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First Test of a Short Period Helical SC Undulator Prototype

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INTRODUCTION

Polarized positrons give extremely useful tool for high-energy physics at future Linear Collider. Suggested many years ago two stage method for polarized positrons production includes generation of circularly polarized high energy gammas at first stage and further theirs conversion into positrons in thing target[1] at second stage [1]. Polarization with this method can reach 65-70% with ~100 m long undulator.

An undulator with superconducting coils having period of 1 cm, 30 cm long with 6mm aperture clearance, was successfully tested in a framework of VLEPP linear collider activity many years ago [2,3]. Field of ~0.5 T was measured at the axis. The design was recommended for future LC application practically without any changes required.

New growing interest to this subject was indicated at last LC02 [4,5]. It was stressed there, that test of ~1m long short period (1-2.4mm) undulator is a good step towards future LC positron production scheme. Existing emittance of the SLAC's beam makes 2.4 mm period more realistic, however. In fact, the 50 GeV beam generates in undulator with 2.4mm period the quantas energetic enough (~10MeV) for effective positron production and further analyses.

UNDULATOR FABRICATION

To see if the technology previously tested can be scaled down to a shorter period required for test at SLAC, we fabricated a ~six inches long model prototype with period 2.42 mm having all peculiarities of full length one.

We used here the stainless steel tube of 1.5 mm in diameter with the wall thickness of 0.3 mm as a vacuum chamber. This tube was in hand at the moment. In a future the tube of gage size 19 with nominal OD 0.042" (1.0668 mm) will be used. This tube has the wall thickness of 0.0035" (0.0889mm) [2]. This tube allows the ID diameter 0.889 mm available for the beam. Brass, StSt or copper tube with this diameter is available at the market.

SLAC 50 GeV beam has emittance $\gamma\varepsilon \cong 3\times10^{-3}\,\mathrm{cm\cdot rad}$, which allows for the envelope function in crossover $\beta_0 \cong 300\mathrm{cm}$ (~twice the undulator length) to have the beam size $\sigma \cong \sqrt{(\gamma\varepsilon)\beta_0/\gamma} \cong 3\times10^{-3}\,\mathrm{cm}$. Half aperture required for ten sigma margins goes to $\cong 10\sigma \cong 0.3\mathrm{mm}$ only, or 0.6 mm for full aperture clearance, slightly (~11%) expanding toward the ends, what is much within the tube ID.

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[1] In terms of radiation length ~0.5X_o

[2] New England Small Tube Catalog, tube GS#19, XTW.

Despite the tube we used is slightly different in diameter of what will be used in final design, all-important elements are the same.

The goals of this work were to see if technology can be useful for scaling down all dimensions and to investigate if any sign of degradation of the wire is present, as the bending radius is small.

