Development of an Elliptically Polarizing Undulator

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Abstract. The design of pure-permanent magnet Apple-II elliptically polarizing undulators (EPU) is discussed. The design specification for this EPU include; maximum period length 60 mm, maximum length inclusive space needed for the phase change 900 mm, in horizontal phase the fundamental photon energy 11 eV at 21 mm gap, the maximum operating temperature is 35oC. The minimum remanence of the magnet material is 1.27 T. The EPU was designed with correction coils for the horizontal and vertical first and second integrals and the normal and skew quadrupoles as the specified ranges were very small.

There is a 0.4 mm separation between the arrays on the same girder to reduce the drop in field strength at x = 0 in planar phase. In this paper we describe the mechanical design, magnetic design, and data from factory acceptance tests.

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INTRODUCTION

ADC has designed, built, shimmed, and delivered an Elliptical Polarizing Unit (EPU), 900 mm long, with a period of 60 mm for the SRC at the University of Wisconsin, Madison.

The shimming was done using ADC's magnet measurement facility [1].

The EPU was designed to allow for the independent translation of all magnetic arrays along the beam direction. This flexibility enables operating modes providing horizontal and vertical polarization as well as left and right circular polarization.

The variable polarization properties of the new beamline allow experimenters to study symmetry related properties in high Tc materials and other highly correlated electron systems. The tunability between light of opposite circular polarization opens up a completely new era for SRC researchers interested in the magnetic or chiral properties of materials in spin electronics and tailored nano structures. Similar devices have been designed and used at other synchrotron facilities [2].

DESCRIPTION

Pictured below in Figure 1, the EPU has a length of 900 mm, and a depth of 533 mm. Even so, the front correction coils and phase motors must be removed in order to lower the ID unit into place on the ring. Referring to the figure below Items 1 and 2 are the upper and lower girder assemblies, Items 3 and 9 are right angle screw jack assemblies, Item 4 is a welded hard stop, Items 5 and 18 are correction coil assemblies, Item 6 and 7 are a sub-girder assemblies, Item 8 is the strong back frame, Item 10 is a corrector magnet (magic fingers) holder, Item 11 is the control box, Item 15 is a latch for the control panel, and Item 16 is a location plate for a Talyvel electronic level.

The upper and lower girders are controlled by two independent motors allowing offset centerline gap control. Each motor drives two right angle gearboxes coupled to two precision ball screws. Each drive train is provided with a manual harmonic adjuster for independent taper control. The gap range is 15 to 110 mm. Hard stops and high repeatability (<2 um) limit switches were provided.

