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NEW NONLINEAR KICKER DESIGN AND MEASUREMENT*

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Abstract

For the beam injection of Hefei Advanced Light Source (HALS), a practicable injection scheme is proposed and a single-pulse nonlinear kicker is designed for off-axis injection. The design of kicker has been improved on the basis of the previous one. The structure of the kicker was calculated by OPERA, and the prototype has been processed and measured. The results illustrated that the kicker designed in this paper has less influence on stored beam and less difficulty in installation.

INTRODUCTION

HALS is a fourth-generation diffraction-limited storage ring with high brightness and good lateral coherence. It is working in the VUV and soft X-ray region, and becomes one of the development direction of NSRL researches at present [1]. The latest version of HALS has a 7BA lattice and an energy of 2.4 GeV. Meanwhile, many high-performance inserts can also be installed at the drift space. Main parameters of HALS are listed in Table 1 [2].

Table 1: Main Parameters of HALS

Beam energy (GeV)	2.4
Circumference (m)	672
Number of lattice periods	32
Natural emittance (pm·rad)	23.0
Tune (ν_x/ν_y)	78.304,29.382
Natural chromaticities	-109,-126
Momentum compaction factor	4.5e-5
Damping time ($\tau_x/\tau_y/\tau_z$, ms)	32.7/49.4/33.2
Length of long straights (m)	5.1

Due to the small dynamic aperture of HALS, we proposed two methods to achieve the beam injection: on-axis swap out injection [3] and off-axis single kicker injection. At present, both injection schemes are taken into account. The latter method is similar to the pulse multipole injection [4, 5] but the magnet is replaced by a pulsed nonlinear kicker(NLK) [6, 7]. There is a zero magnetic field flat in the center of the kicker, which can reduce the oscillation of stored beam significantly during beam injection, and the area with strong magnetic field can deflect the injected beam. The magnetic field of NLK varies with position, which means that the magnetic field at the center is almost zero, extending and increasing outwards on both sides of the symmetrical center.

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According to the different designs of kickers, the distance to reach maximum field strength is also different. Figure 1 shows how the strength of the nonlinear magnet field changes with position. We proposed the first design of this ferrite NLK on IPAC2017 [8]. In this paper, we have improved the kicker's structure based on this, simultaneously, a prototype of the kicker has also been manufactured and tested.

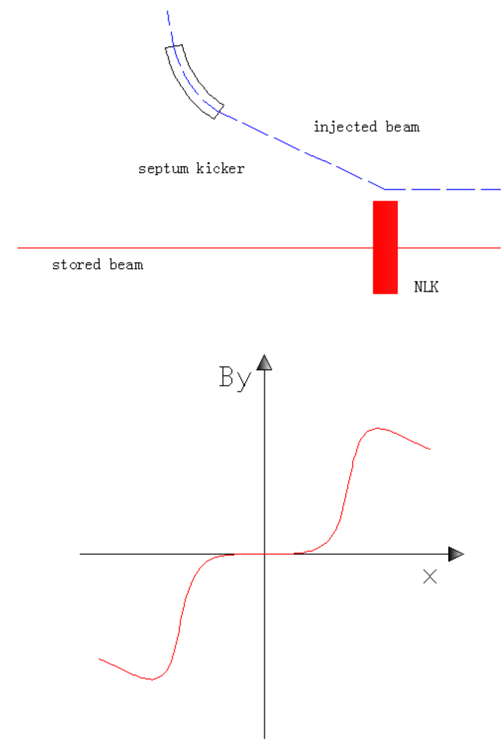

Figure 1: The layout of single pulse nonlinear kicker injection (the injected beam is deflected by the septum magnet into the NLK) and a diagram of magnetic field distribution in NLK.

STRUCTURAL DESIGN OF THE KICKER

The magnet consists of two C-type ferrite cores (the blue part of Fig. 3), vertical shielding plates (the green part on the top and bottom of Fig. 3), horizontal bending shields (the green part in the middle of Fig. 3), and current plates (the red part of Fig. 3). The 0.5 mm thickness vertical shielding plates inserted between the two cores can prevent the flow of magnetic lines caused by the plates. The pulsed magnetic field can be generated by the pulsed current with same size and direction through the current plates. In addition, the

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bending shields with a gap of 12 mm between the arc tops will reduce the central magnetic field. The area in the middle of the shield allows the storage beam to pass without influence of the kicker, while the injected beam will be deflected by the magnetic force.

