# PULSED MICRO-UNDULATOR FOR POLARIZED POSITRON PRODUCTION

A.Mikhailichenko, Cornell University, LEPP, Ithaca NY 14853, U.S.A.

*Abstract*

We represent here the elements of design and results of the testing for the helical undulator with ~2.5-mm period, manufactured in Cornell LEPP for polarized positron production at SLAC. At 2.3 kA undulator reaches K~0.2 and operated at 30 Hz.

## INTRODUCTION

This undulator supposed to be used for experiment E–166 carried out at SLAC [1]-[5]. This experiment is dedicated to test the idea of polarized positron production for the ILC. This idea was proposed in [6] and its basis is that for generation of polarized positrons circularly polarized photons are used in the first place. These gammas, having energy ~10MeV converted into electron-positron pairs in a thin target. Secondary particles selected by energy as the particles with higher energy have higher degrees of longitudinal polarization. Circularly polarized photons can be radiated by high energy (~50 GeV in experiment E-166) primary electron beam passed through helical undulator.

Two types of undulators with parameters represented in Table were fabricated. We also included parameters of SC undulator that is able to satisfy ILC needs for polarized positron production at 150 GeV.

Table 1: Parameters of undulators

| | | | |
|---|---|---|---|
| Energy, GeV | 50 | 50 | 150 |
| Length, m | 1 | 1 | 100 |
| Period, mm | 2.52 | 2.43 | 10 |
| Apert. dia, mm | 0.889 | 1.067 | 8 |
| Axis field, kG | ~7.1 | ~5.4 | ~3.6 |
| K | ~0.17 | ~0.12 | 0.34 |
| $\hbar\omega$ , MeV | ~9.15 | ~9.63 | ~19.3 |
| Losses/part., J | $2.6\cdot10^{-13}$ | $1.4\cdot10^{-13}$ | $6\cdot10^{-11}$ |
| Losses, MeV | 1.65 | 0.88 | 355 |
| Quants/particle | 0.18 | 0.09 | ~18 |
| Curr., kA-turns | 2.3 | 2.3 | 8 |
| Pulse, μs | 12 | 13 | ∞ |
| Heat/pulse °C | ~1.7 | ~1.3 | |
| Inductance, μH | ~1.4 | ~1.5 | |
| Resistance, Ω | ~0.22 | ~0.26 | SC |
| Induct. Volt., V | ~656 | ~592 | |
| Press. drop, psi | ~11 | ~11 | |
| Oil, gal/min | 3.5 | 3.5 | |

Finally these undulators were fabricated, tested and delivered to SLAC. As these undulators have unique characteristics among undulators, we will describe theirs properties, technology of fabrication and results of tests in detail.

## GENERAL PICTURE

Basically, the undulator conductors are bi-helical windings with current running in opposing directions in these windings. This way of helical field generation was originated in [6]. Although some undulators were described in literature, [8]-[12], not one of these came close to the parameter list required. Finally we used here the way what we used successfully many years ago [13] for undulator, having period 6mm and *K*~0.35. We used the wires that have a rectangular cross-section, and they are giving ~15% higher field at the axis compared with the round wire.

Also we suggested that an alignment of these windings could be done using *outer dimension* of winding as a reference. So these helical windings made directly to the (insulated) vacuum chamber. Further on this construction, rather flexible, aligned with the help of three cylinders. Kapton tape was used for electrical insulation here. Two of these cylinders are sitting in lower corners of U shape groove giving insulated lodgment for the whole helix. So this U groove made with high accuracy at all length within ±0.0005 inch margins. That was done in a few steps milling after all flanges with Al/StSteel transitions welded to the case. Two cases were milled at the same time attached to the Jig plate by holders as it will be in use. Cross section of the case is represented in Fig.2.

