ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPMP015

STATUS OF THE R&D FOR HALS INJECTION SYSTEM*

L. Shang, F. L. Shang, Z. B. Sun, W. Liu, W. B. Song, Y. M. Lu
National Synchrotron Radiation Laboratory,
University of Science and Technology of China, Hefei, China

Abstract

Hefei Advanced Light Source (HALS) is a diffraction-limited synchrotron radiation source proposed by the NSRL. A comprehensive R&D program funded by the local government was initiated in the end of 2017. The program focuses on the key technologies including the injection, magnets, vacuum, mechanics, RF, etc. The formal construction of HALS is estimated to begin in 2020.

This paper presents the R&D of the injection system, including the fast kicker, nanosecond pulser, NLK (non-linear kicker) and the septum magnet. Test results of the prototype fast kicker, pulsed power and the NLK are given and discussed.

INTRODUCTION

Hefei Advanced Light Source (HALS) is a newly designed diffraction-limited synchrotron radiation source with an energy of 2.4 GeV, a circumference of 672 meters and a natural emittance of about 23 pm [1]. The latest lattice design of the storage ring uses 32-7BA structure and employs a full energy Linac as the injector.

Injection into storage ring is a critical issue for HALS with such a low emmitance. Because of the small dynamic aperture of the storage ring, traditional off-axis local bump method cannot be used. Several new schemes have been proposed and investigated by some laboratories, including the on-axis swap-out [2], on-axis longitudinal accumulation [3] and off-axis single multipole kicker injection [4].

For the HALS, the injection scheme is not finally determined. Both on-axis injection and off-axis pulsed multipole kicker injection are considered.

A strip-line kicker with ultra-short pulse driven was designed based on the requirements of on-axis longitudinal injection with 100 MHz RF acceleration. Prototype kicker has been assembled and tested.

In the recent research, an off-momentum, off-axis injection scheme is also proposed and under investigation. In this scheme two multipole kickers are employed. And kicker required to have 300 Gauss field strength at 3 mm offset from the center. The NLK is a good choice for this design. The Ferrite NLK is our original design and first presented in IPAC 2017. Based on the initial design, we improve mechanical structure, shielding arcs and increase the strength of the magnetic field.

The R&D also includes the nano-second pulser and septum magnet. Both of them are under developing.

* Work supported by The National Key Research and Development Program of China No. 2016YFA0402000(2016YFA0402002) and Pre-research Project of Hefei Advanced Light Source

This paper presents the test results of the prototype kicker and the NLK. The design of the ultrafast pulser and septum magnet are also discussed.

STRIP LINE KICKER

On-axis longitudinal injection requires ultrafast kicker. A prototype strip-line kicker has been fabricated. The kicker uses two D type blades of 400 mm long. It works in differential mode with positive and negative pulses inputting from the downstream feedthroughs.

The geometry of blades and outer shell of the kicker follows the APS-U style and were optimized to suit our specifications. Both cavity body and blades are made of 316L. The body cavity was firstly divided into two halves along the longitudinal direction. Then each half is machined separately and welded together. For each half, the tapered transition part and uniform part are machined as a whole by CNC. This is quite different from the other's method in which the transition and the main part are machined separately and then brazed together in a high-vacuum furnace [5].

Figure 1 shows the kicker after assembling. TDR and S-parameters were measured by a network analyzer as shown in Figure 2. Detailed design and test results can be found in [6].

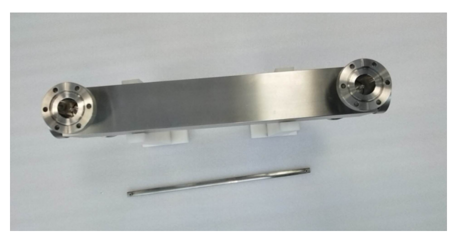


Figure 1: prototype stripline kicker

Figure 2: The kicker is under test

10th Int. Particle Accelerator Conf. IPAC2019, Melbourne, Australia JACoW Publishing
ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPMP015

NANO-SECOND PULSED POWER

Two types of the pulser technology are under consideration. A commercial dual output 20 kV high voltage pulser from FID has been procured. It was used to test the prototype kicker as shown in Figure 3.

