

SLAC TEST PULSED UNDULATOR CONCEPT

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For test polarized positron generation scheme at SLAC, an undulator having period ~2.4 mm, clean aperture ~0.9mm and the length ~50cm required. We represent here for references the concept and parameters of such pulsed device.

GENERAL

Let us remind again some parameters of SLAC beam, important for proper design of undulator. The 50 GeV beam has emittance $\gamma\varepsilon \cong 3 \times 10^3 \text{ cm}\cdot\text{rad}$ with population $\sim 5 \times 10^{10}$ and repetition rate ~10 Hz in experiment planned at FFTB area. The undulator for test of polarized positron production scheme will be located in a crossover of envelope function having its value there $\beta_0 \cong 300\text{cm}$ (~twice the undulator length). This will allow the beam size $\sigma \cong \sqrt{(\gamma\varepsilon)\beta_0} / \gamma \cong 3 \times 10^{-3} \text{ cm}$. Half aperture required for ten sigma margins goes to $\cong 10\sigma \cong 0.3\text{mm}$, or 0.6 mm for full aperture clearance, slightly (~11%) expanding toward the ends, what is much within the tube ID.

We will use a 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)¹. This tube allows the ID diameter 0.889 mm available for the beam. StSt tube required. Basically undulator is an air core one. General concept of pulsed undulator is represented in Fig. 1.

Case made on StSteel allowing good accuracy in positioning and good withstanding against coolant liquid.

One can imagine the wires as two helixes with period 2.4-mm wound around the tube, Fig.1. Kapton insulation of 0.0762 mm (3mils) will interlace wires and tube. Two helixes wound with copper wire of 0.6 mm in diameter enclosed onto the same tube and shifted on a half period. The currents with opposite sign feed these wires. Configuration Fig.2 allows good positioning and alignment of wires and tube.

Concept of design, represented in Figs.1,2 tested [1, 2] in undulator with period 6mm, tube with 4mm ID and copper wires having rectangular shape.

To see if technology used can be scaled to the 2.4-mm period a 240-mm model was fabricated, Fig. 3. G10 end caps allow control of polarization of magnetic field at the exit. Wires used in this model were round. Wires having rectangular shape give better performance (~15% more field) [1].

This model was tested for static voltage insulation breakup up to 1kV, keeping resistance higher than 1Gohms at this voltage.

¹ New England Small Tube Catalog, tube GS#19, XTW.

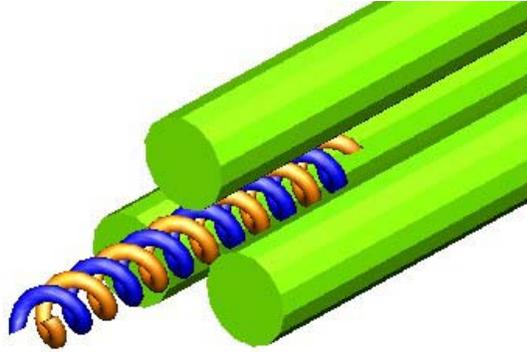


FIGURE 1: Bi-helical wiring. Vacuum chamber is not shown here. Three G10 cylinders serve as part of supporting/alignment system, see Fig.2 below.

Basically the helices squeezed between three rods, so the position of the helices is well established in transverse dimension. Upper rod has grooves having period of helix, fixing longitudinal position of the wires.