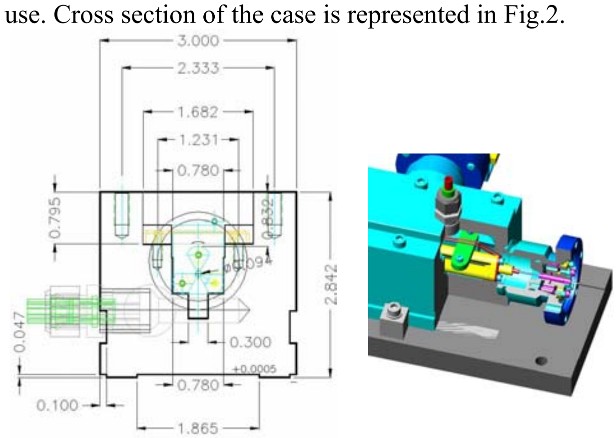


Figure 2: Cross–section in central region. Dimensions are at the left. Oil comes out through the tube connected to the space below G10 rods painted yellow, right.

G10 rods were found to be round with an accuracy within 0.05 mils at entire length; undulator sealed with an Indium gasket.

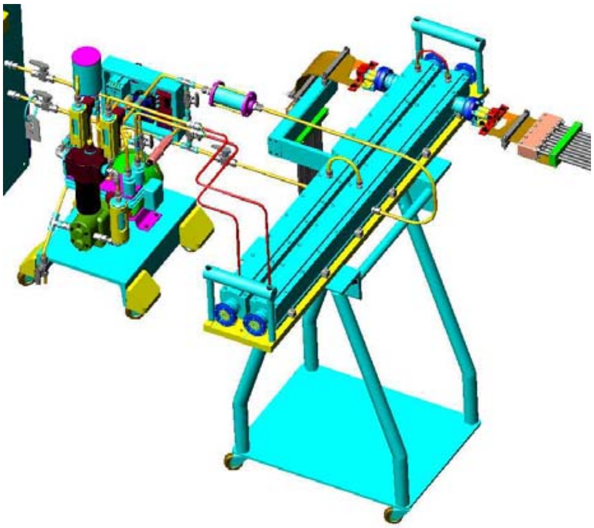

Figure 3: Set of two undulators installed on platform shown with cooling system, left. The last one shown with cover removed for better visibility.

Pure transformer oil used here as a coolant. Oil runs in a circuit that includes Stainless Steel oil pump, heat exchanger, reservoir, pressure gages and valves. Oil comes into the undulator case from the top in the middle and comes out at lowest point in the groove below G10 (See Fig.2) rods also in the middle. Internal pressure inside the case was found to be ~35 psi. Due to specifics in design, see Fig. 4, this pressure helps in stretching the chamber.

Pumping/cooling device is realized as a mobile unit, Fig.3, caring oil pump (made from StSteel), thermo-contacts looped in ready chain, flow meters, 3 phase control electronics, heat exchanger. This device can be turned on/off remotely as well as locally. Pressure transducer PS 302-200GV attached to the line through pressure snub PS-4E together with DP25-SR strain gauge meter, also attached to the ready chain loop. With the help of two valves the pressure transducer can be attached either to the out-going line or to the incoming one. The oil line is also equipped with standard dial-type pressure gages installed at the undulator side.

At the second stage for cooling the Ferrofluid EMG-900 will be used as well [14]. Usage of Ferrofluid allows reaching a ~15-20% higher field. It will also make the pulse rise a bit slower, what helps in guaranteed operation of thyristors. So this will bring undulatority factor to the value $K \cong 0.2$.

## FABRICATION

Oxygen-free CDA 10200 copper wire with square cross-section $0.6\times0.6$ mm2 was ordered from company. Corner radius is $\leq 0.06$ mm. A specially designed machine was made for winding, Fig.7. Four wires were wound at a time: two of these are afore-mentioned copper conductors with rectangular cross–section and two additional wires used as spacers. After winding is finished, the last two wires are removed. Wounding is applied to the tube, wrapped by Kapton insulation directly. A hypodermic 304 L stainless steel small diameter tube 19-XTW with nominal OD 0.042 inch and inch and 18-XTW with nominal OD 0.050 inch and nominal wall thickness 0.004 were used for these purposes. Kapton insulation, having a thickness of 0.5 mils, was used for insulation. After winding was finished, it was found that the windings were attached to the tube strongly enough and no sliding motion was found.

With spacer wire having 20 mils, period was found to be 2.58 mm as calculated, and with spacer 15 mils period comes to 2.29 mm. We used Copper wire having 19 mils in diameter as a spacer.

