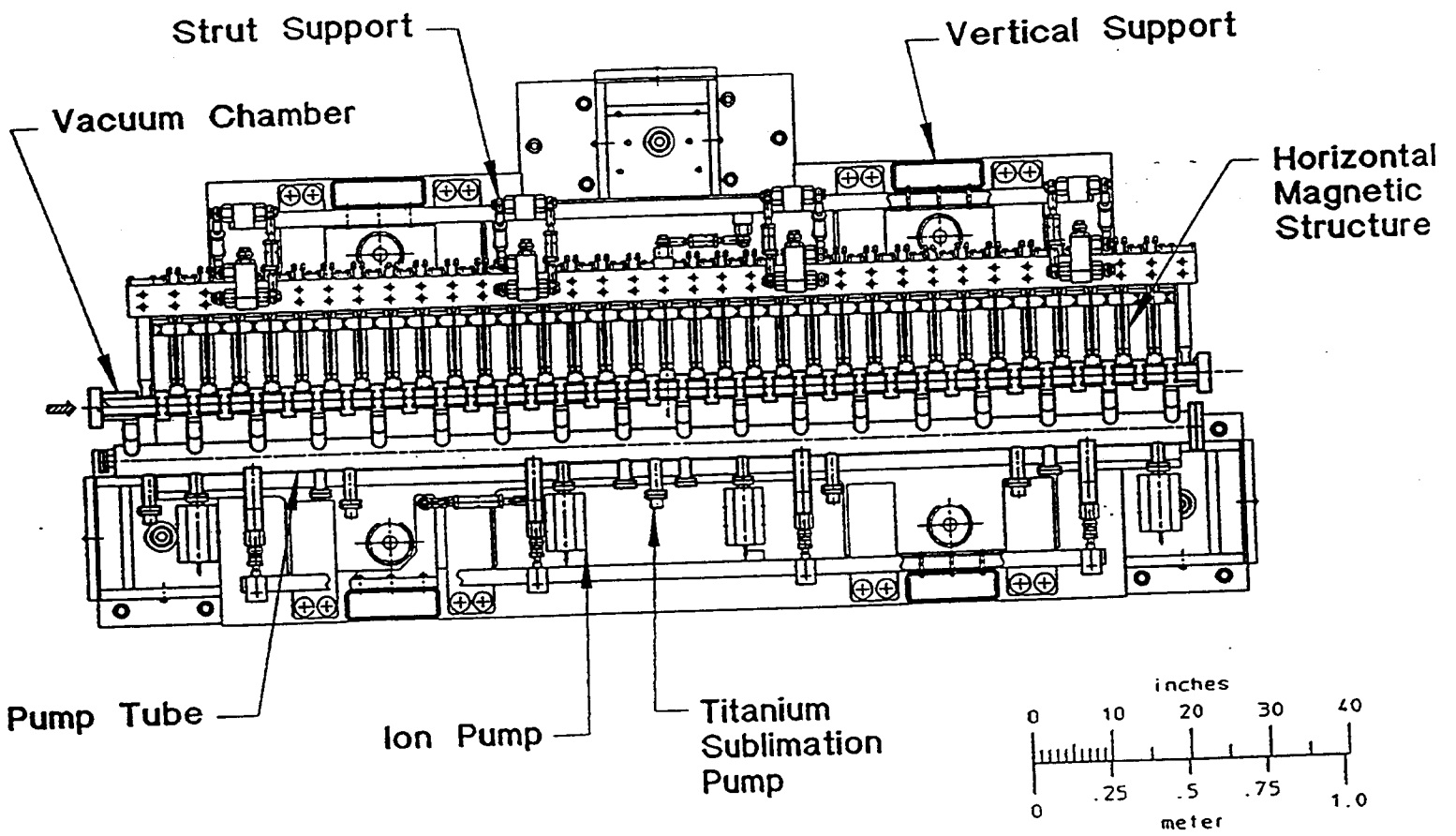


Fig 5. Elliptical Wiggler Plan View

the side where the synchrotron light from the upstream bend magnet strikes; this reduces thermal distortions. Eddy current heating of this chamber at the 1 Hz level is small. With ALS operation at 1.9 GeV and 400 mA, the maximum chamber temperature rise estimate is 4° C.

To achieve good vacuum in the presence of the photon induced desorption, 18 distributed pump-out ports are located along the length of the beam chamber. To further reduce photon induced desorption, a photon stop is located upstream of the chamber to block some of the beam that would otherwise impinge on the chamber. The pump-out ports are connected to the pump tube to which ion pumps and titanium sublimation pumps are attached. The pump-out ports are slotted to provide satisfactory impedance to the electron beam along the length of the beam chamber; these minimally decrease the pumping conductance. The vacuum chamber configuration and the planned installed pumping on the pump tube should provide an average gas pressure of less than 10^{-9} Torr after 40 A hr of beam operation in the ALS.

Supporting and adjusting the vacuum chamber in the elliptical wiggler is accomplished with a system of struts. This arrangement along with the offset pump tube allows the chamber to be lowered in the wiggler and then removed from the device for UHV processing after completion of the magnetic measurements.

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