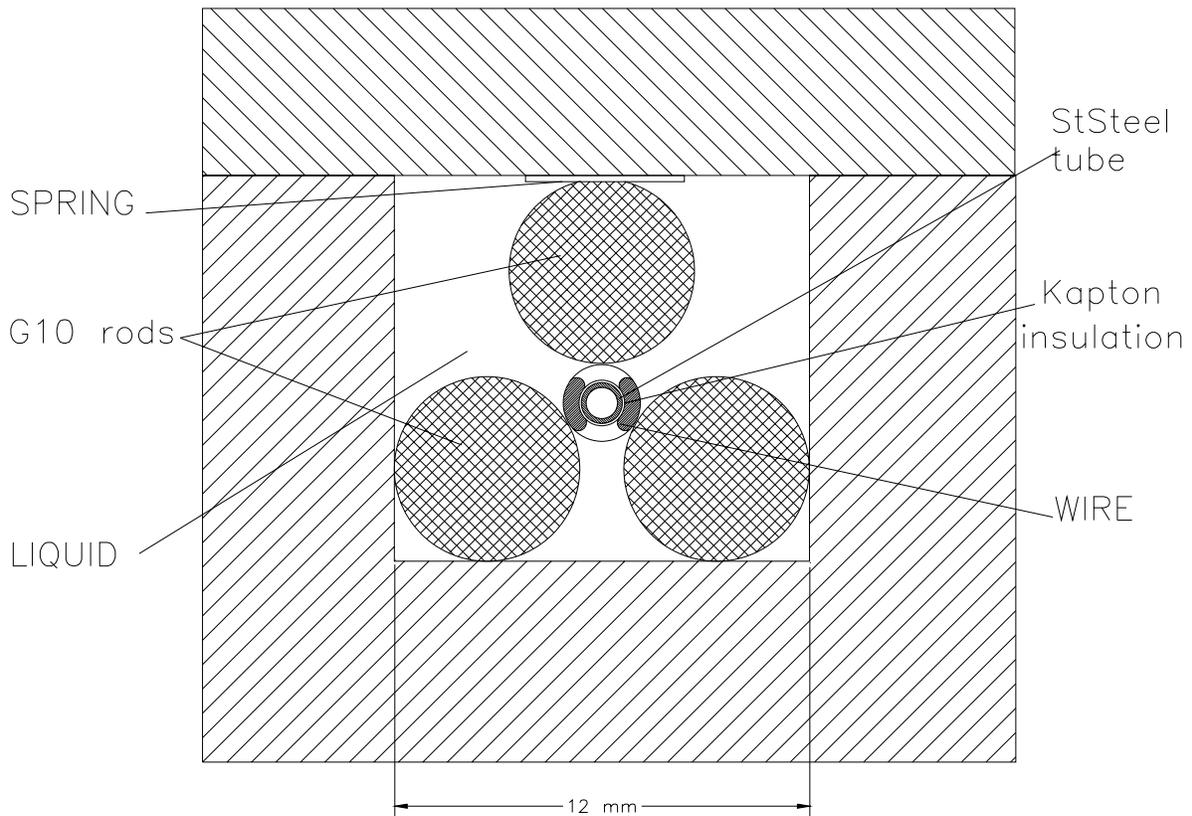


FIGURE 2: Cross-section of undulator. StSteel tube has OD diameter of 1.067mm, ID diameter – 0.889mm, what is $>20\sigma$ however. Wire has diameter ~ 0.6 mm. Two wires separated by gap ~ 0.6 mm. Walls of the case are not in scale, they will be more thick. The case provides good alignment. Coolant liquid is in good contact with wires.

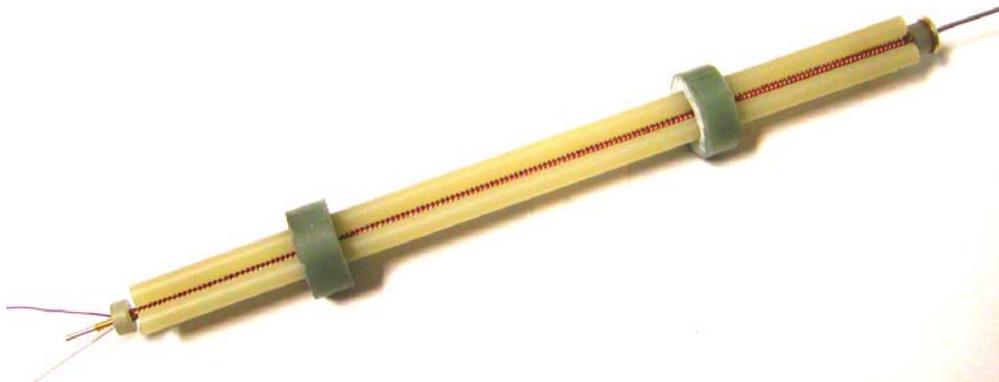


FIGURE 3: Model of pulsed undulator with period of 2.42 mm. G10 rods have length 231.5 mm.

