

# Wigglers at the Advanced Light Source

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## ABSTRACT

Two 3.4 m long wigglers are being designed and constructed at Lawrence Berkeley Laboratory's (LBL) Advanced Light Source (ALS). A 19 period planar wiggler with 16.0 cm period length is designed to provide photons up to 12.4 keV for protein crystallography. This device features a hybrid permanent magnet structure with tapered poles and designed to achieve 2.0 T at a 1.4 cm magnetic gap. An elliptical wiggler is being designed to provide circularly polarized photons in the energy range of 50 eV to 10 keV for magnetic circular dichroism spectroscopy. This device features vertical and horizontal magnetic structures of 14 and 14 1/2 periods respectively of 20 cm period length. The vertical magnetic structure is a 2.0 T hybrid permanent magnet configuration. The horizontal structure is an iron core electromagnetic design, shifted longitudinally 1/4 period with respect to the vertical magnetic structure. A maximum horizontal peak field of 0.1 T at an oscillating frequency up to 1 Hz will be achieved by excitation of the horizontal poles with a trapezoidal current waveform.

## I. INTRODUCTION

The ALS, a third generation synchrotron light source, is now in routine operation with three 4.6 m long undulators. Two of these devices have 5.0 cm period lengths (IDA-U5.0 and IDB-U5.0) and the third device has an 8.0 cm period length (IDC-U8.0), which, at 1.5 GeV ALS operation, produce high brightness in the 50 to 1500 eV and 15 to 1000 eV ranges respectively.[1] A fourth 4.6 m long undulator, with a 10.0 cm period length (IDG-U10.0), is nearing completion and is slated for installation later this year and will produce high brightness radiation, in the 5 to 900 eV range when the ALS operates at 1.5 GeV.[2] Currently, two 3.4 m long wigglers are being designed and constructed. One is a 19 period planar wiggler with 16.0 cm period length (IDD-W16.0) designed to provide photons up to 12.4 keV for protein crystallography.[3] The other is a 14 period, 20 cm period length cross-field elliptical wiggler (IDH-EW20.0) being designed to provide circularly polarized photons in the energy range of 50 eV to 10 keV with chirality switching up to 1 Hz for magnetic circular dichroism spectroscopy.[4] The principal parameters for the wigglers are tabulated in Table I.

## II. W16.0 WIGGLER

The planar wiggler, W16.0 Wiggler, includes a mag-

netic structure, support/drive system, control system and vacuum system and is shown in Fig.1.

Table I Wiggler Parameters

Parameter (units)	W16.0	EW20.0
Min.Vert. Mag. Gap (cm)	1.4	1.4
Horizontal Magnetic Gap (cm)		7.2
Peak Vertical Field (T)	2.0	2.0
Peak Horizontal Field (T)		0.095
Max. Hor. Field Freq. (Hz)		1.0
Period Length (cm)	16.0	20.0
No. of Periods	19	14 V, 14 1/2 H
Entrance/Exit Sequence	0, -1/4, 3/4, -1, 1..	
Vertical End Cor. Range (G-cm)	4000	5000
MTM Range (G-cm)	+/- 3000	+/- 3000

The variable gap, hybrid-permanent magnet magnetic structure design and construction are different from those of the ALS undulators. To achieve the 2.0 T peak field, the design requires that the vanadium permanent poles be tapered in the poletip region in both the longitudinal and transverse directions to reduce saturation. To null the dipole field integral through the device, water cooled coils in the end structures with bipolar power supplies are used. To meet the higher order field integral requirements, in the 1.0 cm by 6.0 cm aperture, block sorting to minimize the effects of the minor components is planned and multiple trim magnets will be used for final tuning.[5,6] The basic building block of the 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, 6 on each side of the pole, that are bonded to both the pole and keeper. The 25 kg half-period pole assemblies, are individually 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 support/drive system, which provides the framework for holding the magnetic structures and the drive system that opens and closes the vertical magnetic structure gap, is very similar to that of the ALS undulators, but shorter. 3.5 m in length and wider, 1.5 m in width. Gap motion is achieved with a stepper-motor/gear box/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 control system, a Compumotor system, is identical to those used on the ALS undulators. The vacuum system is also similar to those of the ALS undulators, but only 3.8 m in length.