All undulators were wound as left-hand ones, i.e. having a twist opposite to an ordinary cork screw. Visual inspection under a microscope allows location of tiny pieces of copper chips inevitably deployed from the wire under the bend. Let just re-instate, that bending radius is of the order of the wire size. Keystone effect does not manifest itself much however and outer dimensions are rather uniform.

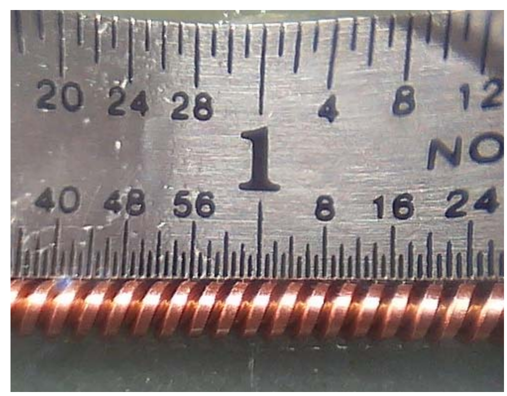


Figure 4: Windings enlarged. Scale in minimal division is 1/64 of an inch.

Inductance of each winding was measured also. It was easy to find any tiny metallic debris shortening the wires as the inductance change is going linearly with the length.

Special attention was paid to transferring the tube to the end cap. This end cap, seen in Fig. 10 at the right allows sealing the inner volume and allowing longitudinal motion, as the heat deposition yields some change in length. Soldering with hard alloy was found to be adequate to the task.

Another important factor defining the overall stability and precision is the case, holding G10 rods and helical windings, Fig.3. This case is made from Aluminum block having overall dimensions $\sim 3\times3\times45$ in$^3$. After preliminary milling was done, the flanges were welded. Stainless steel/Al transitions were used for these purposes. After that the final milling was accomplished. Dimensions were checked in local company with semi-automatic coordinate machine with touching head sensor, pretty standard device for high precision 3D measurements.

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Aluminum Jig plate specially profiled and milled with high precision (better than ± 0.5 mils) accommodates two undulator cases. Attachment of each case to this plate made with special holders, allowing expansion in longitudinal direction. After fabrication, all Al parts oxidized black to minimized contact of Al surface with oil. This procedure does not change dimensions within controllable value.

## TESTING

Six full undulators were wound. Three for each tube: 42 and 50 mils in diameter. Each of these winding was tested in oil. For SLAC emittance $\gamma\varepsilon \cong 3\times10^{-3}\,cm\times rad$ in a crossover of envelope function having value there $\beta_0 \cong 400cm$ sigma of the beam goes to be $\sigma \cong \sqrt{(\gamma\varepsilon)\beta_0/\gamma} \cong 3.5\times10^{-3}cm$. The stainless steel wire, having a diameter of 0.4 *mm* was stretched inside the aperture without touching the walls. The last was identified by absence of electrical contact between wire and tube. As 0.4 *mm* is ~ten sigma, then this is enough for successful beam pass through undulator. Further tests at SLAC after arrival there found that aperture is ~twice of this wire diameter we used in our measurements.

Pulser is about the same as we used for positron production upgrade of CESR [15].

Figure 5: Testing setup. Visible are undulators at the right, pulser at center and cooling system at the left.

Calculations carried with help of three different 3D codes. Undulator running at 2.3 kA was tested at 30 Hz during one our operation. This current developed with power supply EMS800-2.5-5-D at its high limit. This was done on purpose, so in case if all electronics failed, the power supply will be not able to develop extreme current. As all temperature relaxations occur in seconds, this time was found to be adequate. E-166 supposed to run at 10 Hz or even less, limited by radiation conditions. After experiment at SLAC is finished it will be interesting to establish the limits, using other power supply.

## CONCLUSIONS

This unique undulator was built in a very tight time frame (approximately six months from the beginning of calculations). Nevertheless all elements of design were found adequate to the task and remaining so.

This undulator, besides the test of polarized positron production experiment E-166 itself, can be used for arrangements of *polarized* electron-positron collisions in SLAC B-Factory, [16].

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