At the ends, the helices will be made with slow increase of diameter, extended from regular one to about three times bigger. Some metallic screening cylinders will be used to adjust the field profile.

PARAMETERS

Parameters of undulator are represented in Table below. Voltage required based on the calculation of inductance done together with field calculations ².

Table 1.

Parameter	Value
Length	50cm
Period	2.4mm
K	0.19
I	2 kA
Pulse width	30 μ s
Energy/length	~ 0.072 J/cm
Inductance	$\sim 3.6 \times 10^{-8}$ H/cm
Resistance	~ 0.0025 Ohm/cm
Inductive Voltage/length	6.9V/cm of length
Resistive Voltage/length	5V/cm

So, a 50 cm long device will have total inductance $\sim 1.8 \mu$ H and it will be necessary to have full input voltage ~ 600 V. Power supply needs to be design for a higher voltage, due to the losses in transmission line. Discharge will be with significant aperiodic component, significant amount of energy will be dissipated. The temperature gain per pulse calculated to be ~ 5 deg. Full resistance of 50 cm long unit goes to 0.125 Ohm, so impulse power goes to 0.5 MW. For 30 μ s duty pulse averaged per single pulse per second power goes to 7.5 W, which comes to 75 W for 10 HZ repetition rate. Transformer oil will be used as a coolant liquid. Cooling of this oil will be done either in

² Will be published in a separate note.

special heat exchanger and/or by cooling the walls of case by water, so convection in will be responsible for transferring heat from wires to the walls and further to the water.

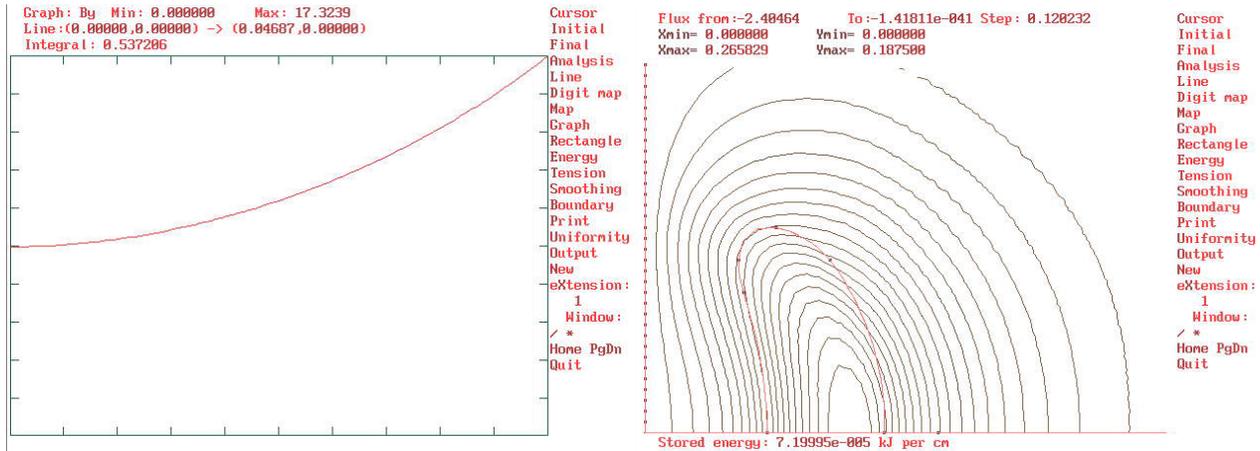


FIGURE 4: Field profile across undulator aperture. Feeding current 2 kA. Calculations from MERMAID for round wire. Wire with rectangular cross section will give ~15% more field for the same current.

In Fig.4 some outputs from MERMAID are shown. On the left graph the field as a function of transverse coordinate is represented. Field at center is ~8.5kG. At the right the lines of magnetic field in transverse plane are represented.

