A NEW SLOTTED-PIPE KICKER MAGNET FOR BEPCII STORAGE RING

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Abstract

For the severe requirements of BEPCII injecting kicker magnets, the two schemes of low impedance kicker magnets used in other accelerator labs in the world are not adaptive to the BEPCII storage ring. A new scheme of kicker magnets proposed in this article solves the difficult problem of BEPCII kicker magnet design. And the successful construction of a prototype has demonstrated that the new scheme of kicker magnets is viable and the design of the kicker magnet structure is reasonable.

INTRODUCTION

The physics design of BEPCII storage ring requires that the kicker magnets for injection must have properties of both wide good field region with high field uniformity and low beam impedance. In the range of $\Delta x=\pm 20$mm, the field uniformity is required to be better than ±1% in the central plane, ±2% in the y=±5mm plane and ±5% in y=±10mm plane. And the effective beam impedance of each kicker magnet must be lower than 0.025Ω.

At present, one type of low impedance kicker magnet widely used in other accelerator labs[1-2] in the world is window-frame ferrite-core kicker magnet with ceramic tube metallized on the inside surface as its vacuum chamber. The ceramic vacuum chamber is the key component of the kicker magnet. It is used to allow the external time-varying field to penetrate the vacuum chamber, while a thin metallic coating is required to carry beam-induced image currents. However, for BEPCII kicker magnets, since the aperture of its vacuum chamber is so large (108mmx54mm) and the rise time of its magnetic field is very fast (<300ns), the simulation of OPERA program shows that the field penetrating the ceramic chamber metallized on the inside surface deforms dramatically. Both the field waveform and the field uniformity of the kicker magnet could not meet the requirements of its design.

Another low impedance kicker magnet is called slotted pipe kicker magnet, which is developed at Delta[3]. The magnet is constructed by placing a slotted metal pipe inside a stainless steel vacuum vessel. Four slits are cut along the length of the pipe to create the two buses along with image current paths. Both buses are driven from the one end by a bipolar kicker pulser, and are shorted at the opposite end.

One of the most important features of the slotted-pipe kicker design is the two metallic bands between the buses above and below the beam axis. Because of their small distance to the beam, they carry the dominating fraction of the image currents traveling with the beam along the vacuum pipe. Consequently, wake fields and RF losses are reduced significantly. However, the two metallic bands also shield the time-varying field completely at the center of the magnets and spoil the field uniformity seriously. That is to say there is a great contradiction between the field uniformity and the beam impedance. The wider the bands are, the lower the beam impedance is, but meanwhile the worse the field uniformity becomes. For the large vacuum chamber and the severe requirements of the BEPCII kicker magnets, the simulation of OPERA program and MAFIA program shows that the contradiction of the slotted-pipe kicker magnet is too strident to be resolved.

In order to solve the difficult problem of the BEPCII kicker magnet design, a new idea that using the ceramic plates with metal coating films replaces the metal bands as the image current path of the slotted pipe kicker magnet is proposed. With the appropriate thickness, the metal coating films on the ceramic plates can shield completely the electromagnetic field induced by the beam, meanwhile let the kicker field passing through it almost without deformation and attenuation. The idea derives from the design thought of the ceramic vacuum chamber metallized on the inside surface, but it releases the contradiction between the field uniformity and the beam impedance of the slotted pipe kicker magnet. That means the new idea has combined the advantages of the two type of low impedance kicker magnets and produced a new kicker magnet with low impedance, wide good field region and high field uniformity for BEPCII storage ring.

THE DESIGN OF A NEW SLOTTED PIPE KICKER MAGNET

The cross section of the new slotted-pipe kicker magnet is given in Figure 1. The magnet is surrounded by a cylindrical vacuum tank of 305 mm in diameter separated into three parts. It is formed by two current busses and two ceramic plates. The plates have double functions of fixing the current busses and supporting the coating films. The aperture of the kicker magnet is 90mm×44mm. The coating strips are coated on the inner surface of the ceramic plates. The width of the coating strips is 34 mm. The sheet resistance of coating is 0.2Ω. The magnet is fed by a bipolar pulser via a feedthrough at one end of the magnet, the other end of the magnet is grounded by the vacuum vessel. For the different apertures of the normal vacuum chamber and the kicker magnet, the end transition parts are needed. The smooth transition between the apertures of the kicker magnet and the normal vacuum chamber is very important to make the whole beam impedance of the kicker magnet small. In order to decrease the difficulties of the ceramic plate manufacture, each ceramic plate of 1564mm long is cut into two pieces of 782 mm long, but meanwhile the films coated on the plates are also broken off. The problem could be solved as following ways. While the two pieces of plates are arranged in series to form the whole one, the image current return path could be resumed by inserting

0-7803-8859-3/05/$20.00

an elastic copper connector in the joint of the two ends as long as the end surfaces are also coated the metal films. The other ends of the whole coating films are connected to the transition end parts with a good electrical contact. The heat due to synchrotron radiation, image and eddy current is extracted by the water-cooling systems embedded in the buses.