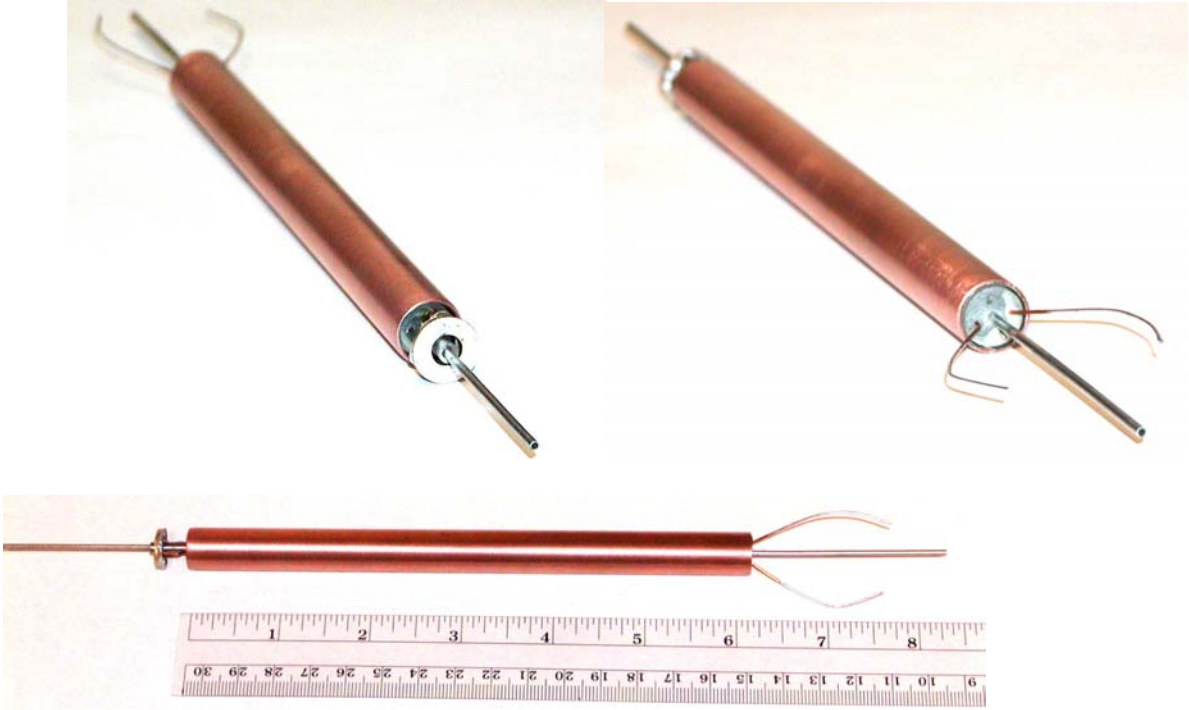

FIGURE 1: SC undulator model. One end of undulator has iron shield for proper tapering of magnetic field. Copper jacket of ~12mm in diameter hides soft iron semi-cylinders having diameter ~9.8 mm.

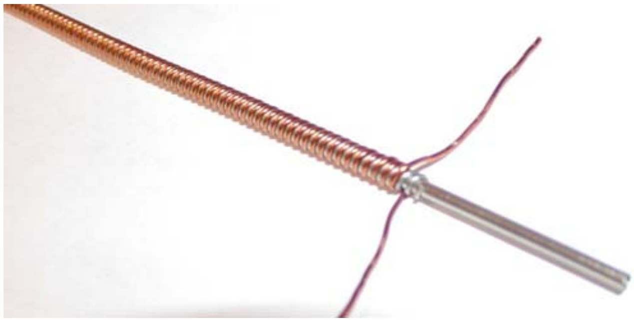

FIGURE 2: Central core first try. The winding done with pair of SC wires and pair of iron ones at once. Period of the winding is 2.42 mm. StSt tube has diameter 1.5 mm.

The winding goes with pair of SC wires and pair of soft steel ones with the help of cylindrical director made on G10. SC wire has 0.6mm in diameter- standard OXFORD 54 filament wire insulated by Formvar. The steel wires were taken with round shape and was annealed by direct current flow arranged with transformer, making the wire light red. The steel wires serve as a part of magnet yoke arranged by these wires and soft iron half cylinders. These cylinders surrounding the windings, shown in Fig. 2, attached to the windings by thermo-conductive epoxy Epotek T-905. Undulator assembled on stock, allowing precise alignment of the inner tube during the process of squeezing and curing of epoxy.

Design allows exact control of angular out-positions of the wires at the ends, and, hence, polarization of the magnetic field at the exit. The last required for proper tapering of the undulator field. Symmetric commutation with small iron cylinder as a magnetic shield was also used for this purpose.

TEST

Undulator was tested in a Dewar filled for the wiggler coil test set in parasitic mode, Fig.3. Pair of additional feed-through allowed independent feeding of this undulator model.

