TEST OF SC UNDULATOR FOR ILC

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Abstract

We represent details of design and results of test SC 40-cm long undulators having period 10 and 12 mm and aperture ~8 mm allowing K=1. These undulators can be used in ILC positron conversion system.

INTRODUCTION

High energy electron–positron collisions are essential for understanding the fundamental properties of matter. In pursuit of this understanding, the world physics community has put the International Linear Collider (ILC) project forward as the next instrument of choice. Although the basic idea of such collider is rather simple, the technology is challenging. One of the challenges is the production of positrons sufficient for the required luminosity. A new approach [1] that is not possible at the energies of previous e^+e^- colliders has been adopted for the Baseline Concept Design (BCD) and involves a short period helical undulator as its essential component. In [1], the helical fields obtained with electromagnetic waves, crystals with helical dislocations and ordinary static fields were considered. The static helical fields were found the mostly practical way to realize such undulator.

SC undulator with period 10 mm, aperture $\cong 6$mm, $K \cong 0.6$ was tested successfully many years ago in a framework of VLEPP activity [2]. This publication is further development of this activity [3] in a framework of ILC collider. Activity in Cornell is covering the modeling of fringe fields, fabrication and test of prototypes and modeling technology. Aperture clean for the beam will be 8mm. Here we are describing some parameters of undulators with periods 10 and 12 mm and aperture 8 mm. Calculations done for the best polarization required $K^2 \cong 0.1$ and the length of undulator 200m. For these conditions polarization reaches ~70% and the number of positrons after capturing is 1.5 per initial particle for the length of undulator 200m and a single target.

One major task was identification of largest possible aperture of undulator possible. As we just mentioned there is no problem with fabrication of undulator with aperture 6 mm. We decided to investigate, probably highest limit for aperture allowed by given period.

GENERAL CONSIDERATIONS

Vacuum chamber made from Oxygen-free Copper. So the vacuum is not a problem here. Perturbation of emittance in undulator is a key issue and calculations are rechecked. Simulation of different entrance tapering is under progress. Restoration of “start to finish” simulation code is under progress. It was written for Li lens as a focusing element now it is added to be able to use focusing with solenoidal lens.

Fringe field compensation is the mostly important item for the scheme, as the undulator installed before IP. Methods of compensation include proper tapering (see Figs. 3,4,8,9 below) and installation of sections in series with alternative polarities.

Test of module with beam at low energy will be done at Cornell.

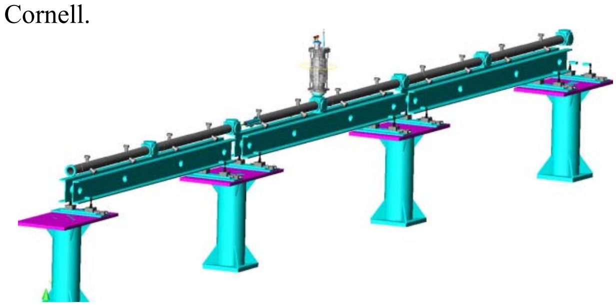

Figure 1: Sections of cryomodules, each 2x3-m long, installed in series.

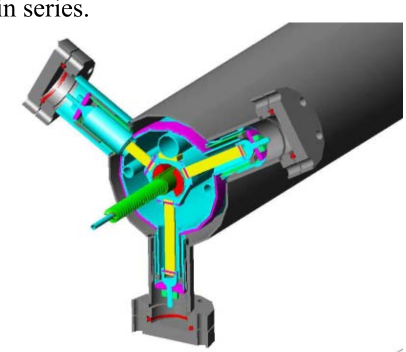

Figure 2: Details of cold mass support. Outer tube diameter is 5 inch.

Perturbation of emittance is a crucial moment of all method, if undulator installed before IP [11]. ~3 m–long sections with the same spatial orientation of input ends installed in series and feed with opposite polarity. This automatically delivers first integral $I^1_{x,y} = \int_{-\infty}^{+\infty} H_{x,y}(s)ds = 0$.

This integral is responsible for transverse kick, as $x' = I^1_x/(HR),\ y' = I^1_y/(HR)$. So the 6m—long module delivers zero kick. To eliminate displacement, two 6 m–long modules need to be fed with opposite polarity. This will bring second integral to zero $I^{(2)}_{x,y} = \int_{-\infty}^{+\infty} d\sigma \int_{-\infty}^{\sigma} H_{x,y}(s)ds$

So two 6 m –long sections deliver zero first and second integral. Resistive wall instability in Copper chamber is cooled to LHe temperature for the beam moving in vacuum chamber was considered and no problems were found here [3].