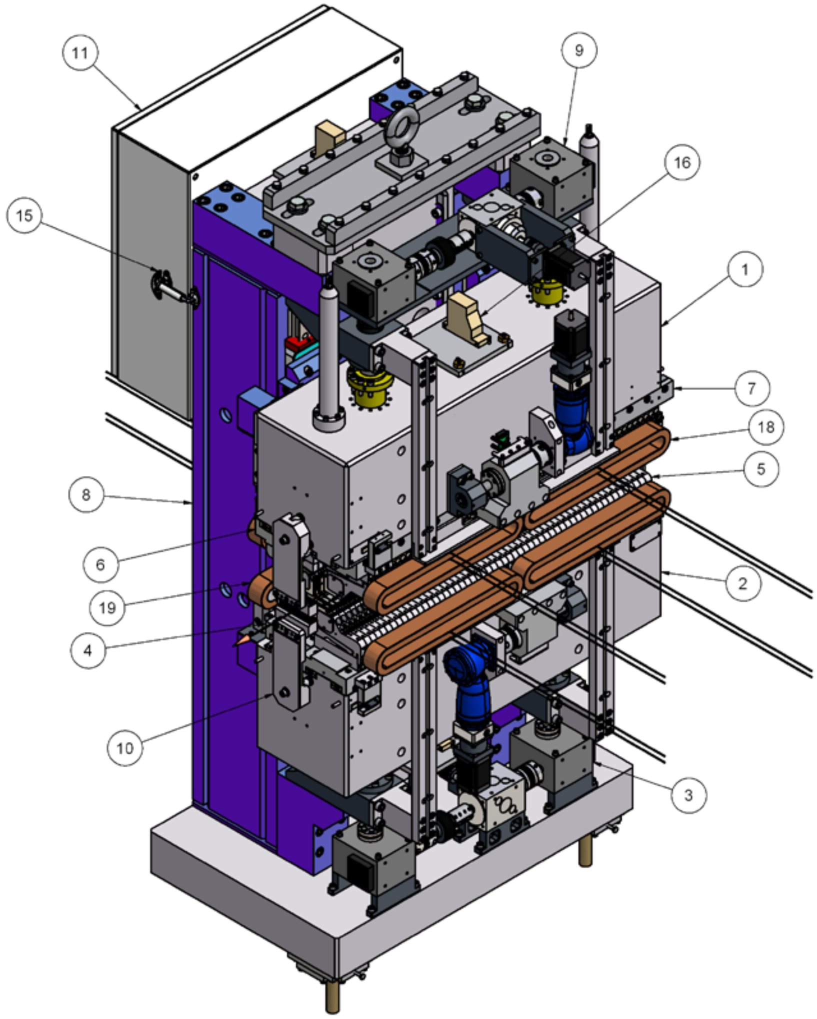

FIGURE 1. SRC EPU Assembly

The four phases are each driven by a separate motor through a right angle gear box with a ball screw that is supported with bearings on both ends. Each phase drive assembly moves one magnet array on a sub-girder. There are two sub-girders, front and back, per main girder assembly. Each phase could travel +/- 30 mm, hard stops and precise limits are provided.

The strong back consists of two tubular box frames with stiffener plates welded to the front and back and then ground flat. The bearing rails for the vertical guidance are bolted to these frames and to the girders. The vertical frames are bolted to the base and top and to two thick aluminum spacers between them.

The corrector magnets are held in a special holder that is attached to the girders using three balls mounted to the girders and three “V” grooves in the magnet assembly. These are held to the girder by a single bolt and bevel washer spring stack. This combination provides extremely precise repositioning of the magnet assembly which must be removed fairly often for tests and magnet field adjustment.

The motor controls were provided completely assembled and debugged by SRC. These are directly mounted to the back of the frame because of the relatively low beam energy at SRC.

The correction coils consist of 8 short coils that were wound on a mandrel and potted in epoxy. These correction coils are driven by 8 bi-directional, 200 watt, Kepco power supplies. The coils are all wired separately; however, they are used in combinations to create long coil as well as short coil effects. A special look up table shown below in Table 1, was devised to produce 6 corrective effects: vertical (Task 1) and horizontal (2) integral, normal (3) and skew (4) quadrupole, vertical second (5) and horizontal second (6) integral.

TABLE 1. The Power Supply Polarities for the Different Tasks.

Task	*A1*	*B1*	*C1*	*D1*	*A2*	*B2*	*C2*	*D2*
1	+	-	-	+	+	-	-	+
2	-	-	-	-	-	-	-	-
3	-	-	+	+	-	-	+	+
4	-	+	-	+	-	+	-	+
5	+	-	-	+	-	+	+	-
6	-	-	-	-	+	+	+	+

This correction coil arrangement proved quite successful but did run the risk of heating the coils to 50 C at 5 amps per coil. The skew quadrupole was impacted somewhat by the close proximity of permeable material in the frame. This was overcome by shimming the skew quadrupole closer to spec. A photo of the outer correction coils, girders, and corrector magnets is provided below in Figure 2.

FIGURE 2: Correction Coil Mounting

Magnet Material

The magnet material chosen was Vakuumschmelze VACODYM 776 TP. This material has a minimum remanence of 1.28T and a maximum of 1.32T. The minimum coercivity is 21 kOe, and the temperature coefficient is -0.61 % per degree C. The magnets had an aluminum nitride coating.

Thermal tests on the material showed a modest decrease in remanence over 45 degrees C.