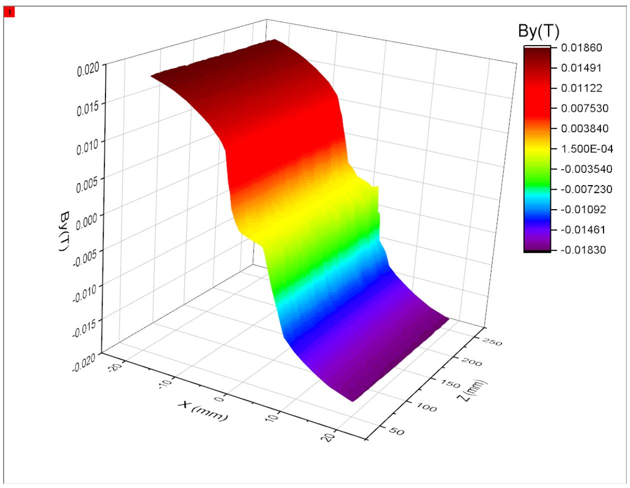

Figure 2: Simulation by OPERA3D and the magnetic field in the By direction on the XZ plane.

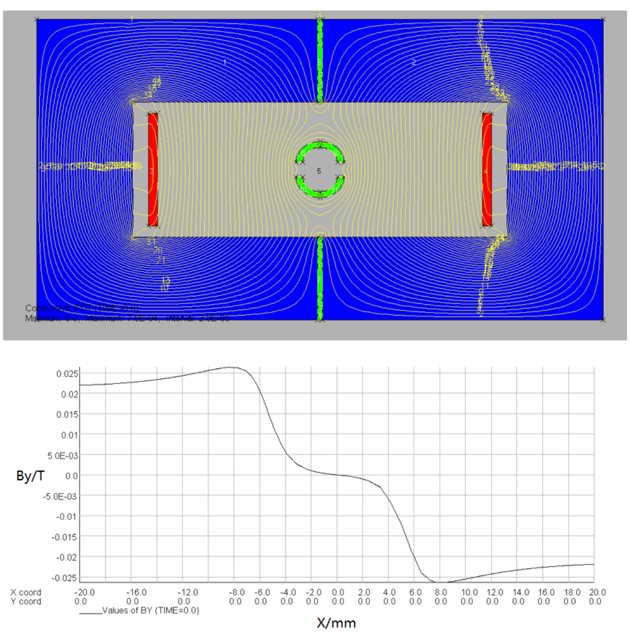

Figure 3: Simulation by OPERA2D and the magnetic field line Distribution in the NLK.

The NLK was calculated by OPERA2D/3D with a 600 A analysis current at 238 kHz. Calculation results are in expectations, since the gradient in the central region field is extremely small, and the position of the peak region is also not far from the center.

After that, a cavity will be placed outside the bending shields, and the injection beam can pass through the vacuum

Table 2: Main Parameters of the NLK

Magnet aperture (mm×mm)	85×36
Magnet length (mm)	300
Analysis current (A)	600
Analysis influence (kHz)	238
Peak magnetic field (Gauss)	263.5
Position at peak magnetic field (mm)	7
Slope of the central magnetic field (T/mm)	8e-5
Gap between the two shields (mm)	12
Power loss of the copper bending shields (W)	3.66
Magnet inductance (uH)	9.83

cavity. In addition, whether a titanium layer is needed or not is determined by impedance measurement, however, if a layer is used, it may cause eddy currents and attenuation of the magnetic field.

PROTOTYPE BUILDING AND MEASUREMENT

Before processing the prototype of the kicker, we designed it with SolidWorks [9] and determined the size and fixing details of each component.

The current plates are placed on both sides of the magnet to form a circuit. And the bending shields are a little longer than the kicker that can be set outside the shell easily.

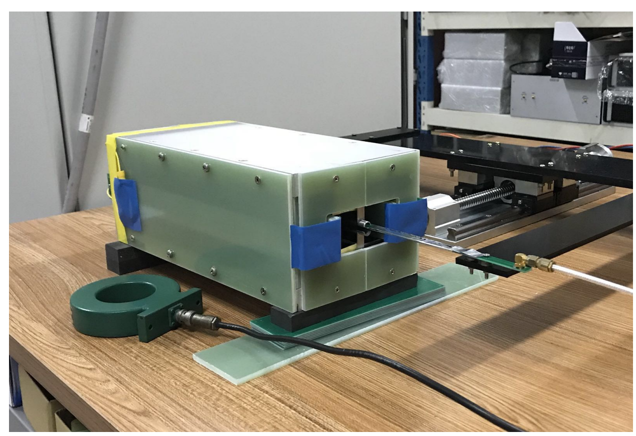

Figure 4: Measurement of the prototype.