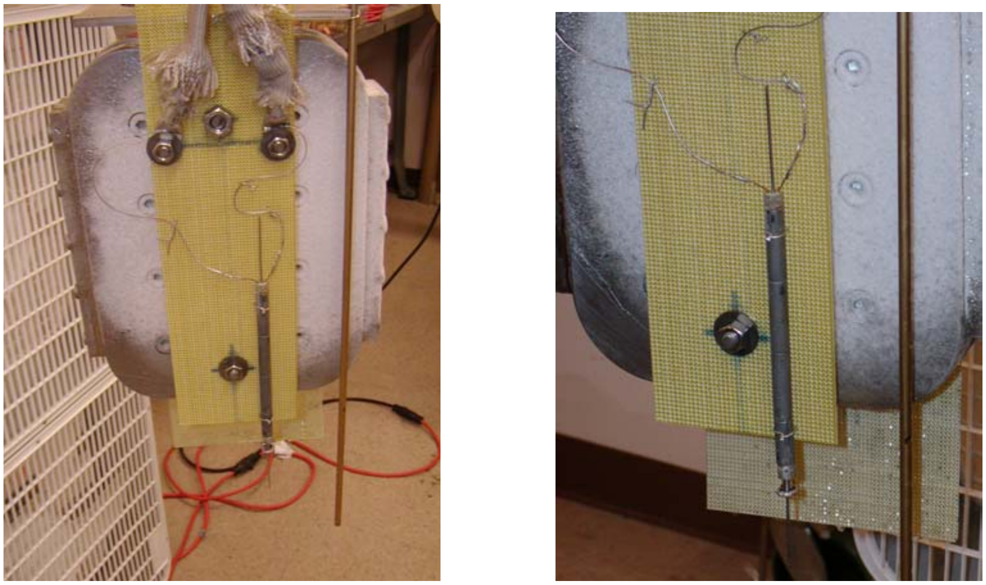

FIGURE 3: Undulator can be seen attached to the wiggler coil test fixture.

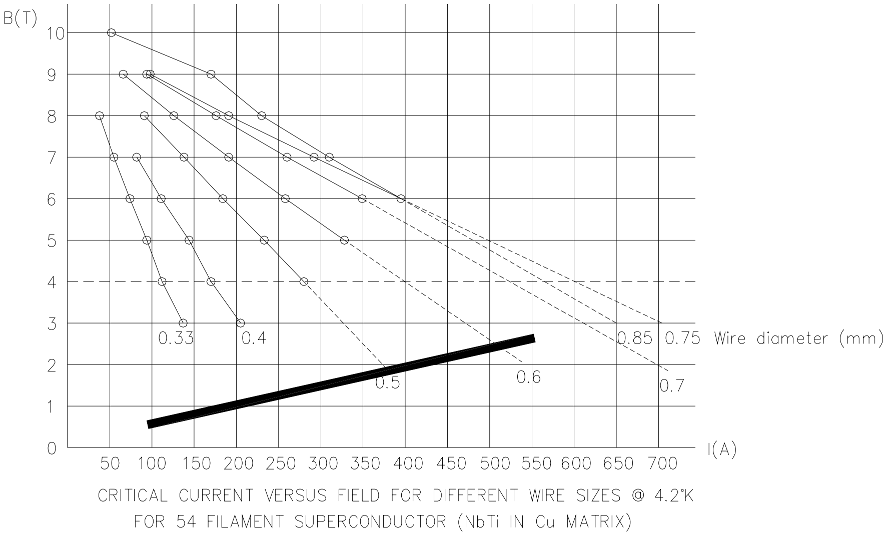

FIGURE 4: Properties of the SC wire. Loading curve for the points with highest field is represented as a solid line.

In Dewar tests we reached the current ~510A which is close to the short sample limit. The field at the axis, according to calculations, reaches ~0.34T, *K* parameter, respectively, goes to ~0.08. The field amplitude between SC wires reaches ~2.3T in specific points inside the wire. The field was calculated with 3D code MERMAID. Details of calculation will be represented in a separate publication.

With the tube having OD=1.0668 mm, as planned, we expect to reach with the same current the field at the axis~0.59T and *K*=0.13 as the field at the axis is exponentially dependent on the tube diameter. Fields between the wires remains practically the same, however. In final design we also are considering utilization of soft steel wire with rectangular shape, giving additional 10% to the field at the axis. The wire of this shape is available at the market. We investigated the possibility of rolling the wire of this shape from the round one in the Laboratory, however. Filling epoxy with iron-like powder (ferrite), can also give additional few percent in field strength at the axis.

CONCLUSION

Result achieved indicates that there are no problems with the wire in geometry of undulator, allowing 2.4 mm period for undulator. No doubt, that technology can be successfully used for full-scale model of 1-meter long undulator planned for test at SLAC.

There are no apparent limitations in scaling this technology even more down with appropriate tube and wire diameters. The aperture will go down proportionally to the period and field will drop exponentially, however.

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