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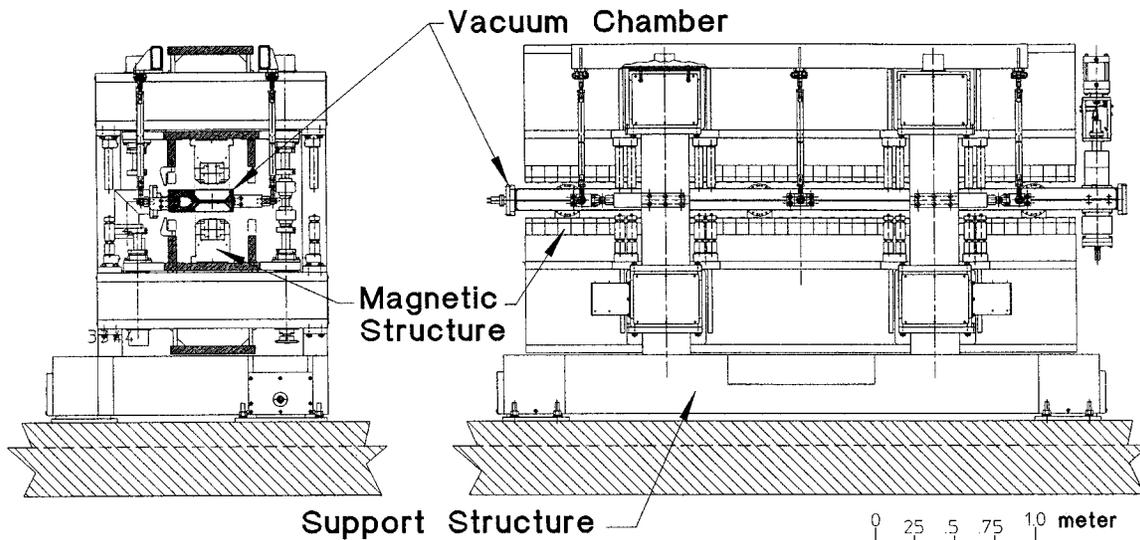


Fig. 1 W16.0 Wiggler end sectional and elevation views

Predicted spectral output of the W16.0 Wiggler, when inserted in the ALS operating at 1.5 and 1.9 GeV - 400 mA, is shown in Figure 2. Design of W16.0 Wiggler is nearly completed and fabrication is well along. Completion is slated for the end of this year.

### III. EW20.0 ELLIPTICAL WIGGLER

The mechanical configuration of the Hybrid-Electromagnet Elliptical Wiggler is shown in Fig. 3. 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. The support structure/drive and control systems are identical to the W16.0 Wiggler. The vacuum chamber configuration features a beam tube with multiple pumping ports that are connected to a pumping chamber.

The vertical magnetic field structure consists of a periodic structure with 14 periods. To achieve the 2.0 T peak field, the vanadium permendur poles are tapered in both the transverse and longitudinal directions near the pole tip. The design requires that the Nd-Fe-B material be retracted from the midplane to allow the horizontal magnetic field structure to be brought as close to the vacuum chamber as possible. The entrance and exit vertical magnetic structures are configured so that the central electron beam orbit is on-axis for all field values. To achieve this, the normalized pole potential sequence for the entrance/exit is 0 (field clamp),  $1/4$ ,  $-3/4$ , 1, -1... The appropriate pole potentials are achieved by modifying the amount of permanent magnet material and adjusting with electromagnetic coils. Except for period length and pole configuration, design and construction of the EW20.0 vertical magnetic structure is very similar to the W16.0 Wiggler.

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. The poles and coils of the horizontal magnetic field structure are tucked between the upper and

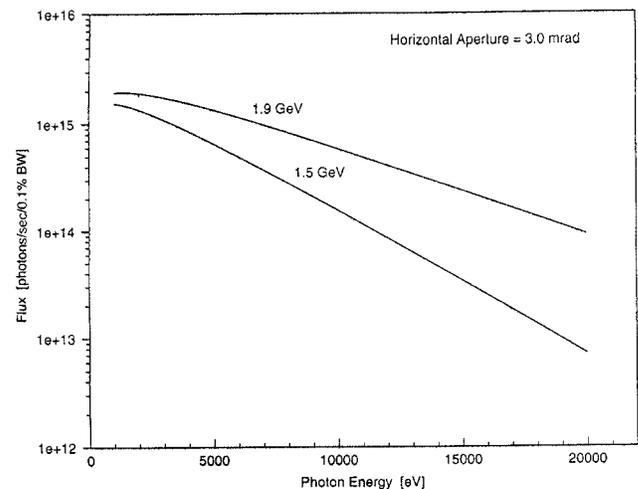


Fig. 2. Estimated flux from W16.0 Wiggler at ALS storage ring energies of 1.5 and 1.9 GeV.

lower vertical magnetic field structures. The magnetic field distribution includes  $14 \frac{1}{2}$  periods and the ends are modified to achieve the same normalized potential structure as those 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. They are powered by water cooled electrical coils. A system of struts are 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.

