PULSED UNDULATOR TO TEST POLARIZED POSITRON PRODUCTION AT SLAC

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Abstract[1]

We represent technical details and results of testing pulsed undulator with ~2-mm period, K~0.1, manufactured by Cornell LEPP for test of polarized positron production at SLAC.

INTRODUCTION

Conversion system for polarized positron production [1] contains ~130 m-long helical undulator followed by thin target. Helical gammas radiated by primary high-energy beam in undulator transfer theirs polarization to the positrons and electrons at the high edge of energy spectrum. Selecting secondary positrons/electrons by energy, one can at the same time select theirs polarization (higher energy–higher polarization). Right now there is a proposal for E-166 experiment at SLAC [2] to test this idea, initiated by publication [3].

Experiment requires, that undulator ~1-long, must be installed in FFTB channel. Here ~50 GeV SLAC beam will generate ~10 MeV gammas [2]. General descriptions of ~2 mm –period undulators suitable for these purposes were done in [4], [5], and model with period 2.4mm was manufactured, Fig.1. This model was tested for 1 kV of static voltage. In this publication we describe more engineering details of undulator design.

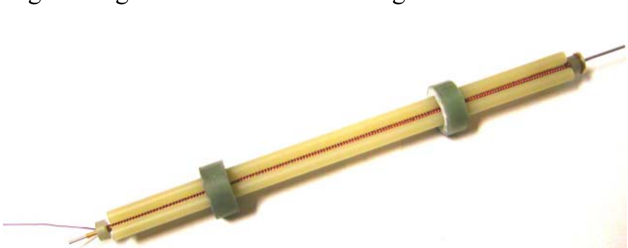

Figure 1: Model of pulsed undulator with period of 2.42 mm and 231.5 mm long [4]. Three G-10 rods squeezed with help of short rings having cylindrical grooves. This arrangement serves as a positioning system

One meter long pulsed undulator having 6 mm period and the axis field ~6*kG* ($K \cong 0.35$[2]) was successfully tested many years ago [6]. The feeding current in a wire with 1×1 mm^2 cross section was ~10 kA. Pulse duration was ~50 μsec, feeding voltage ~ 1.19 kV required by inductance ~1.3 μH allowed operation with repetition rate of 25*Hz*[3]. Such high current (and inductance) was forced by the aperture clearance of 4mm in diameter required. Intensive cooling of this device was a main engineering achievement.

Namely this technology was used for short period undulator suitable for test at SLAC.

GENERAL DESCRIPTIONS

Undulator has two helixes shifted in longitudinal direction by half-period [7], Fig.2. Technology for manufacturing of double helix with period 2.4 mm was tested successfully [4]. There was not found any limitation to make the windings with period 2 mm. Small period required for generation of gammas with appropriate energy ~10 MeV, forcing shrinkage of aperture. Fortunately this drastically reduces inductance of undulator. In its turn this yields proportional reduction of voltage required for excitation of necessary current ~1.6 kA. The helixes immersed in coolant liquid avoiding overheating.

Basically the helixes will be wound on the StSt tube of gage size 19 with nominal OD 0.042" (1.0668 mm). Kapton insulation 0.003″ - thick will serve for electrical insulation. This tube has the wall thickness of 0.0035" (0.0889mm)[4]. This tube allows the ID diameter 0.889 mm available for the beam.

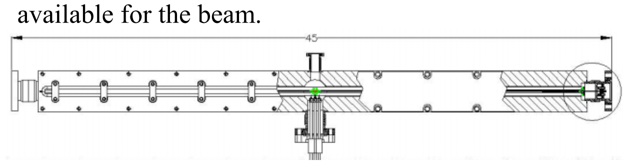

Figure 3: General view of undulator. Length is shown in inches. The current feed-throughs (four in total) located at the central part. Circled region scaled in Fig.6. StSteel flanges are the parts of transitions welded to Al corps.