Correction elements include trim coils allowing generating dipole field in two rectangular directions located at the ends of each module. Natural realization of these trim magnets as having superconducting wiring and integrating into cryo-system.

Lower-impedance pickups are two types: one is a differential type located in short cavity covered by thin stainless steel foil and the second one located *outside* of perforated tube serve as a continuation of vacuum chamber in joint . These perforations made for the purposes of vacuum pumping.

We are considering few scenarios for tuning the undulator during installation. In one scenario the operation begins with ballistic passage of beam through un-powered undulator. During this passage the beam positions at pickup stations collected and processed. Then undulator is powered on and the trajectory measured again. On the basis of these measurements the commands are given to specific correctors to adjust the trajectory. Sections of undulator will be adjusted in positions with the help of remote movers with moderated resolution. Correctors are realized as additional windings in quadrupoles. Panofsky-Hand type of lens looks mostly suitable for these purposes. This allows avoid organizing mechanical movement of lenses.

With aperture 8 mm the wall heating as a result of irradiation at big angles by beam becomes negligible.

MODELING OF SC UNDULATOR

As far as engineering issues, we have fabricated and tested 36-cm long regular part, 1 and 1.2 cm period undulators having aperture 8mm and wound with NbTi 0.6 mm in diameter bare wire. With Formvar insulation the diameter comes to 0.635mm in diameter (25mils). Iron helixes are slightly trapezoidal to accommodate wires as the pinch angle is changing while radius of winding is changing.

New ones will be manufactured with Nb_3Sn wire also having diameter 0.6mm bare. Oxigen free Copper tube with inner diameter 0.8 mm serve as a vacuum chamber.

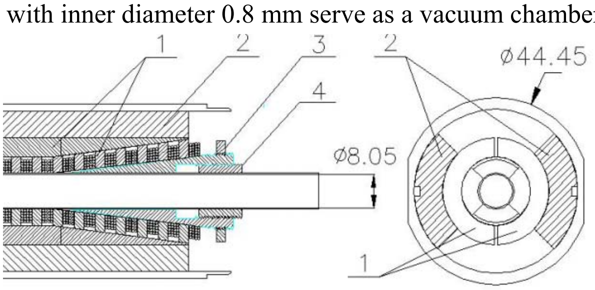

Figure 3: Details of design. 1–Iron yoke, 2–Copper collar, 3, 4–trimming Iron nuts. Inner diameter of Copper vacuum chamber is 8mm.

Special attention paid for spatial orientation of opposing ends of undulator. Orientation done allows zero first integral over section of undulator.

Period, mm	10	12
Aperture, mm	8	8
K factor	0.36	~1.0
# wires	4x5	6x6
# coil sections	2(3)	3
Yoke length, cm	46	46

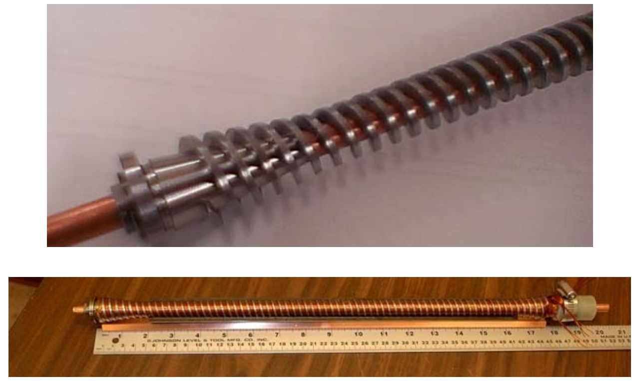

Figure 4: Yoke of undulator having period of 12 mm and aperture 8mm, upper picture. Period controlled with steel balls. Undulator coil completed, picture below.

Figure 5**:** Undulator cold mass installed into Dewar vertically for measurements with Hall probe. Undulators with 10 and 12-mm period look identically. Stick at the right is a liquid Helium level meter. Hall probe holder is running through central hole.

Coil is sectioned with possibility for independent supply of sections for the field enhancement, see Fig 6 below. Calculations show, that enhancement can reach ~30% with proper current distribution. In current version of 10mm-period undulator the coli has two sections however. Undulator with 12 mm period has three sections. In a future we are planning to make 10mm-period undulator with three sections too. Utilization of few coils allows having K factor 10-20% bigger, than with homogenous feeding.

