

## SHORT-PERIOD SC UNDULATOR

A. Mikhailichenko, Cornell University, LEPP, Ithaca NY 14853, USA

### Abstract<sup>1</sup>

We describe here design of short period helical undulator with SC windings. 2mm period,  $K \sim 0.12$  undulator can be used in positron production scheme. Results of test of 6 in-length prototype cold mass is represented also.

### INTRODUCTION

Polarization in future linear collider recognized as a factor increasing collisions rate, effective polarization and as an instrument for drastic reduction of background especially if both electron and positron bunches are polarized. Method for polarized positron production was suggested many years ago [1]. At first stage circularly polarized high-energy gammas generated in a short period helical undulator by (used) high-energy beam after collision. At second stage these circularly polarized gammas converted into positrons/electrons in a thin target. *Energy selection* of secondary particles delivers polarization to the beam as a result of transferring polarization of gammas to the secondary particles at high-edge of energy spectrum. Polarization with this method can reach 65-70% with  $\sim 130$  m long undulator.

Cold mass of undulator with superconducting coils having period of 1 cm,  $\sim 30$  cm-long with  $\sim 6$  mm aperture clearance, was successfully tested in a framework of VLEPP linear collider activity [2], [3]. Field of  $\sim 0.5$  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]. Publication [4] now grew up into proposal for E-166 experiment at SLAC [6], carried by international community. One other potential utilization of polarized positrons –arrangement collisions in SLAC B-factory is also connected with undulator-based positron generation. Here  $\sim 4$ -m long undulator allow generation necessary amounts for normal operation of B-Factory [7]. SC can be used in future Linear Collider full-scale project. Nice advantage of SC undulator is that its functionality does not depend on repetition rate.

Main point of concern for small aperture undulator is operational stability of SC coil while few kW high-energy beams is running within 2mm from cold walls. So in this case manufacturing and testing *section* of SC undulator is necessary.

For successful operation of conversion system, undulator-having  $\geq 1 - 1.3 \times 10^4$  periods required. In any case this undulator will be manufactured as relatively short sections of  $\sim 2$ -m long.

<sup>1</sup> Extended version is available at [http://www.lns.cornell.edu/public/CBN/2003/CBN03-4/CBN03\\_4.pdf](http://www.lns.cornell.edu/public/CBN/2003/CBN03-4/CBN03_4.pdf).

### CRYOSTAT

Cryostat serves as housing for cold mass core. The cryostat sketch is represented in Fig.1. 2-meter long module will be able to work with cryocooler having 1.5W power at LHe temperature and  $\sim 40$  W at  $50^\circ\text{K}$ . It also allows operation with filling by LHe directly trough the input 9 in fig.1. In this case cryocooler can operate too or can be replaced by LN cylindrical container.

Main support of long cold mass, having  $\sim 1''$  in diameter and length  $\sim 4$  m, is going with suspension elements shown in Fig.2. As the cold mass is light weighted this solution allows good control of position of axis.