Figure 3: FID dual channel power

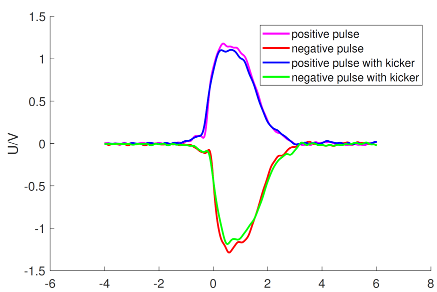
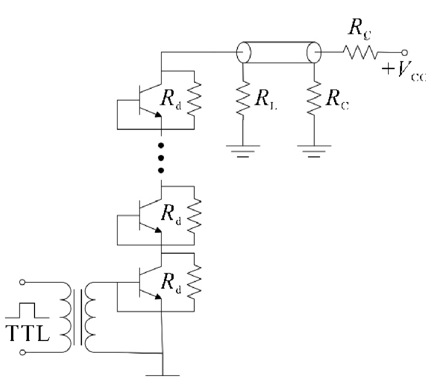


Figure 4: Pulser outputs comparison

Figure 4 shows a comparison between direct output of the pulser and output after the kicker. Voltage amplitude decreased by 6%.

Another pulse technology under consideration is avalanche circuit which is based on stacking of avalanche transistors like Figure 5. We have developed a cell circuit which consists of 40 FMMT 415 avalanche transistors two in parallel and 20 in series. It can output 3 kV/ 60 A with a 6 kV power supply as shown in Figure 6. To reach 10 kV output about 16 cell boards are needed to combine the power together.



(a) cascaded circuit

Figure 5: Pulser based on avalanche transistors

For the combination of power, the most challenging technology is the synchronous trigger and low jitter of each cell board. We now testing the combination of 4 board and results are promising.

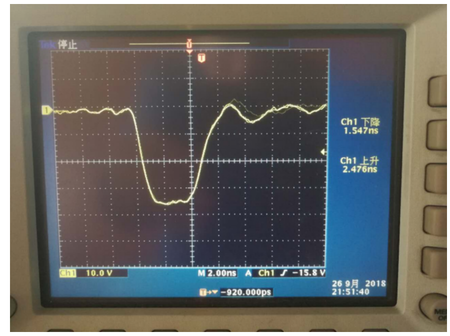


Figure 6: Output of the cell avalanche circuit

NON LINEAR KICKER DESIGN

The Ferrite NLK is our novel design and was first presented in IPAC 2017. Based on the initial design, we improved mechanical structure, shielding arcs and increase the field strength in order to have enough deflection. The cross-section of the NLK is shown in Figure 7. Table 1 lists the the specifications of the NLK. The description of the principle of the NLK can be found in [7].

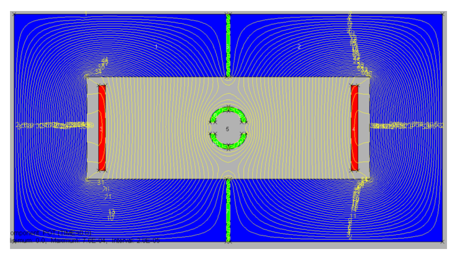


Figure 7: Cross-section of the prototype FNLK

Table 1: Specifications of the FNLK

Length	300 mm
Aperture	85*36 mm (H*V)
Inductance	9.8 uH
Gap of shielding bar	12 mm
Peak current at test	1800 A
Pulse width of current	2 µs
Max field at flat part	800 Gauss

The kicker is driven by a pulsed current with a bottom width of 2 µs. Since the kicker is so long, a long sensor coil is adopted to measure the magnetic field as shown in Figure 8. The long sensor has two turns with 0.25 mm width and 500 mm length.

With a 15 kV voltage and a peak current of 1800A, the measured peak value of magnetic field is 800 Gauss. The measurement result shows that the field pattern obtained in

10th Int. Particle Accelerator Conf. IPAC2019, Melbourne, Australia JACoW Publishing
ISBN: 978-3-95450-208-0 doi:10.18429/JACoW-IPAC2019-WEPMP015

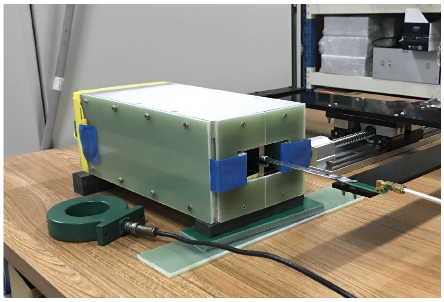


Figure 8: Bench measurement of the NLK

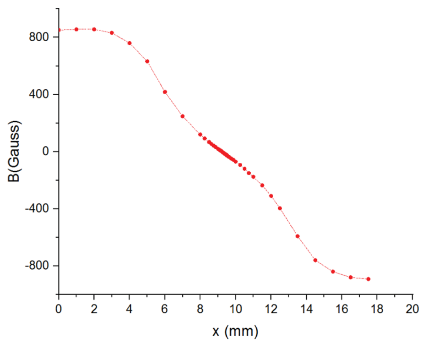


Figure 9: Field profile of the NLK

the experiment is consistent with the simulations. Figure 9 shows the field profile along horizontal direction. The peak field is about 7 mm away from the magnet centre [8].