Longitudinal field distribution is represented in Figs.7-9. Some non-uniformity explained by accuracy of fabrication, namely by shift of iron helix outer diameter from one period to another. We found the way on how to control it. In future manufacturing this will be included in technological process.

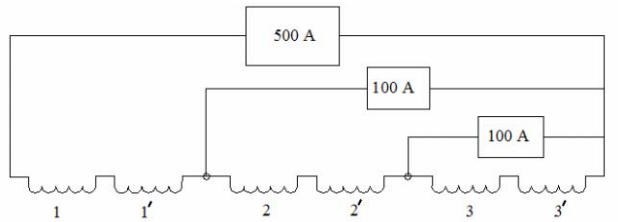

Figure 6: Electrical scheme of feeding the undulator windings. In 12mm-period undulator coils 1 and 1′ are located closer to the Iron helix, coils 2 and 2′ are the next, 3 and 3′ are in the middle of coil (Indicated current is approximate).

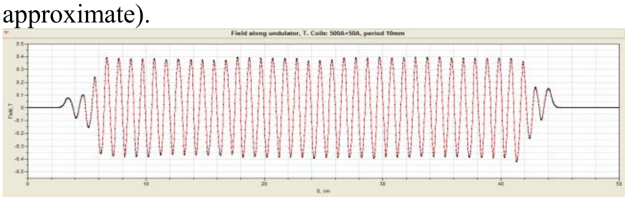

Figure 7: Longitudinal field profile for 10-mm period undulator measured with Hall probe. Current in main PS 500A, additional PS running at 50A. K=0.36 in regular part. Variation of field is picks is from 0.399T to 0.309 T.

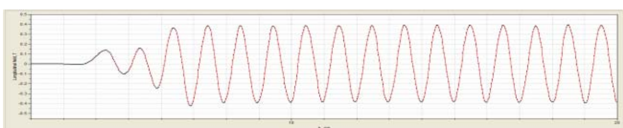

Figure 8: Field profile at the entrance of free end. Current in main PS is 500A, in additional-60A. 10mm period.

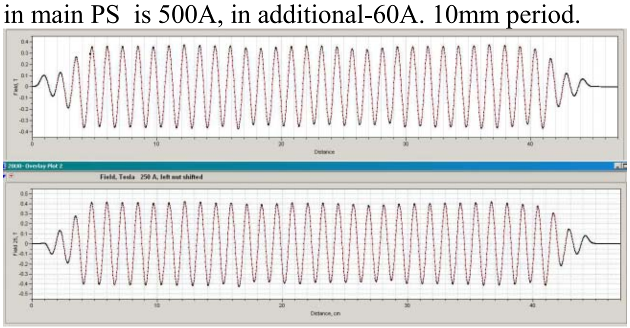

Figure 9: Longitudinal field distribution for 12 mm period undulator at 200 A and 250A. Here the let nut shifted inside undulator (graph below). One can see the difference at the left.

Tapering of undulator realized with 1/10, 3/10, 5/10, 7/10, 9/10, 1. This allows zero displacement of trajectory in undulator [10]. The first and the second integrals for two different orientations of Hall probe were measured. Typical value of first integral for 10mm period model is I_{1x}~0.02, I_{1y}~2 T-cm and for the second is $I_{2x,y}$ ~2T-cm^2. For 10 mm undulator it was not possible to tune the Iron nuts, so the tuning was not done. Dividing coil was not optimal for undulators too. In a future we are planning to test another division of windings, which will allow higher field.

Unfortunately the coil of 12mm-period undulator was grounded, so the PS did not allow operation above 250A. We are planning to rewind the undulator soon after the Conference.

CONCLUSIONS

Fabricated and tested helical undulators with free aperture 8 mm, period 10mm, K=0.36 and 12mm period in agreement with calculations. Developed technology allows practically infinite length of unit section of undulator, however length ~3m found mostly suitable for handling. So the total length of module comes to ~2×3 meters. Developed winding machine allows winding of such undulator. Tapering in fractions +1/10, -3/10, +5/10, -7/10, +9/10, -1 found to be adequate to the problem. Identified all difficult places and found solution to all problems associated with wounding and tuning of undulators. Undulator with smaller aperture, say 7 mm allow to have the field exponentially higher, we however conclude, that better to have a bit longer undulator, 150-200m, to compensated reduced photon flux, than use, lower aperture 7-mm aperture.

Utilization of sectioned coil found to be useful and practical. Tuning by magnetic nuts proved to be successful.

In conclusion Authors thanks W.Trask for help in assembling of undulators. Work supported by NSF.

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