FAST KICKER FOR HIGH CURRENT ELECTRON BEAM MANIPULATION IN LARGE APERTURE

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Abstract

Pulsed deflecting magnet (kicker) project was worked out in BINP (Budker Institute of Nuclear Physics). The kicker design task is: impulsive force value is 1 mT*m, pulse edge is 5 ns, and impulse duration is about 200 ns. The unconventional approach is for plates to be substituted by a set of cylinders. Obtained magnet construction allows controlling field homogeneity by changing currents magnitudes in cylinders. Furthermore we demonstrated the method of field optimization. In addition the harmonic components measurement technique was considered and the possibility to control harmonic components value was shown.

THE KICKER CONCEPT DESIGN

The kicker design should accept several requirements. The first one is vacuum chamber and kicker symmetry axis coincidences. The second one is that central angel should be about 90˚. The optimisation parameter is magnetic field homogeneity in centrally located square area (2 cm x 2 cm).

THE KICKER ACTUAL DESIGN

Taking into account the kicker design optimization results described in [1], the BINP designers developed a kicker prototype. The kicker dimensions were selected based on measurements. The magnet cross section is shown in Fig. 1. The physical magnet length is about 650 mm. The magnet aperture is 100 mm. The vacuum chamber diameter is 164 mm. The cylinder diameter is 28 mm. The cylinders are made of steel, as well as the body of the magnet. The ceramic feedthrough also was developed in BINP.

For the simulation of dynamics of charged particles beams the CST Studio is used. These simulations are in the initial stage. Only preliminary calculations have been held. One of the first results is shown in Fig. 2.

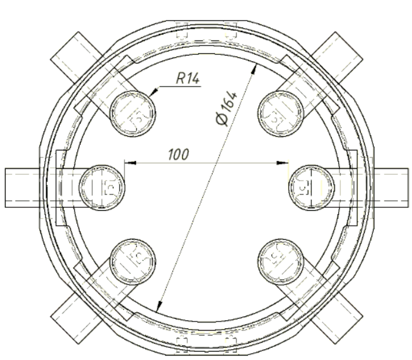

Figure 1: The kicker actual design (all dims are in mm).

MAGNETIC FIELD MEASUREMENTS

To control magnetic field quality the experimental measurements was carried out.

Experimental Stand Description

Experimental stand shown in Fig. 3 consists of the following parts:

1. Kicker
2. Pulse generator
3. The induction coil magnetometer
4. VSDC2 - Precision digital signal integrators with an accurate synchronization [2]
5. Hand caliper
6. Step motors with controllers
7. PC with a special software

The kicker is fixed on a metal frame. Step motors provide the movement in the horizontal plane. The vertical displacement of step motors is realized only by screws turning by hand. For both step motors we have to control vertical position using hand caliper. All of the stand components were precisely aligned with the help of BINP geodesy group.

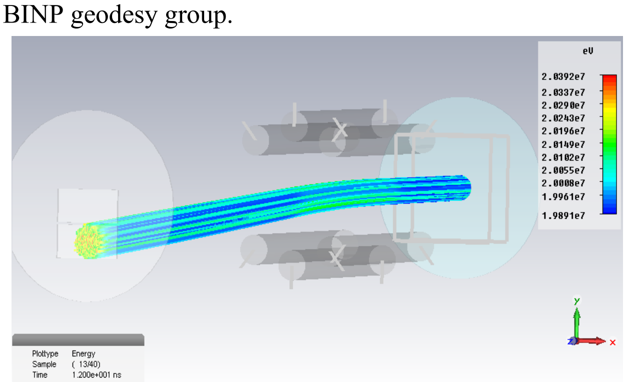

Figure 2: Beam dynamics simulation in CST.

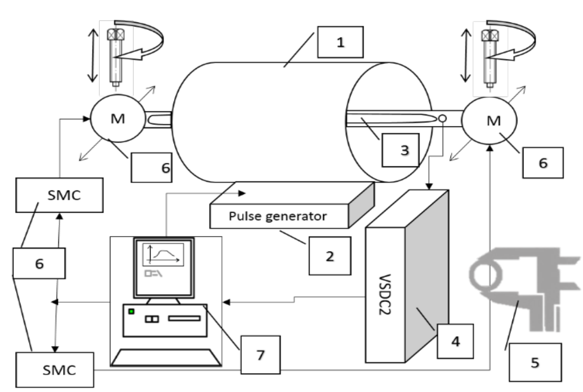

Figure 3: The principal scheme of magnetic field measurement stand: 1) kicker, 2) pulse generator, 3) the induction coil magnetometer, 4) VSDC2, 5) hand caliper, 6) step motors with controllers, 7) PC with special software.

