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TEST OF SHORT PERIOD SC UNDULATOR*

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Mikhailichenko#, Cornell University, LEPP, Ithaca, NY 1485, U.S.A.

Abstract

We represent the design details of a 4-m long undulator in cryostat having a period ~12mm and aperture ~6.35 mm allowing K~1.0. This undulator can be used in ILC positron conversion system as well as the insertion device for developing FEL systems.

INTRODUCTION

Helical undulator is a part of ILC positron source [1]. Helical magnetic field created by a stationary magnetic field or by electromagnetic wave, forces primary particles (electrons or positrons) to develop tiny helixes. So called Undulator Radiation (UR) is generated in this case, when the energy of photons is much less than the energy of the primary beam. UR used for further conversion into polarized positrons/electrons in a thin target (convertor). Peculiarity is in fact that UR, generated in helical field, creates secondary positrons/electrons with longitudinal polarization, which is higher for the particles having higher energy.

Laser bust can be treated as a kind of undulator, while the energy of secondary photons (gammas) remains less than the energy of the primary electron/positron beam. This analogy manifests itself in full, when the laser radiation illuminates the particles from the side with an incident angle of 90^o. The concept of positron production with the help of polarized gammas, obtained from appropriately chosen undulator, electromagnetic waves and laser radiation (as a specific example of electromagnetic radiation) was originated a while ago [2], [3]. Recently, polarized positron generation with the help of a scaled 1m-long undulator was confirmed; 80% polarization was measured and the yield was found in agreement with calculations [4]. Earlier, polarized photon production with help of laser radiation and further conversion in polarized positrons was also confirmed in [5]. In our previous presentations [6], [7] we reported about development of undulator for ILC collider at Cornell. The works for development of helical undulator are going in UK as well [8]. General conclusion is that helical undulator for ILC is feasible, parameters achieved and just some optimization of size of cryostat and cost required.

The general direction of development at Cornell was associated with the development of technology by fabricating short (~40 cm-long) samples of helical SC undulators. These short samples, beside their short length, were long enough indeed to test different type of tapering at the ends as well as investigate different types of wire. Saying ahead we come to multi-wire strand conductor and smooth transition from an iron helix yoke to a Brass one at the distance of one undulator period (10-13.5 mm).

As all activity in SC undulator is on hold at the moment we are using this opportunity to summarize our achievements, so this work could be restarted easily.

HELICAL UNDULATOR WITH SC WINDINGS

Although this type of undulator was tested successfully in 1986 [9], latest efforts were associated with the development of the best technology for fabrication was restarted at Cornell in 2000. In some times this work was carried in parallel with the fabrication of a pulsed helical undulator with room temperature single wire Copper conductor; this undulator was used in E-166 experiment at SLAC [4].

Bi-helical iron yoke made from soft steel 1008 on special winding machine, typically used in industry for winding springs. These two iron helixes have a cross section with the thickness along the longitudinal coordinate being ~2mm and ~6mm high, are tightly settled on thin –wall copper tube. Oxygen-free copper (OFC) tubing with RF quality smooth inner diameter is used for these purposes. So, two helical groves between two iron helixes are filled with multilayer SC coil. For winding we used a few types of wires. We came to the conclusion finally, that the mostly progressive way to form the coil is to make it with two separate flat strands, carrying four (for 10mm period) or six(for 12mm period) wires jointed with Formwar enamel. These strands are wound simultaneously; each pair of strand goes to the neighboring grove after turning around the opposite yoke helix, so dipole symmetry is kept at fringe region also. AS this technology required multiple joints of SC wires, we made some investigation for determination of minimal length of joint. We made rather long tight twisted joint of ~20 mm long and tested in Dewar for determination of critical current. After critical current was reached, SC conductor quenched. Right after that, the current loop (see Fig.1, left), quickly removed from Dewar ant joint and was cut a couple mm and immersed in Dewar again for measurements of critical current. This procedure was repeated a few times until we reached common jointed length ~3mm. After test with this 3mm-long joint the wire typically breaks (like a fuse), see fig.1, right.

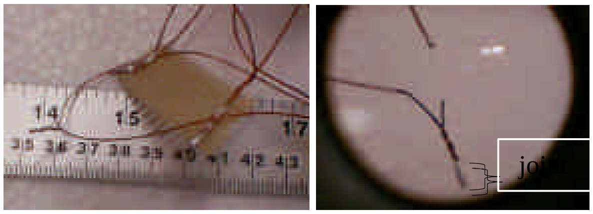

Figure 1: To the determination of shortest allowed length of SC wire joint.