The elliptical wiggler vacuum chamber is a welded stainless steel assembly that includes a beam chamber, 18 pumpout tubes and a pump tube. 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

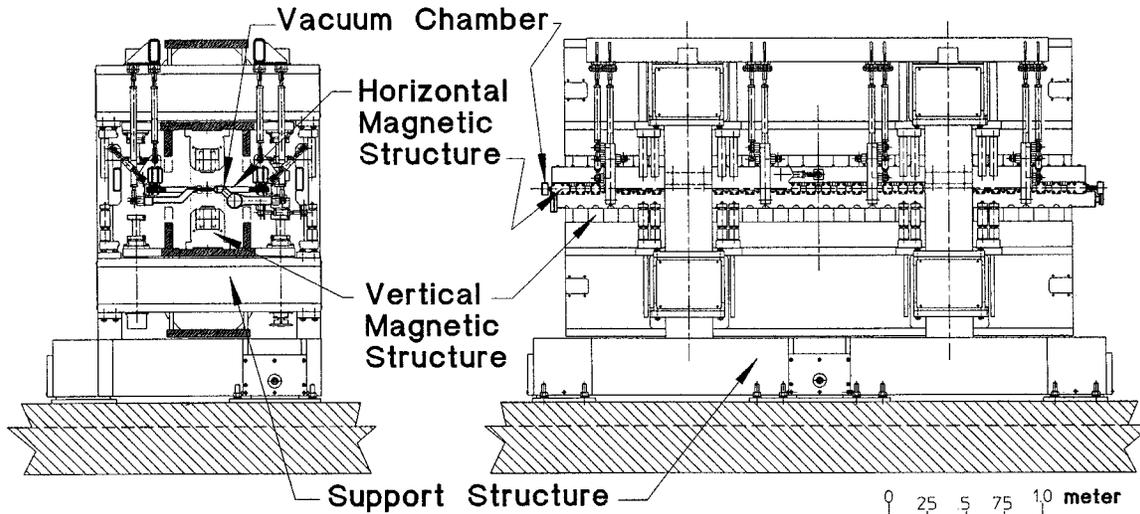


Fig. 3 Side sectional and elevation views of the EW20.0 Elliptical Wiggler

chamber has a rectangular water cooling channel on the side where the synchrotron light from the upstream bend magnet strikes; this reduces thermal distortions. With ALS operation at 1.9 GeV and 400 mA, the maximum chamber temperature rise is 4 °C. To achieve good vacuum, 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. The vacuum chamber configuration and planned pumping 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 allows the chamber-pumptube assembly to be lowered in the wiggler and then removed from the device for UHV processing after completion of the magnetic measurements.

Spectral calculations, shown in Fig. 4, indicate that the device will produce a 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 fan with the ALS operating at 1.5 GeV and 400 mA.[7] Status of the elliptical wiggler is that the conceptual design is complete and design and fabrication has started. The project is currently on hold.

#### IV. REFERENCES

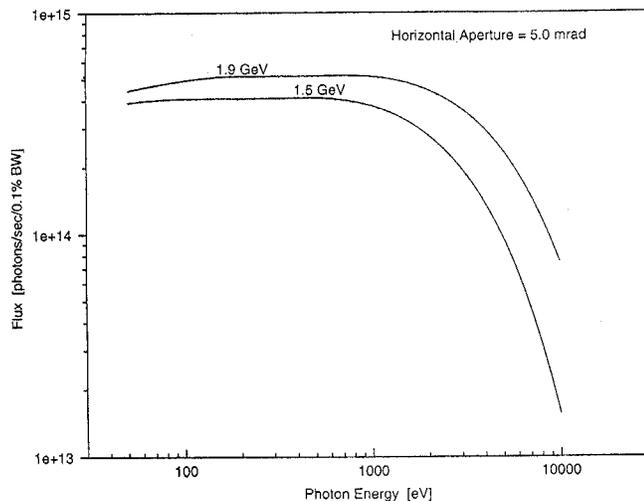


Fig. 4 Polarization figure of merit for the EW20.0 Elliptical Wiggler

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