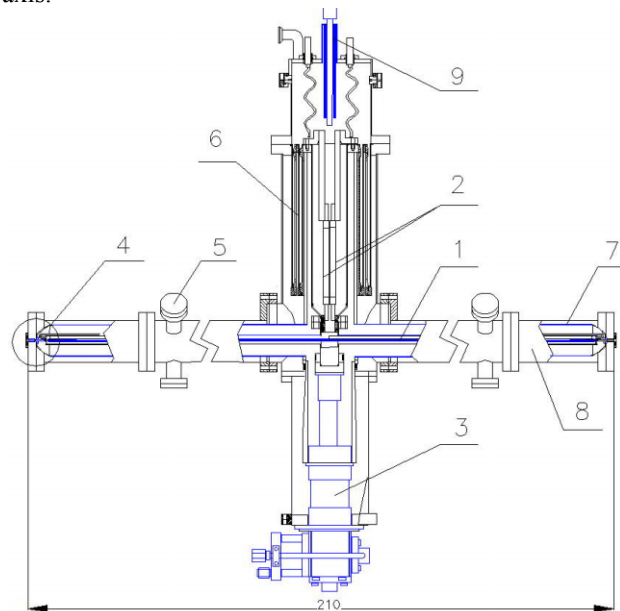


Figure 1: Cryostat for 2 m-long module. 1-is a cold mass, 2-HTS leads, 3-Cryocooler, 4-end region, see Fig.2, 5-is suspension elements, Fig.2, 6-are coaxial Al-StSteel cylinders, 7-is intermediate  $50^\circ\text{K}$  temperature shield, 8-is a vacuumed corps, 9-is filling tubing for operation with filled liquid He. All responsible spaces interlaced by superinsulation. Full height of cryocooler is 21.91".

These suspension straps made from composite glass fibers impregnated and cured with epoxy (Fiberglass). These straps are commercially available in broad variety of sizes.

Central support unit made with few coaxial cylinders with two Al ones among them. For the heat flow all the length is working in series. For the lengthening the thermal expansion coefficients of Al and StSteel are working one against other, like in gridiron pendulum.

Total heat losses calculated remains formally below 0.5W, however to get some operational margins the cryocooler with 1.5W at  $4.2^\circ\text{K}$  and 40 W at  $50^\circ\text{K}$  chosen for testing device (Model RDK-415D from Janis Co.).

Maintenance interval ~10kHours is big enough to accomplish any experiment. As it was mentioned full-scale undulator will work with LHe supply.

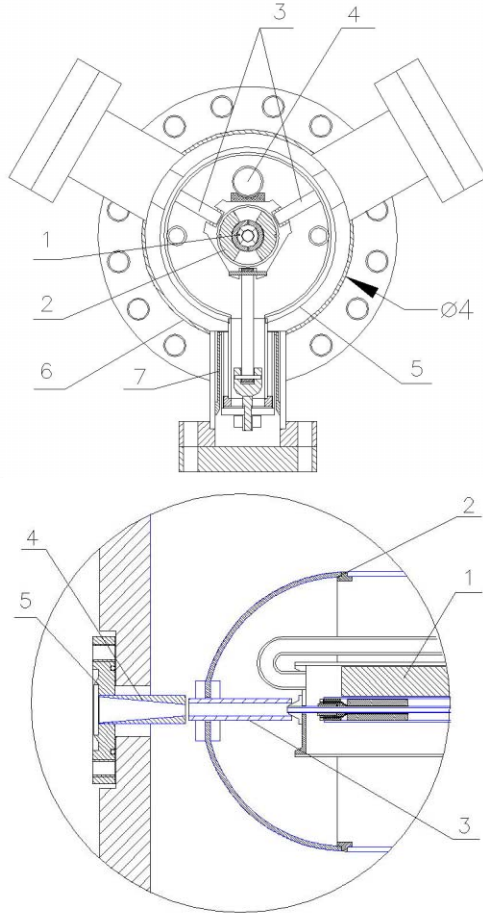


Figure 2: Suspension system and end of cryostat, circled in Fig.1. Left: 1-is a cold mass, 2-is a copper collar, 3-are suspension straps, 4-is two phase He tube, 5-is a 50°K shield, 6-is a vacuumed corpus, 7-is a stretching mechanism and heat lock. Right: 1-is a cold mass, 2-is a 76°K-shield, 3-is an aligning cylinder, 4-tapered diameter transformer, 5-is a flange.

### COLD MASS WITH 1-cm PERIOD

As we mentioned in introduction the cold mass was tested in framework of VLEPP activity. Suggested that cooling can be arranged by flow of LH in gaps between yoke.

Yoke helix was machined in ~10-cm long sections. After trimming these pieces soldered by Indium to the tube, so it is going without brakes.