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The Induction Coil Magnetometer

The induction coil consists of five wire turns ($N = 5$). It has the width w=5 mm and the length l=1000 mm. The wire diameter is 0.2 mm. The coil base is made of the fiberglass plastic strip. Induction coil principle is derived directly from the Faraday's law:

$$E(t) = -\frac{d\Phi_B(t)}{dt}, \qquad (1)$$

where E is the electromotive force (EMF) and Φ_B is the magnetic flux. The EMF time integration gives us magnetic the flux. From magnetic flux definition we get the maximal magnetic field value:

$$B_{\max} = \frac{-\int_0^{T_0} E(t)dt}{N \cdot w \cdot l}, \qquad (2)$$

where T_0 is the integration time chosen such to provide a maximum integral value, N, w and l described upper are the coil geometrical parameters.

For example, in Fig. 4 one can see typical signals. The first channel (grey dashed curve) is a signal from the coil and the second channel (black curve) is a current monitor signal.

We supply the coil signal to VSDC2. The software "S-Wire Kicker" created at BINP is close integrated in the experimental stand. The program can control step motors, pulse generator and store results of measurements on HDD.

Magnetic field distribution was measured in central part of the kicker. The exploring area is almost 2x2 cm square. Measurements were carried out in the five vertical positions: -2 cm, -1 cm, 0 cm, 1 cm and 2 cm. Horizontal shift was realized by the program "S-Wire Kicker" automatically within the range from -1.8 cm to 1.8 cm with a step of 0.1 cm. In each point five measurements were done and then they were averaged. Using obtained values we form the magnetic field distribution map. To compare experimental results with calculation we simulated FEMM task with the same current value as we get from the current monitor.

Magnetic Field Measurements

To measure the magnetic field distribution in experiment we used a single generator. With the aim to control a current in the separate cylinders the Variable Resistance Unit (VRU) was made. The commutation scheme with VRU is shown in Fig 5. To anticipate we can get the better magnetic field distribution as a result of using this scheme.

Experimental Results

In this part we present the results of magnetic field measurements. The experimental data in comparison with calculated once in FEMM are shown in Fig. 6 ((a) – experimental, (b) – calculation in FEMM).

We can see that the measurement results with a sufficiently high accuracy agree with the simulation results.

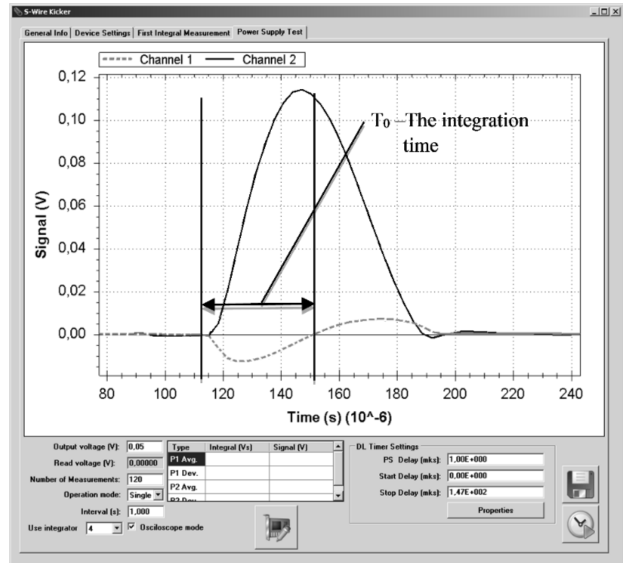

Figure 4: Typical signal from magnetometer (Channel 1) and current wave form (Channel 2).

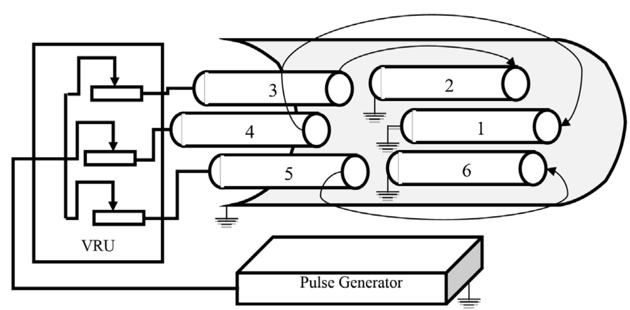

Figure 5: The kicker commutation diagram with Variable Resistance Unit (VRU).

We have an opportunity to control a magnetic field distribution and homogeneity. To implement this we need to set the specific current values in each conductor. The parametric optimization simulation was done in FEMM. We consider upper and lower conductors current value to be I_0 A. The current value in central conductor is $k \cdot I_0$ A, where k is optimizing parameter:

$$I_2 = I_6 = -I_3 = -I_5 = I_0,\ I_1 = -I_4 = k \cdot I_0.$$

The optimization goal is to minimize ΔB – field quality indicator:

$$\Delta B = \frac{B_{\max} - B_{\min}}{B_{\min}} \cdot 100\% \qquad (3)$$

As a result of the optimization we have the following ratio: the first and fourth currents must be one point five times greater than others, i.e. k=1.5.

By means of VRU mentioned above the current in each conductor was tuned in accordance with optimization results. After this measurement was repeated. Obtained results are shown in Fig.7.

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The magnetic field measured experimentally turned out non-symmetric. However we see that the homogeneity value is close to calculated one. The reasons of this non-symmetry is not completely explored.