HARDWARE IN GENERAL

For more accurate measurements two sections of pulsed undulator will have opposite helicities allowing opposite helicities for gammas respectively³. These sections will be located in the same case along the vacuum tube. Suggested, that each of these two sections can be feed by pulser with any time pattern, for example switching helicities of gammas every next pulse. In principle, two sections can be triggered in the same time with some adjustment of charging voltage required, Fig 4.

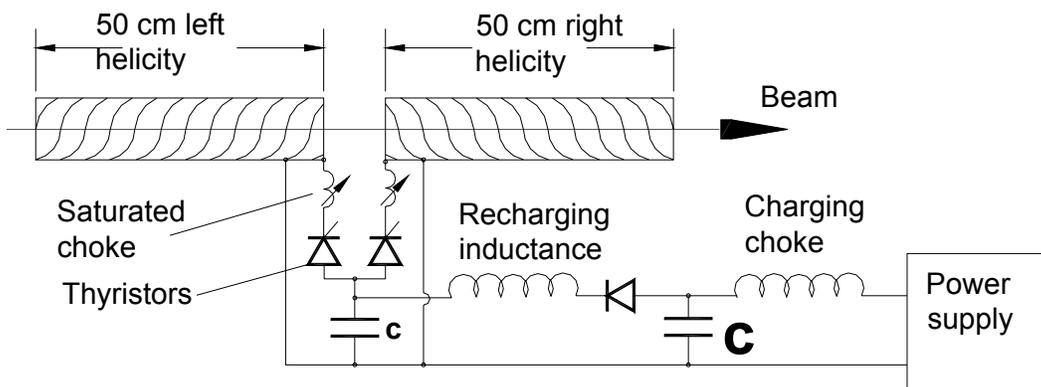


FIGURE 5: General pulsed undulator concept.

³ In future Linear collider polarization will be switched at the exit of the damping ring with help of solenoids and skew quads allowing switch of polarization with any pattern.

In Fig. 6 below the schematic view of device is represented. Some standard elements and techniques will allow preliminary alignment of undulator in line with beam pass.

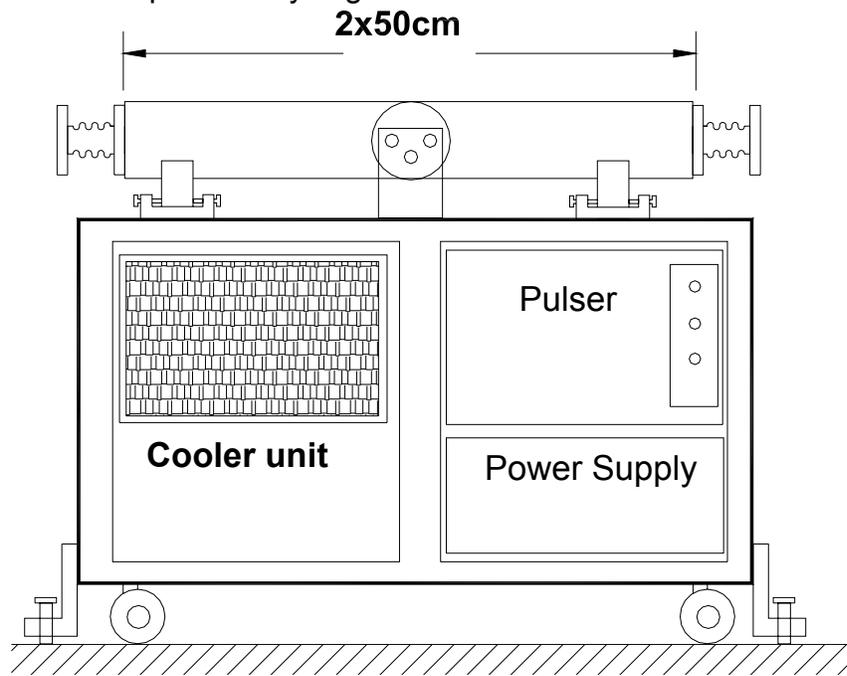


FIGURE 6: General view. Bellows hide in this picture tiny vacuum chamber of undulator.