Heat losses due to imaginary currents can be evaluated for  $N = 10^{10}$ , bunch length  $\sigma_b = 0.001 \equiv 1\text{mm}$  one can obtain  $\hat{W} \cong 3.27 \cdot 10^{-6} J$ . For repetition rate  $f$ , Hz and for the number on bunches in train  $n$ , average power dissipation will be  $P \cong \hat{W} \cdot f \cdot n$  Watts, remaining within  $mW$  level. As the chamber has temperature of liquid He, this resistance must be lowered at least ~100 times.

It was shown in [2] that thermal relaxation of core cooled by flowing Helium could be described by space and time parameters  $\kappa \cong 10\text{cm}$ ,  $\tau \cong 22.4\text{s}$ .

Measurement in this model was carried with a help of Hall probe moved along the axis in liquid Helium. Maximal current was ~6 kA × turns (marked by \*). With present day wires available on market all parameters for total current above 6 kA × turns in Table 1 can be guaranteed.



Figure 4: 30 cm-long superconducting undulator with period 10 mm and the axis field ~ 5 kG. Diameter of StSteel chamber is 6 mm, wall thickness 0.1mm.

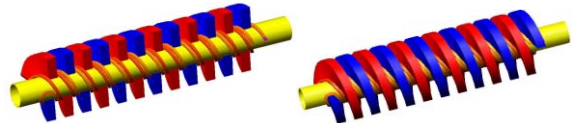
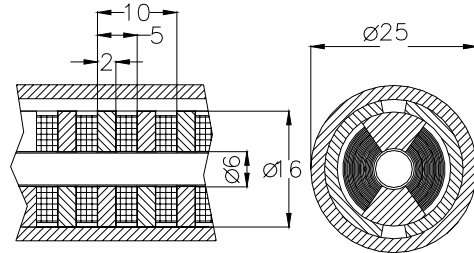


Figure 3: (Color) Yoke of 6 mm in aperture, 10-mm period of undulator with SC wires [2]. At the left vertical cut made for better look inside. Colored red and blue helical yokes made from soft steel. Half cylinders, covering yoke are not shown.

### 2.4 mm PERIOD MODEL TEST

Technology tested can be scaled down to a shorter period required for possible test (or implementation, [7]) at SLAC. A ~six inches long model prototype with period 2.42 mm having all peculiarities of full length one was tested [9].



Figure 4: SC undulator model. Iron cylindrical shield for end trimming and ring jumper are visible here. One end of undulator has Copper jacket of ~12mm in diameter hides soft iron semi-cylinders having diameter ~9.8 mm.

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. The goals of the work done 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.

The winding done with pair of SC wires interlaced by 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. Undulator model was tested in a Dewar filled for the Cornell LEPP wiggler coil test set in parasitic mode [9].

Field measurement in such small aperture is a problem. However the axis field module is a constant along the undulator. Measuring integrated value with *scalar* probe will give the value of axis field. So here the magneto-resistive sensors as a Bismuth wire can be used [10].

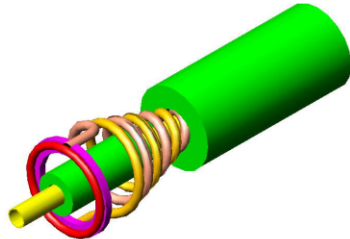


Figure 5: (Color) End commutation. Red ring is a SC wire circled and soldered with Indium to the Copper ring. Green cylinder at the right made with two halves.

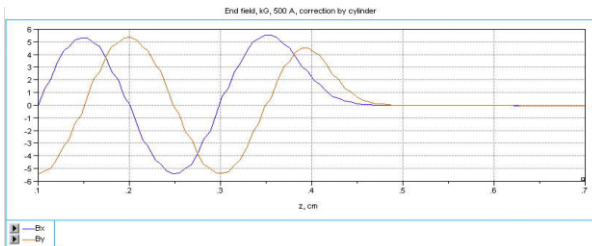


Figure 6: (Color) End field with conical expansion and trimming magnetic cylinder. Period –2mm.