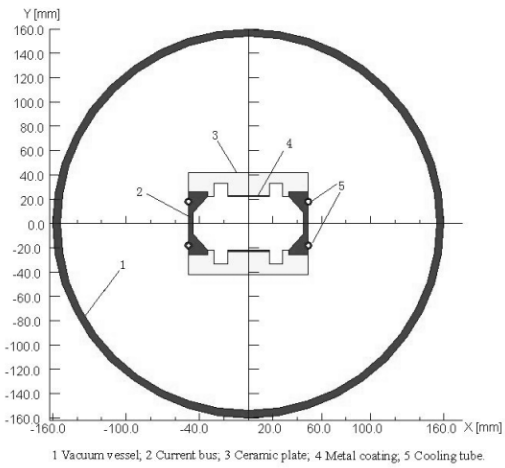

Figure 1: The sketch map of the kicker magnet

The calculated results of the magnetic field by OPERA are shown in Figure 2 and Figure 3. Within the region of $\Delta x=\pm 20$mm, the field uniformity is ±0.6%, ±0.7% and ±2.9% respectively on the plane of y=0, y=±5mm and y=±10mm. They are all better than the requirements of the BEPCII injection kicker magnets.

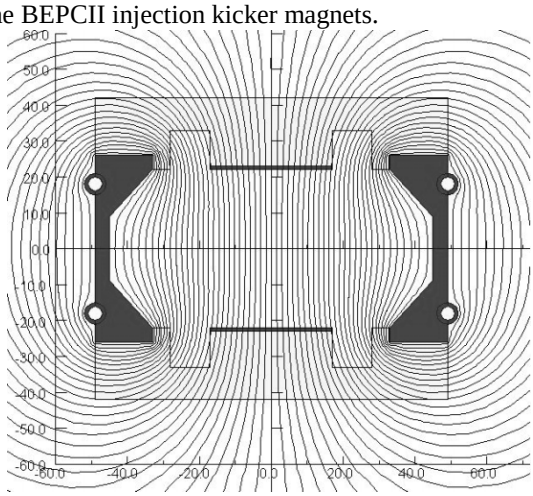

Figure 2: Field plot of the magnet

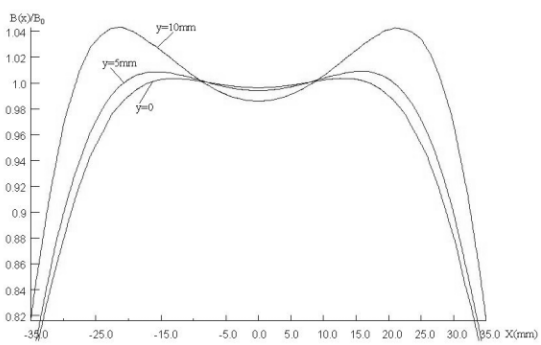

Figure 3: Field distribution of the magnet

The simulated results from MAFIA program show that the effective value of the beam impedance $|Z/n|$ is less than 0.022Ω, it also meets the requirement of the beam impedance. So the contradiction between the beam impedance and the field uniformity, which exists in the slotted-pipe kicker magnet developed at DELTA, has been nicely solved. And a new slotted-pipe kicker magnet used for BEPCII injection was finally come into being.

MANUFACTURE OF THE NEW SLOTTED-PIPE KICKER MAGNET

The new slotted-pipe kicker magnet consists of vacuum tank, current buses, ceramic plates coated with metal films, end transition components and high voltage feedthrough. The vacuum tank is made of three cylindrical stainless steel tubes of 305mm in diameter. It services not only to provide vacuum for the kicker magnet, but also to support the whole magnet. The buses and their cooling tubes are made of copper for its good thermal and electrical conductivity. Since they are 1500mm long, the manufacture and their cooling tubes welding with good quality are very difficult. The ceramic plates are 781mm long, 100mm wide and 20mm thick, it is the most challengeable work to produce such large ceramic plates and to coat high quality films on their appointed surface regions. To finish the hard work, four different high-tech companies in China have made their great efforts. In the process of manufacture, the ceramic plates have broken several times because of less experiences. The method of silk-screen of resistive paste was adopted to produce the film on the ceramic plates. The advantages of the method are the easy control of the sheet resistance values, the uniformity, the electrodes making and the whole quality of the films. One of the finished ceramic plates is shown in Figure 4.

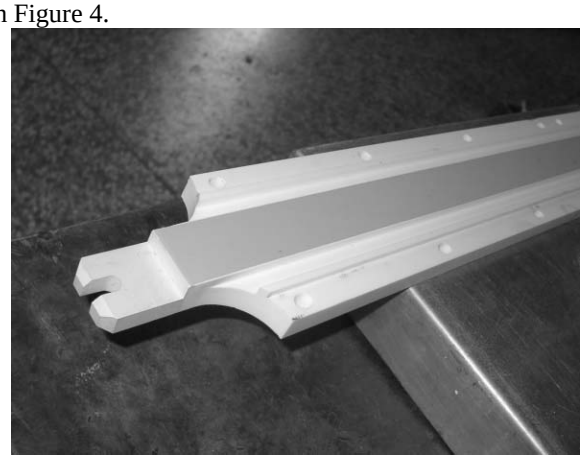

Figure 4: The finished ceramic plates

The end transition components function as the aperture matcher between the kicker magnet and the normal vacuum chamber, the supporters for the ceramic plates and the connectors with the vacuum tank. They are also made of copper for its good thermal and electrical conductivity. The high voltage feedthrough is another troubled component to be made, the welding between the copper electrodes and the ceramic tubes has failed several

times before finally finished. We are considering modifying the design of the feedthrough in the other BEPCII kicker magnets.