Power dissipated planned up to ~ 1 kW needs to be removed by circuit with transformer oil as a coolant. The circuit for coolant has a pump and radiator, located in a basement of the undulator stand. The oil will provide additional insulation.

The job will start with preparation of detailed drawings of whole unit. Meanwhile the necessary materials will be ordered. Design will go in the line of utilization as simple elements as possible. After the parts manufactured the assembly will start. Power supply will be not a problem as the voltage and current within single thyristor parameters. It requires some time and lot of small-scale jobs.

Flanges will be the standard VARIAN ones allowing easy accommodation in vacuum system of SLAC. Some pumps will require keeping the vacuum in the chamber at acceptable level, reducing the background.

As the magnetic measurements become difficult in such a small aperture, fields at the center will be evaluated by calculation mostly after careful measurements all dimensions. We suggested as a possibility, that the method with Bismuth wire⁴ [4] might suitable here. Peculiarity here is that the absolute value of magnetic field is constant along the undulator, magnetic field vector makes helical excursion only. So if the signal/noise ratio made acceptable the signal will be equivalent to the one obtained from usual dipole magnet having the same field as on axis and having 50 cm in length.

Scheme of pulser, represented in Fig. 7 below is basically a slightly modified one from [3], successfully tested at CORNELL.

⁴ Bismuth's specific resistance is a function of magnetic field.