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.

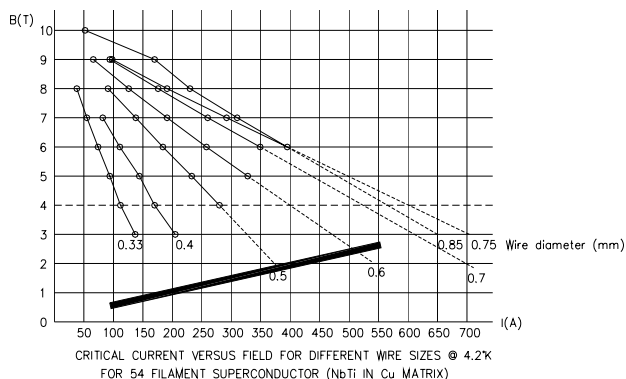


Figure 7: Properties of the SC wire. Loading curve for the points with highest field is represented as a solid line.

With the tube having OD=1.0668 mm, as planned, parameters we expect to reach with current 500 A current the field at the axis~0.54T and  $K \cong 0.12$ . In final design we also are considered utilization of soft steel wire with rectangular shape, giving additional 10% to the field at the axis. Filling epoxy mixed with iron-like powder (ferrite), can also give additional ~10% percent in field strength at the axis.

## CONCLUSIONS

The cryostat described can accommodate any core with short-period undulator. Utilization of such SC undulator might bring significant relief in operational cost of linear collider.

Cold mass of helical SC undulator having 1-cm period and 6 mm aperture clearance was successfully tested years ago. No doubt, that technology can be successfully used for full-scale wiggler with 0.8-1 cm period and ~100-130 m long.

Six-inch long model of undulator cold mass with 2.4 mm period was manufactured and tested in Dewar.

There are no apparent limitations in scaling this technology even more down with appropriate tube and wire diameters down to period of 0.1mm and  $K \sim 0.05$ .

## REFERENCES

- [1] V.E. Balakin, A.A. Mikhailichenko, “Conversion System for Obtaining Highly Polarized electrons and positrons”, Preprint INP 79-85, Novosibirsk 1979.
- [2] A.A. Mikhailichenko, Dissertation, BINP, Novosibirsk, 1986, Translation: CBN 02-13, Cornell 2002.
- [3] T.A. Vsevoljskaya, A.A. Mikhailichenko, E.A. Perevedentsev, G.I. Silvestrov, A.D. Cherniakin, XIII International Conference on High Energy accelerators, August 7-11, 1986, Novosibirsk.
- [4] R.Pitthan, J.Sheppard, “Use of Microundulators to Study Positron Production”, LC02, Proceedings, SLAC-WP-21.
- [5] A. Mikhailichenko, “Optimized parameters of the Helical Undulator for test at SLAC”, LC02, Proceedings, SLAC-WP-21.
- [6] See: <http://www.slac.stanford.edu/~achim/positrons/>.
- [7] A.A. Mikhailichenko, “The feasibility of polarized  $e^+e^-$  collisions at SLAC B-factory”, CLNS 99/1645, CORNELL U., 1999.
- [8] H. Lierl, P.Shmüser, “Cooldown of a HERA Octant Equipped cold Dipoles”, DESY, HERA, 84/16, 1984.
- [9] A. Mikhailichenko, T. Moore, “First test of short period helical SC undulator prototype”, Cornell CBN 02-6, June 3, 2002
- [10] A.Mikhailichenko, “Low aperture magnetic element measurements”, (Novosibirsk, IYF). IYF-89-94, Jun 1989, 12pp. See: [http://ccdb3fs.kek.jp/cgi-bin/img/reduced\\_gif?198911230+1+14](http://ccdb3fs.kek.jp/cgi-bin/img/reduced_gif?198911230+1+14)).