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#mikhail@lepp.cornell.edu

So finally we came to conclusion that 5mm twisted wire, soldered with Indium (or Lead) is enough for our purposes. In next series of measurements we investigated the total resistance of joints by excitation of current in a closed loop, and by measurement of decay time of current. Excitation of current in closed loop was done with SC transformer technique, used earlier in [9] (see references there). Resistance measured to be $<10^{-10}$ Ohm. Wounded coil looks pretty uniform, see Fig.2.

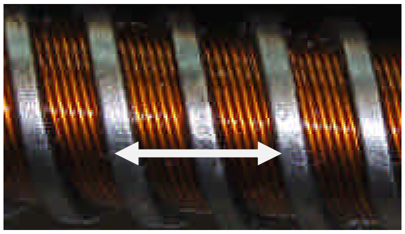

Figure 2: Magnified view of the yoke and windings in regular part. Windings are made directly to the thin-wall OFC tube. Period of undulator, marked by arrow, is 10mm. Inner diameter of Copper tube is 8mm.

ELEMENTS OF CRYOSTAT

As the OFC tube serves as vacuum chamber from the side of beam, the vacuum is not a problem here. The wall of the tube is RF quality smooth. Total diameter of cold mass sealed is 1.5 inches (38.1mm). We developed design of Iron yoke and holding collars fit within Ø1in (25.4mm), so in future we could use it. Diameter of cryostat in regular part of Fig.3 is 4in (101.6mm). Inner Copper tube at the exit of cold mass, welded to a Stainless Steel brace which could be joint to the analogous one with the help of a copper gasket. There is no mentionable jump in diameter after the gasket deformed for vacuum sealing, although this gasket separates two vacuumed volumes-the vacuum volume of cryostat and inner vacuum of undulator.

A lot of effort was applied to make smooth transition from Helium temperature cold mass to room-temperature flanges. We have chosen a transition as a thin-wall Stainless Steel tube connected to the transition bracket by welding, see Fig. 4.