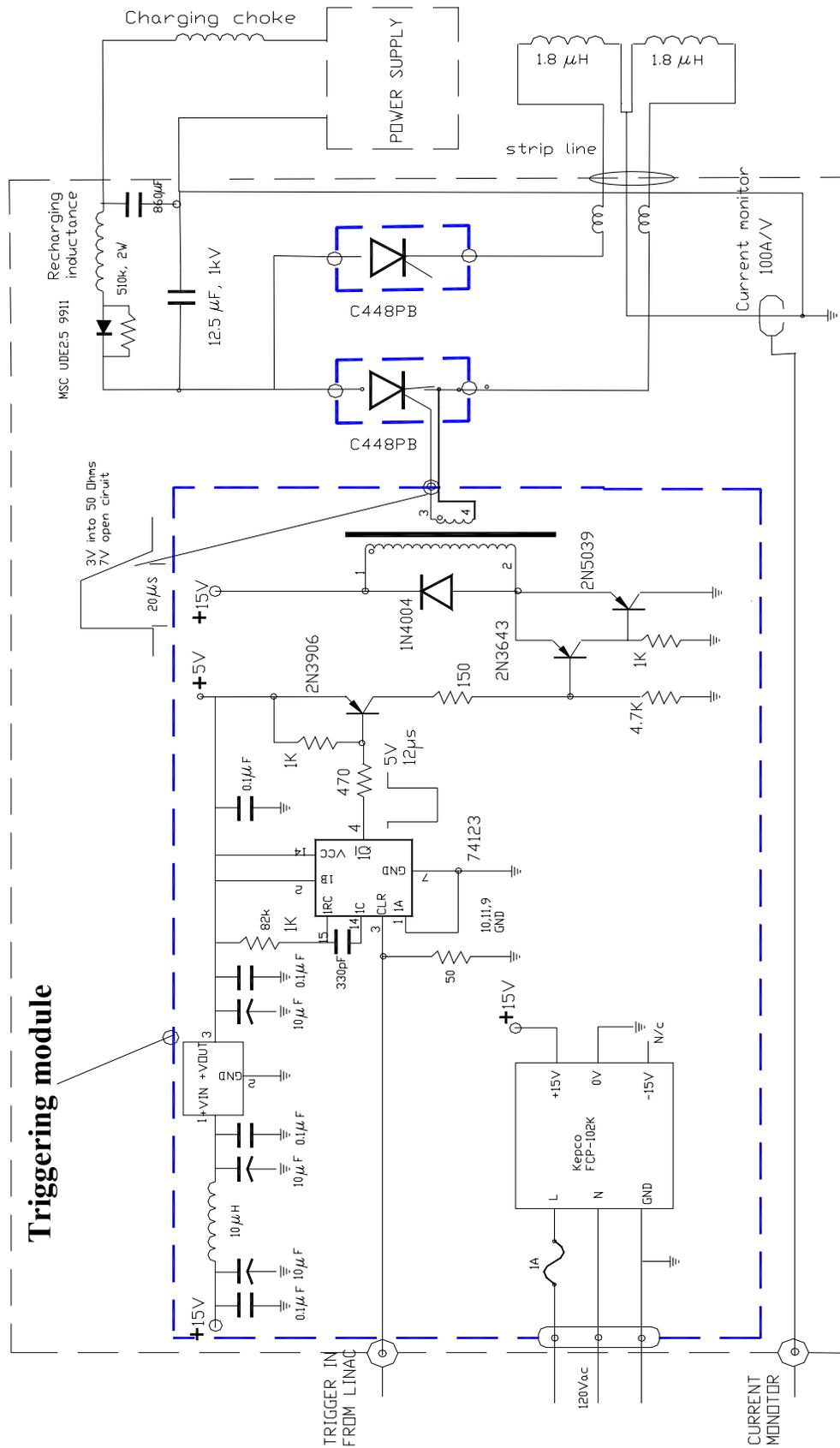


FIGURE 7: Detailed scheme of pulser. Triggering module for second thyristor is not shown.

BUDGET

Cost estimated represented in Table 2 without salaries. Time required for fabrication is less than one year as it is indicated in Table 3.

Table 2.

Institution	Item	Cost, k\$
LEPP	Tests of short models of undulator	5
LEPP	Engineering work, two months	
LEPP	Materials and components	30
LEPP	Manufacturing, tools	10
LEPP	Testing equip., electronics, controls, interfaces, power supply	5
LEPP	Delivery to SLAC and accommodation	10
LEPP	Travel (meetings, workshops)	10
	Total	70
LEPP	Indirect costs (20%)	15
	Grand total	85

Salaries are not included here can be estimated as 100k\$ total for one year. So time schedule looks as indicated in Table 3. Some procedures are going in parallel, however the timing indicated includes this into account. So all elements aligned in time according present best understanding of all job scope.

Table 3.

Procedure	Time estimated
Preparation of drawings	2 months
Obtaining of materials	1 month
Manufacturing	2 month
Assembling (undul.+Pulser)	2 months
Testing	2 months
Spare	2 months

This evaluation gives ~11 months, so one year looks realistic.

CONCLUSION

For test of principle pulsed undulator looks very promising. No doubt, that technology allows fabricating the undulator. It is possible even to reduce period, if the K factor reduction allowed and/or diameter of aperture reduced too⁵. It will be easy to replace core of undulator with the smaller tube, and wiring with shorter period, as the cost of this part is much smaller, than the total one.

LEPP can start manufacturing right after whole experiment is approved. One-year period looks as solid realistic.

For positron collection the optics described in [3] well as SLAC's one can be used. This will require additional power supply and of cause collecting short focusing lens.

Undulator must be equipped by some kind of diaphragm, preventing direct hit by intensive beam. Some steering coils must be implemented in there.

Initial tuning and alignment will go with beam with reduced population at lowered repetition rate, however.

REFERENCES

- [1] A.A. Mikhailichenko, *Dissertation*, BINP, Novosibirsk, 1986.
- [2] T.A.Vsevolojzkaya, A.A.Mikhailichenko, E.A.Perevedentsev, G.I.Silvestrov, A.D. Cherniakin, *Helical Undulator for Conversion System of the VLEPP project*, XIII International Conference on High Energy accelerators, August 7-11, 1986, Novosibirsk, Proceedings, High energy accelerators, vol. 1* 164-167 and SLAC Stanford - SLAC-TRANS-225 (86, rec.Feb.87) 13 p., (IYF) BUDKER INP 86-129, Novosibirsk, 1986
- [3] J.Barley, V.Medjidzade, A.Mikhailichenko, *New Positron Source for CESR*, CBN 01-19.
- [4] A.Mikhailichenko, *Low aperture magnetic elements measurements*, (IYF) Budker INP 89-94, Novosibirsk, Jun 1989, 12 pp.

⁵ Remember, the aperture opening is a 20 sigma with the tube selected by now.