After all the components are completed, the much care need be taken on the assembly of the whole kicker magnet, because any asymmetry of the magnet structure could spoil the field symmetry and further cause the field uniformity worse than ±1% in the central plane. The final assembled kicker magnet is shown in Figure 5.

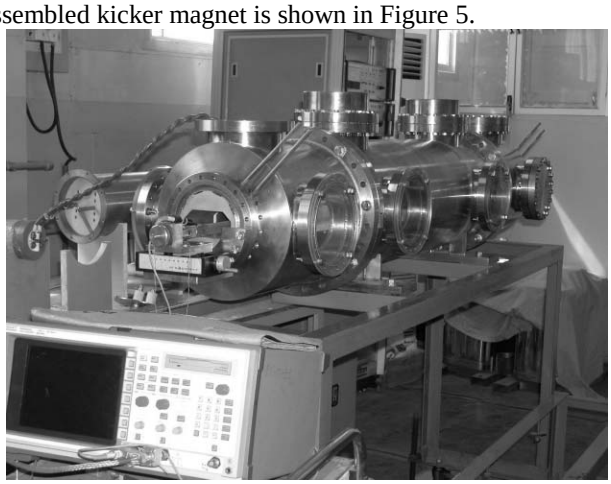

Figure 5: The assembled kicker magnet

EXPERIMENTAL RESULTS

A field map was measured on a test bench as shown in figure 5. During measurements, the kicker was driven by a half sinusoidal current with an amplitude of 680 A and a bottom width of 578ns. The waveforms of the exciting current and the magnetic field of the kicker magnet are shown in Figure 6. It can be seen that the magnetic field penetrates the metal coating on the ceramic plates with a little time delay as the OPERA program predicted[4].

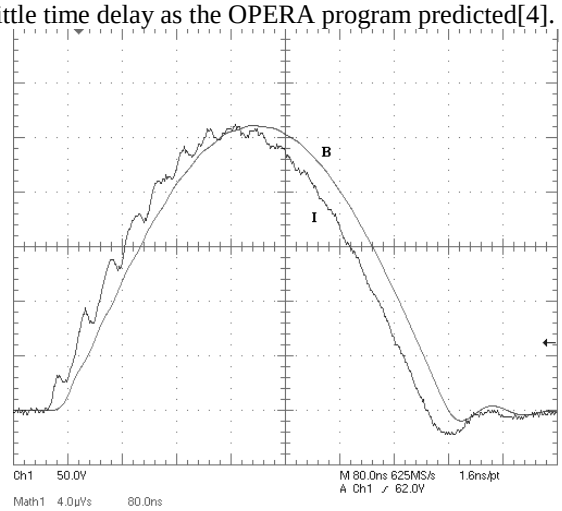

Figure 6: The wavforms of the current and field

The measured field uniformity on the plane of y=0, y=±5mm and y=±10mm are ±0.74%, ±0.91% and ±2.85% over the transverse dimension of ±20mm as shown in the figure 7. The measured results show a good agreement with the simulated values as shown in figure 3.

The impedance of the kicker magnet has also been carefully measured and studied by the accelerator physics team. In the frequency range from 0 to 1.5 GHz, the measured loss factors of 0.011V/pC[4] for the impedance of the whole kicker magnet are so small as MAFIA simulated.

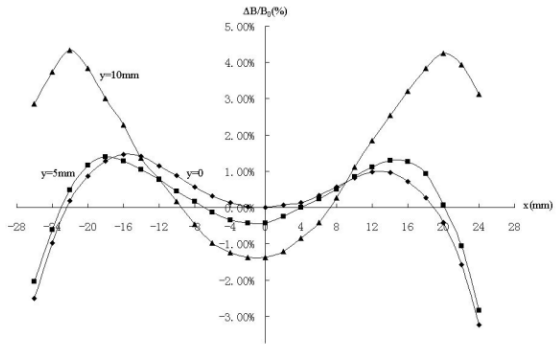

Figure 7: The field distribution curves

CONCLUSION

In order to meet the severe requirements of BEPCII injection, a new slotted-pipe kicker magnet has been creatively proposed and successfully developed. Either the computer simulation or the experimental results has shown that the new kicker magnet has the required properties of both wide good field region with high field uniformity and low beam impedance.

ACKNOWLEDGEMENTS

We would like to thank Dr. Wang Jiuqin who has done a lot of research work on the kicker impedance calculation and measurement. We also thank Prof. Huang Nan for her strong support in all phases of the new kicker development.

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