General view of undulator represented in Fig. 5. Total length of undulator is 45″($\cong$114) cm allowing pure helical winding occupy 2×50 cm of each helicity. Corps made from Aluminum alloy. We used here the same scheme for fixation core with helixes as in [6]. StSteel flanges are welded to the corps using commercially made transitions[5]. Cross section of undulator in regular part is represented in Fig. 6. Basically the body of undulator is an $3''\times 3''\times 41''$ Aluminum block with groove in the middle. Inside this groove two roads 5 located in corners, giving the basis by theirs surfaces. These roads made from G10 cylindrical rods of 0.375″ in diameter. After making cut with 60° upper surfaces of these roads coincide with axes of undulator. This axis located $\cong$1.5″ from the bottom surface. The third road presses the helical windings to the basement lodgment arranged by

[1] Extended version is available at http://www.lns.cornell.edu/public/CBN/2003/CBN03-5/CBN03_5.pdf

[2] This value is optimal for 150 GeV primary beams.

[3] Required by VLEPP parameters at that time.

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

[5] Thermionics Northwest, Inc.

other two by springing bars seeing if Fig.4, and marked as 4 in Fig.6.

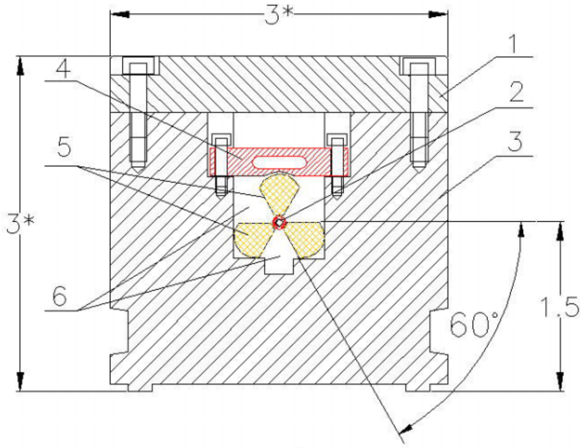

Figure 4: Cross-section of undulator, Fig.5. Two G10 rods are based in corners of long groove. Third rod with help of springing bars 4 compresses the windings to the other two ones. 1 –is a cover, 2 –is bi-helix. 3 –is a corps, 5 –are G10 rods, 6 –is filled with coolant. Parts 1, 3 made from Aluminum.

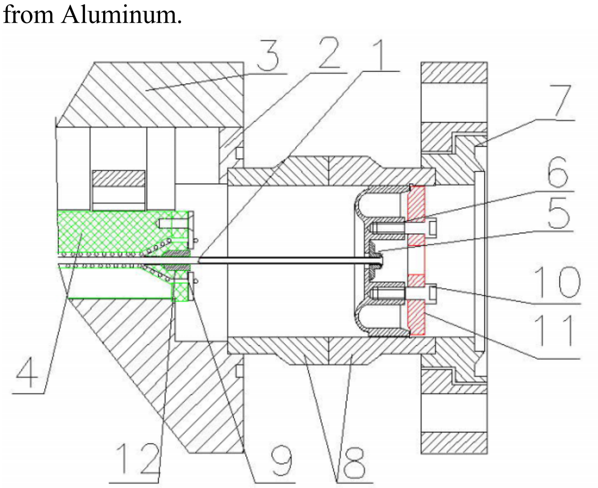

Figure 5: Scaled view of circled parts in Fig.3. 1 –is the helixes, wounded on StSteel tube. 2–is the corps, 3–is a cover, 4 –is the upper rod, 5–is end cup, 6–is intermediate cup, 7–is a standard 2¾ flange, 8–is a StSteel-Aluminum transition, 9–is the end commutation, 10 –are screws, 11–is a springing washer, 12–is a trimming conducting cylinder (flux attenuator). Inner volume filled by coolant.

End part of undulator circled in Fig. 5 is shown scaled in Fig.7. Here helixes 1 with tube based on the surface of two rods. It is clearly seen the end commutation 9 made with ring. Conically expanded helixes can be seen here too. Conical expansion made for proper adjustment of integrals along edge region. For the same purposes the conducting cylinders (See Fig.8) serve too. For high-energy particles the radius of space helix of trajectory is very small, $\rho \cong \lambda_u K / 2\pi\gamma$, where K–is undulatority factor. For 50GeV beam $\gamma \cong 10^5$ and for our parameters $\rho \cong 3\cdot 10^{-7}\,mm$ allows to treat trajectory as a straight line when calculating integrals along trajectory.