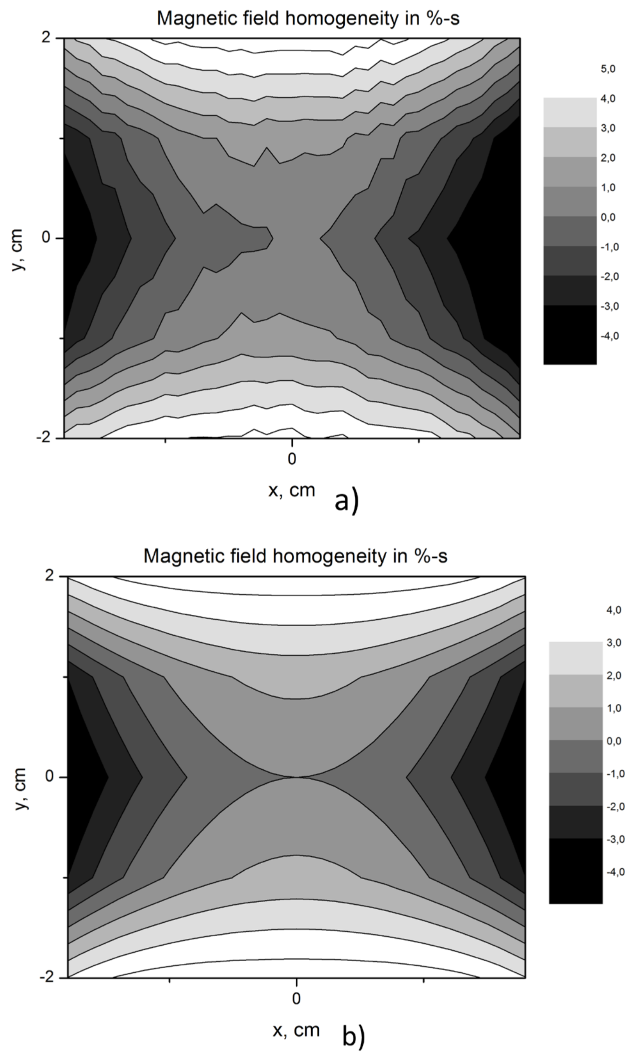

Figure 6: Magnetic field homogeneity: a) measured, b) calculated.

We have a number of assumptions, but they need to be checked. One of them is the limited induction coil magnetometer accuracy and other is some imperfections in electrical contacts. We plan to repeat measurements to provide more accurate results.

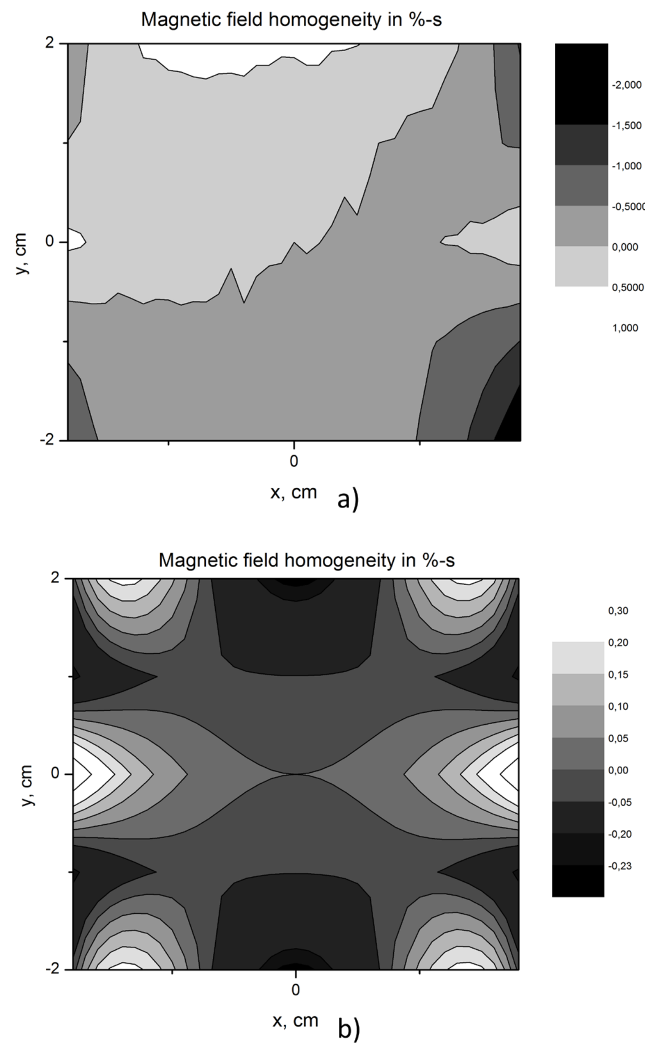

Figure 7: Magnetic field homogeneity: a) measured, b) calculated.

SUMMARY

The design of non-conventional kicker was developed in BINP. The kicker was manufactured. We carried out the magnetic field measurements. For this purpose the magnetic measurement stand was created and tested. We have plane to improve our measurements in future.

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