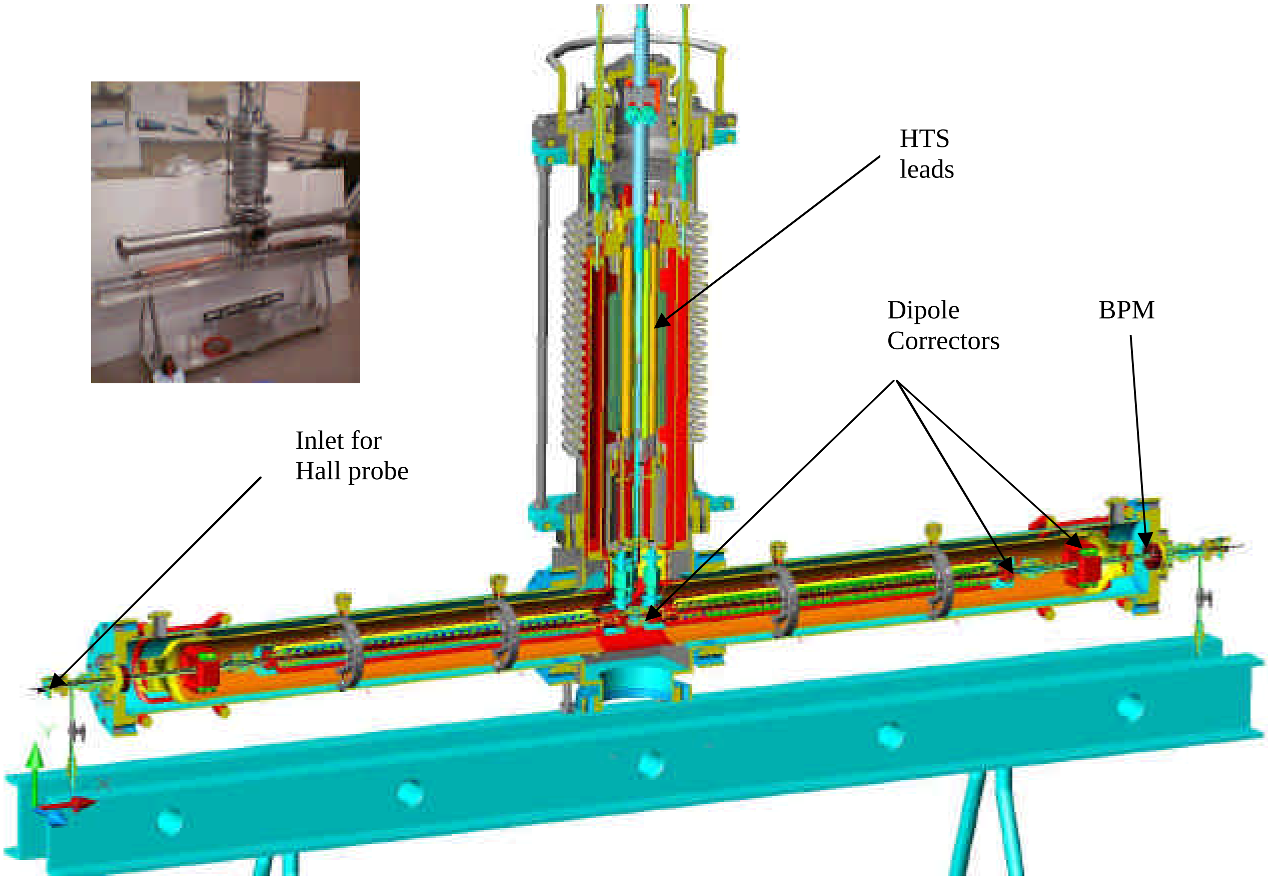

Figure 3: Cross section of cryostat. Vertical addition serves as housing for the input of currents.

This stainless steel transition tube will be coved from the inside with a few micrometer thick layer of Gold for better electrical conductivity. At some distance apart from cold mass this transition tube will have thermal contact with 70^{o}K shield. Design of supporting elements allows controllable shrincage of all elements while cooling from room temperature down to $4.2\,^{o}$K . The cryostat is shown in Fig.3 with additional insertion for magnetic measurements with Hall probe. This insertion is a coaxial tubing system with vacuumed insulation between tubes. So this transition delivers maximal possible smoothness.

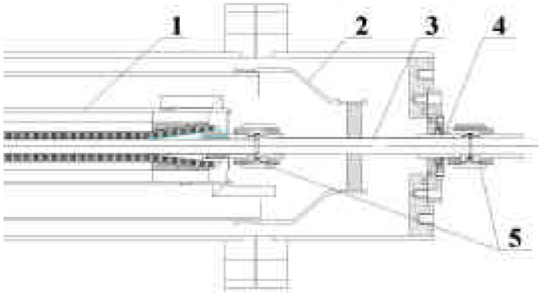

Figure 4: Schematics of transition region between cold mass and the room temperature flange in Cornell undulator. 1—cold mass, 70 ^{o}K shield, 3—StSteel thin wall tube, 4—Wilson type sealant, 5—Conflat® joints.

Figure 5: Cold mass, transition to the room temperature flange, part of 70 ^{o}K shield.

Correction elements include trim coils allows for generating dipole field in two rectangular directions located at the ends of each module and between two sections in between. Trim elements located inside cold mass will be realized as compact magnets with SC coils.

MEASURED MODELS

A few models ~40 long were manufactured and tested; results are summarized in Table 1 below. These models have Ø8mm inner diameter.

Table 1. Results of tests of five models.

SC Wire	54 filam.	56 filam.	56 filam.
#Layers	5	6	11
l =10mm	K=0.36	K=0.42	K=0.467
l =12mm	K=0.72	K=0.83	K=1 (calculated)

Results of test one model fabricated with ¼ in tube represented in Table 2. Period of 13.5 is 1.5mm bigger *than* the biggest period with 8 mm tube. That was moved with the desire to cover all possible range of periods, as utilization of undulator with higher energy beam (ILC possible upgrade range). Finally we acquired experience in fabrication of solid single piece-wise helical yoke of length up to 3 meters long for 8 and 6.35 mm tubes.

Technology at hand allows manufacturing SC helical undulators with practically with any period and aperture.

Table 2. Result of test and calculation for undulator with 6.35 mm tube.

SC Wire	56 filam.
#Layers	12
l =10mm	K=0.7 (calculated)
l =13.5mm	K=1.48 (measured)

The coil for this model is wound with a two-strand conductor sheets having six wires bonded flat in each strand.

We can recommend this model for usage in broad variety FELs.

CONCLUSIONS

Although according to our calculations a low K factor is possible; K<0.4 with period 10 mm (Li lens) we applied some efforts to make undulator with highest K ~1. For this we switched OFC tube from 8mm to 6.35 inner diameters.

Helical iron yokes of ~3 m long obtained from industry; Reached K=0.467 for 10 mm period, aperture 8 mm. Reached K=0.83 for 12 mm period, aperture 8 mm (old wire). Reached K=1.48 for 13.5 mm period, aperture 6.35mm (¼”). Pumping of Helium down to ~10mm Hg was tested also delivering gain ~10%;

In conclusion Author thanks W.Trask for his help in assembling undulators.

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