The ceramic chamber is still needed in in this design. But the shielding arcs act well as beam image path. So the the coating of ceramic pipe may not be needed. But it finally depends on the result of impedance measurement.

SEPTUM MAGNET DESIGN

For both on-axis or off axis injection, a septum magnet is still indispensable. The injection of HALS will take place in the horizontal plane and we design an in-vacuum eddy current septum to meet the requirement (Figure 10).

The septum composed of two magnets, one thick and one thin with the specifications in Table 2.

Table 2: Specifications of the Septum Magnet

Total length	650*2 mm
Magnet technology	Eddy current, in-vacuum
Total deflection	120 mrad @2.4GeV
Aperture	30*12 mm (H*V)
Pulse waveform	Half sine wave
Magnetic field	0.8T @ 7.7 kA
Stray field	0.1%

CONCLUSION

The R&D of HALS injection are in progress. Prototype fast kicker and NLK are fabricated and tested. Nano-second pulser and septum magnet are under development.

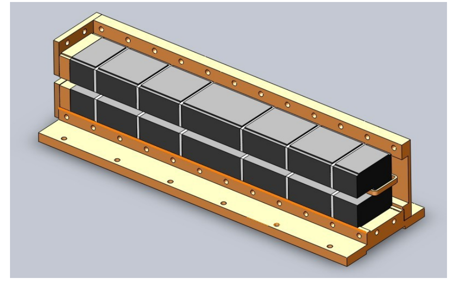


Figure 10: In-vacuum, eddy current septum magnet

REFERENCES

[1] Z. H. Bai, W. Li, L. Wang, P. H. Yang, and Z. H. Yang, "Design of the Second Version of the HALS Storage Ring Lattice", in *Proc. 9th Int. Particle Accelerator Conf. (IPAC'18)*, Vancouver, Canada, Apr.-May 2018, pp. 4601–4604. doi:10.18429/JACoW-IPAC2018-THPMK121

[2] De Santis, Stefano*et al.*, "Injection/Extraction Kicker for the ALS-U Project", in *Proc. IPAC'14*, Dresden, Germany, Jun. 2014, pp. 1977–1979. doi:10.18429/JACoW-IPAC2014-WEPRO016

[3] Aiba, M. and Böge, M. and Marcellini, F. and Saá Hernández, Á. and Streun, A., "Longitudinal injection scheme using short pulse kicker for small aperture electron storage rings", in *Phys. Rev. ST Accel. Beams*, vol. 18, p. 020701, 2015. doi:10.1103/PhysRevSTAB.18.020701

[4] Harada, K. and Kobayashi, Y. and Miyajima, T. and Nagahashi, S., "New injection scheme using a pulsed quadrupole magnet in electron storage rings", in *Phys. Rev. ST Accel. Beams*, vol.10, p. 123501, 2007. doi:10.1103/PhysRevSTAB.10.123501

[5] F. Lenkszus *et al.*, "Fast Injection System R&D for the APS Upgrade", in *Proc. 6th Int. Particle Accelerator Conf. (IPAC'15)*, Richmond, VA, USA, May 2015, pp. 1797–1799. doi:10.18429/JACoW-IPAC2015-TUPJE069

[6] W. Liu, F. L. Shang, L. Shang, W. B. Song, and Z. B. Sun, "The Design and Preliminary Test of a Stripline Kicker for HALS", presented at the 10th Int. Particle Accelerator Conf. (IPAC'19), Melbourne, Australia, May 2019, paper WEPMP016, this conference.

[7] W. B. Song, W. Liu, Y. Lu, F. L. Shang, L. Shang, and Z. B. Sun, "A New Nonlinear Kicker Design and Measurement", presented at the 10th Int. Particle Accelerator Conf. (IPAC'19), Melbourne, Australia, May 2019, paper WEPMP017, this conference.

[8] L. Shang, W. Liu, Y. Lu, F. L. Shang, and Z. B. Sun, "Considerations of the HALS Injection System and a New Non-linear Kicker Design", in *Proc. 8th Int. Particle Accelerator Conf. (IPAC'17)*, Copenhagen, Denmark, May 2017, pp. 1503–1505. doi:10.18429/JACoW-IPAC2017-TUPAB080