Intermediate cap 6 made from St Steel welded to the transition. In this design standard transition Al/StSteel with rotatable flange used at both ends. StSteel tube (vacuum chamber) caring the helixes brazed to the cap 6 with end cap 5. This end cap 5 allows small transverse movements, accommodating the transverse position of the end cap on the orifice of intermediate cap 6. With the help of threads 10 and washer 11 the vacuum tube can be stretched in longitudinal direction. That is why the intermediate cap 6 made with developed surface. Copper cylinder 12 serves as trimming flux attenuator.

Upper rod has grooves with period of helix, fixing longitudinal positions of the wires.

FIELDS IN UNDULATOR

Fields in undulator calculated analytically and numerically with 3D code MERMAID. We used both ways for the field evaluation. Both gave the same result [4]. Field attenuation defined by skin-depth in StSteel, what is of the order ~3.6mm for such duty times. So attenuation is going to be 2.4%.

For our case the only first longitudinal harmonic is important. For the axis field of undulator with thin wires, one can obtain expression as [4]

$$H(0,0,z) = \frac{I}{\pi a} \times \left(\frac{2\pi a}{\lambda_u}\right)^2 \times \cos\left(\frac{2\pi z}{\lambda_u}\right) \times K_1'\left(\frac{2\pi a}{\lambda_u}\right). \quad (2)$$

This formula is illustrated in Fig.6. One can see from there, that for $\lambda_u \cong 2a$ the field is only ~17% less, than asymptotical value for infinitely long two-wire line.

Longitudinal profile at the end of helixes is represented in Fig.7. This type of field mapping used for modeling end field effects. Fig. 8 explains what type of corrections used to trim end fields.

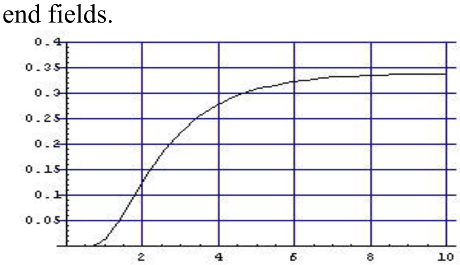

Figure 6: Field at the axis, *G*, for radius *a*=1 as a function of λ_u, Current *I*=1 A. Saturation indicates that the field can be calculated as for two parallel infinitely long wires.

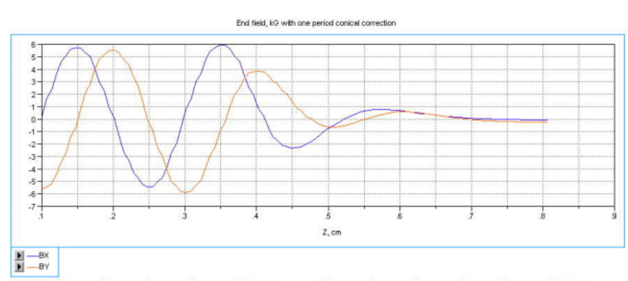

Figure 7: (Color) Longitudinal field profile, kG along undulator aperture near the end, cm. End correction.

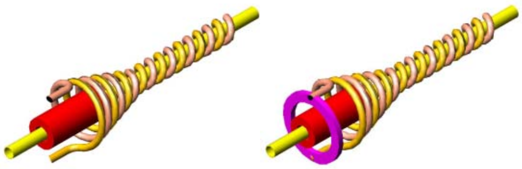

Figure 8: (Color) End correction made for input, left and conductor jumper, right. Cupper cylinder serves as a flux attenuator.

Integrals calculated from fixed point inside the undulator to the point far out from the end and the integral for central (axes) line subtracted from every one, calculated for off-axis position. The difference after correction remains within 0.0025kGcm. Even not corrected end commutation gives integral deviation ~$0.035\,kG\cdot cm$, what yields the angular kick $x'\cong 2\cdot 10^{-7}\,rad$ only for 50GeV beam. Nevertheless this commutation correction is a useful tool.