The kicker is driven by a pulsed power supply with a pulse duration of 2 us. Since the kicker is so long, we planned to use a long sensor coil to measure the magnet. The sensor is two turns with 0.25 mm width and 500 mm length. It is very sensitive to small magnetic field. Both sides of the sensors are fixed to prevent one of the ends from moving apart during measurement. After integrating the voltage signal of the sensor, the noise of the signal becomes smaller and can be measured by an oscilloscope.

With a 15 kV voltage and a peak current of 1800 A, the peak measured magnetic field is 800 Gauss. The measurement results show that the magnetic field shape obtained by the experiment is consistent with the calculated ones. Since

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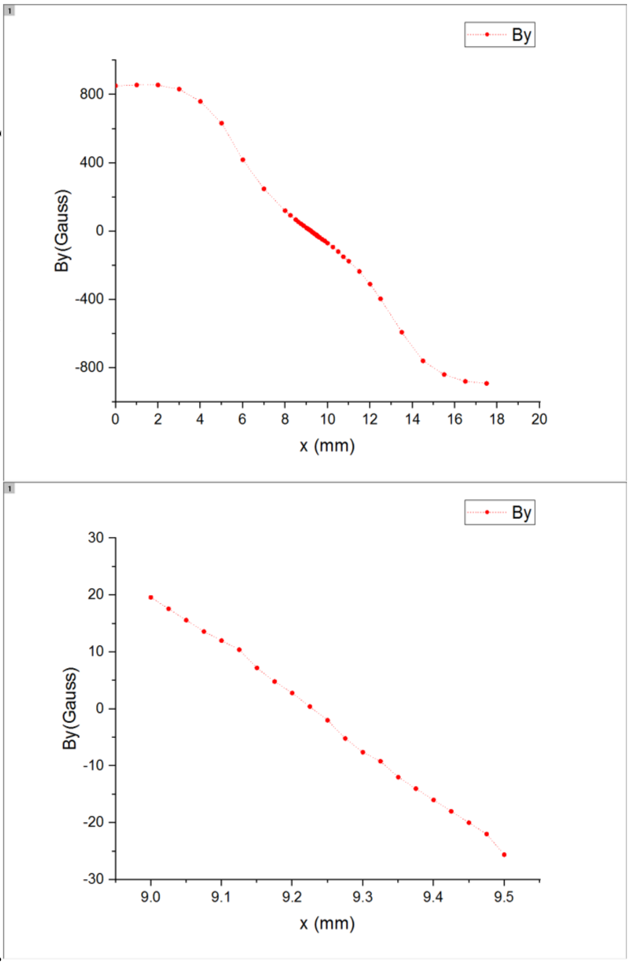

Figure 5: The magnetic field along horizontal direction and a horizontal zoom of magnetic field in central region.

the measurement step size is 0.25 mm, that would result in a limited data collection, and meanwhile, the size of the center region field may not be mapped accurately. When the data is magnified, we can see very small changes at the center area.

CONCLUSION

From the experimental data, it can be seen that the magnetic field in the central region of the magnet does have a platform, which is consistent with the simulation results. Therefore, the magnet can meet the basic requirements of non-linear injection. In order to obtain a larger magnetic field, we only need to increase the current value, but the maximum current will be limited by the peak charging voltage, circuit parameters and insulation of the current plate.

Another factor affecting the work of magnets is the heat, however, the heat problem can only be determined after measuring the impedance of the kicker. It is expected that the heat is mainly generated by the beam coupling impedance, which can be absorbed by the flanges at both ends and cooled naturally.

OUTLOOK

In the future, we will continue to optimize the structure of the magnet and measurement scheme to make the small magnetic field area more obvious. The beam is required to be injected at 3 mm in HALS, so the magnet must be modified to achieve 300 Gauss magnetic field at 3 mm. In addition, it is necessary to simulate the injection beam with ELEGANT as soon as possible.

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