Phase Angle

The phase angle was specified to be equal to or under 2 degrees in all modes and gaps equal to or above the nominal gap of 20.5 mm. The machine was shimmed so that this was accomplished without correction coils at the nominal gap.

The phase angle was well under spec in the HP and VP+ mode but just at spec or slightly over for VP- mode at all gaps. Phase angle for a low energy (.8 Gev) beam is more difficult to achieve because the electrons lack the kinetic energy of higher energy beams and are therefore more influenced by multipoles.

Gaps

The gaps required for testing, were derived from the Kx and Ky values specified for this machine. The gaps are shown below in Table 2.

TABLE 2: Kx and Ky Gaps

HP Mode		**VP+ Mode**	
Ky	**Gap**	**Kx**	**Gap**
4.079	20.5	2.544	20.5
3.653	22.6	2.286	21.99
3.175	25.26	1.996	23.89
2.609	28.98	1.655	26.58
1.877	35.21	1.222	31.07
0.502	60	0.053	44.5

Multipoles

The multipoles are important on an EPU and in particular the skew quadrupole spec was tight due to the beam coupling at SRC. The correction coils were needed for some correction at all but the nominal gap. This machine also has a strong sextapole which is corrected nearly within spec with corrector magnets. Refer to Table 3 below.

TABLE 3: Multipoles By Gap

Mode	Units	Spec	Correction amps	17.00 HP	Correction amps	20.50 HP	Correction amps	25.26 HP	Correction amps	60.00 HP
ND1	Gcm	50	**0.11**	**-30.9**		**-40.6**		**-33.2**		**-28.4**
ND2	Gcm^2	7500	**-0.12**	**7503**		**6176**		**6034**	**-0.49**	**3380**
SD1	Gcm	15		**-2.4**		**13.2**	**0.04**	**4.8**	**-0.08**	**8.6**
SD2	Gcm^2	2500		**-2105**		**425**		**-542**		**-646**
SQ	G	5	**-0.71**	**-5.5**		**-8.1**	**-0.48**	**-5.4**	**-1.76**	**-3.8**
NQ	G	25		**-8.7**		**-13.2**		**-9.9**		**-7.4**
Phase Angle	Degrees	2		**1.607**		**1.963**		**1.632**		**na**
NS	G/cm	20		**37.1**		**17.1**		**4.5**		**0.9**
SS	G/cm	20		**73.6**		**21.8**		**0.4**		**-0.4**
NO	G/cm2	25		**-19.4**		**-3.8**		**2.2**		**10.6**
SO	G/cm2	25		**47.8**		**25.4**		**0.9**		**7.0**

Mode	Units	Spec	Correction amps	17.00 VP+	Correction amps	20.50 VP+	Correction amps	23.89 VP+	Correction amps	44.50 VP+
ND1	Gcm	50	**0.22**	**-45.5**		**-33.5**	**0.11**	**-34.6**		**-36.4**
ND2	Gcm^2	7500		**8351**		**6799**		**6855**		**5326**
SD1	Gcm	15		**15.2**		**13.7**	**0.06**	**9.3**	**0.01**	**-2.3**
SD2	Gcm^2	2500		**-1293**		**-819**		**-974**		**-1682**
SQ	G	5	**-1.58**	**-34.8**		**-10.3**	**-0.50**	**-5.2**	**-1.58**	**-1.1**
NQ	G	25	**-1.32**	**-48.7**		**-17.9**	**-0.54**	**-20.1**		**-10.4**
Phase Angle	Degrees	2		**1.493**		**1.384**		**1.308**		**1.499**
NS	G/cm	20		**52.5**		**15.7**		**17.9**		**3.2**
SS	G/cm	20		**23.9**		**-3.9**		**-10.4**		**-0.9**
NO	G/cm2	25		**0.6**		**14.6**		**9.6**		**-12.6**
SO	G/cm2	25		**168.8**		**24.1**		**10.3**		**-5.3**

CONCLUSION

Despite some last minute problems with the magnet transverse gap, the machine met spec and was installed in the SRC ring in April of 2009.

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