PARAMETERS

Parameters of undulator are represented in Table 1 below. Voltage required based on the calculation of inductance done at the same time with field calculations. Number of quants radiated, radiation losses and polarization value are taken from [4] and [9].

Factor Power supply described in detail in [5]. It is pretty much the same type used in [8], see Fig. 9.

Table 1.

Parameter	Value	Value
Length	2 × 50cm	2 × 50cm
Period	2.0mm	2.4mm
Axis field	5.6 kG	7.62 kG
K	~0.1	~0.17
$\hbar\omega$	11.7MeV 9.94	10MeV(50GeV) 8.5MeV(46GeV)
Losses/part.	1.15×10^{-12} J/m	0.31×10^{-12} J/m
Losses		1.902 MeV/m
Quants/particle	0.16/m	0.36/m
Current	1.6kA	2.3 kA
Pulse duration	30 μs	30 μs
Heating/pulse	~3 degC	~2.7 degC
Inductance	~9.9x10^{-9} H/cm	~8.6x10^{-9} H/cm
Resistance	~0.0035Ohm/cm	~0.0011Ohm/cm
Inductive Voltage/length	1.65V/cm	~1.54V/cm
Resistive Voltage/length	5.6V/cm	~2.5V/cm
Average polarization	90%	~90%

Radiation in the undulator is typical for quantum regime: the amount of energy radiated by particle in less, than energy of quanta. This brings the radiation process in statistical regime.

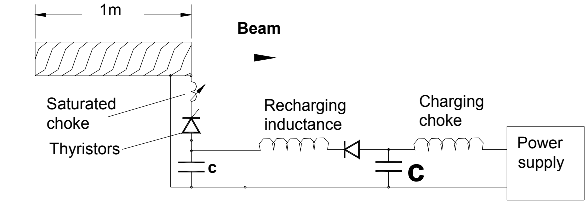

Figure 9: Scheme of pulser for undulator.

CONCLUSIONS

Pulsed undulator developed for E-166 experiment at SLAC itself despite its unique parameters looks also a pretty guaranteed from the engineering point of view. Real test with designed pulsed current is under preparation. Static test of insulation done at the Air for 1 kV DC voltage applied to the chamber and wires.

We believe however, that for future linear collider a SC undulator with large (~6mm in dia) aperture and ~8mm period is more suitable from the exploitation point of view.

REFERENCES

[1] V.Balakin, A. Mikhailichenko, "Conversion System for Obtaining Highly Polarized Electrons and Positrons at High Energy", Budker INP 79-85, September 13, 1979.

[2] E-166, see: http://www-project.slac.stanford.edu/lc/local/PolarizedPositrons/pdfs/E-166TLD.pdf

[3] R.Pitthan, J.Sheppard, "Use of Microundulators to Study Positron Production", LC02, Proceedings, SLAC-WP-21.

[4] A.A. Mikhailichenko, "Pulsed Helical Undulator for test at SLAC the Polarized Positron Production Scheme, Basic Description", CBN 02-10, September 16, 2002, Cornell University, LEPP.

[5] A.Mikhailichenko, "SLAC test pulsed undulator concept", Cornell LEPP CBN 02-7, Aug.16, 2002.

[6] A.A. Mikhailichenko, "Dissertation", BINP, Novosibirsk, 1986, Translation: CBN 02-13, Cornell LEPP, 2002. Electronic version is available at: http://www.lns.cornell.edu/public/CBN/2002/CBN02-13/DISSERT.pdf.

[7] R.C. Wingerson, "Corkscrew" -a Device for Changing the Magnetic Moment of Charged Particles in a Magnetic Field", Phys. Rev. Lett., 1961, Vol. 6, No. 9, pp. 446-449.

[8] J.Barley, V.Medjidzade, A. Mikhailichenko, "New Positron Source for CESR", CBN 02-8, Cornell LEPP, 2002.

[9] A.A.Mikhailichenko, "Optimized parameters of the Helical Undulator for test at SLAC", LC02, Proceedings, SLAC-WP-21.