THE ULTRA-FAST INJECTION KICKER FOR SXLS*

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Abstract

The single bump injection scheme for the SXLS (Superconducting X-Ray Lithography Source) compact synchrotron required very stringent rise and fall time of no more than 15 nsec and a flat-top of 50-60 nsec. These parameters were achieved in a magnetic device of 75 cm length with a maximum field of 75 gauss. The construction and switching techniques along with the associated components will be described. Results of magnetic field measurements and measurements of the effect of the kicker on the injected beam will be presented. The device is presently working in the room-temperature magnet prototype of the SXLS ring and will be used as injection bump for the final superconducting compact synchrotron.

I. INTRODUCTION

The development of X-Ray lithography by the semiconductor industry will require a large flux of X-Rays at 10 Å wavelength from as small a source as possible. To achieve this goal, Brookhaven National Laboratory, with funding provided by DoD/DARPA is constructing a Superconducting X-Ray Lithography Source (SXLS), namely an 8.5 m circumference synchrotron that will be able to supply the required flux of X-Rays at 10 Å for a semiconductor production facility.[1-3] Because of space limitations on this compact machine, a single bump injection system was developed, requiring a fast kicker with a rise and fall time of 10-20 ns and a flat-top of 50 ns, which gives two horizontal kicks to the stored beam and one kick to the injected beam. The angular deflection of > 8 mrads for this device at an injection energy of 200 MeV, plus the limited space available for the magnet itself and the energy storage and trigger systems set the parameters of .75 m magnet length with a field strength of 7.5×10^{-3} T. Figure 1 shows the location of the kicker in the plan view of the warm prototype ring. It is located in the straight section opposite the injection septum and extends through the quadrupole-sextupole-quadupole triplet. Currents in excess of 1,200 mA have been stored in this compact synchrotron.

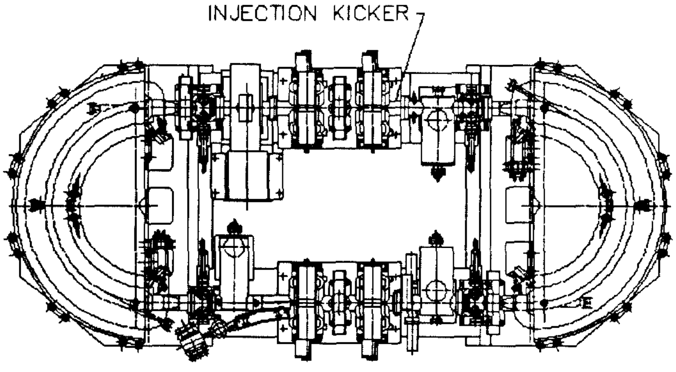

Fig. 1.

II. MAGNET CONSTRUCTION

The magnet is a single turn split cylinder, concentric with the stainless steel vacuum pipe, and is water-cooled. The water-cooling is not necessary from a power dissipation point of view; but the entire straight section will be used in the superconducting dipole version of this machine, where enough synchrotron radiation will strike the outer plate to cause a severe heating problem. Figure 2 shows a cut-away schematic view of the device.

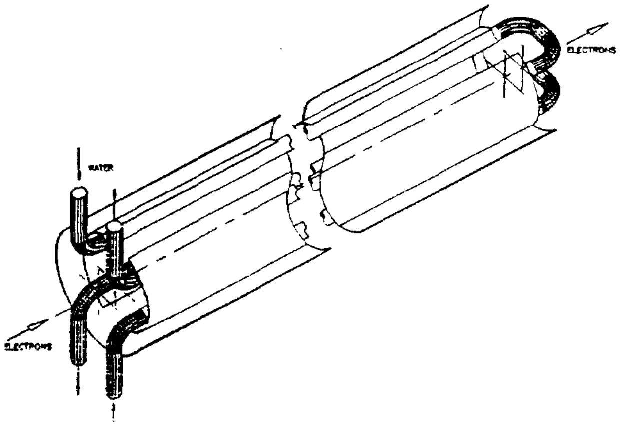

Fig. 2.

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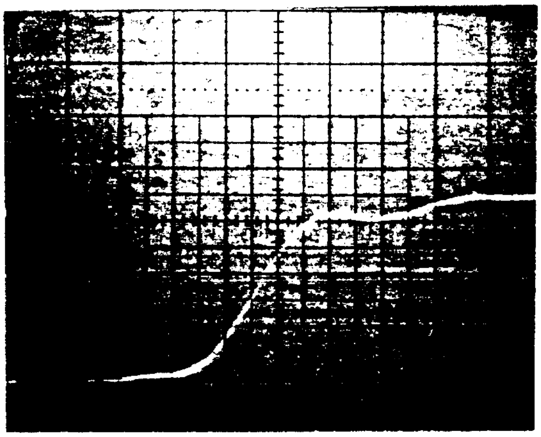
The magnet design is a result of several compromises. The angle subtended by the copper conductors are ± 30° from the horizontal instead of the expected ± 60°. This is to increase the field strength at the center of the magnet at the expense of field homogeneity. The large sextupole component of the field is offset somewhat by the overhang caused by the cooling pipes and by the image currents generated in the vacuum chamber walls. The spacing from the chamber walls was optimized to provide enough field versus providing sufficient horizontal aperture for the circulating electron beam. The 2-D magnet configuration was verified with POISSON.

III. MAGNET DRIVE SYSTEM

The switch tube selected for this circuit was the English Electric Valve Type CX1588, a hydrogen-filled ceramic thyratron. It was the only tube that proved capable of driving this device. It consistently exceeded its advertised current rate of rise (125 kA/μsec) and has exceedingly low timing jitter (~ 200 ps). Since we are operating the tube in the crowbar mode, it easily handles the 2000 Amperes at an energy storage voltage of 20,000 volts. Jitter and drift are major concerns; the filaments and reservoir are powered by regulated DC power supplies. To further increase stable operation, the tube is supplied with a 1500 V trigger pulse having a rate of rise of 65 V/ns (see Fig. 3).



10 ns/cm 500 V/cm
Fig. 3.

To achieve the rapid rise-time, the trigger circuit, consists of 20 Unitrode type GA301 SCR's in a series string. The circuit was adapted from the Unitrode Applications Handbook.[4]

To avoid introducing additional inductance, the thyratron and its energy storage capacitors were mounted coaxially in a copper cylinder directly connected to the beam pipe at the feedthrough location. Reverse current blocking diodes are mounted as close to the magnet as possible, and all connections are made with low-inductance copper strips. Needless to say, the placement of components is extremely critical and a considerable effort was expended to obtain the optimum magnet performance. The entire assembly of trigger and charging circuits was shielded to the maximum possible RFI specifications to avoid interference with the single turn beam position determination system.

IV. MAGNET PERFORMANCE

It proved extremely difficult to measure the fields produced at the pulse widths required by the design. Therefore, a much larger capacitance was connected to the magnet, resulting in a longer pulse length, thus enabling the calibration of the magnet to be determined with a known pick-up coil. The table below shows the field in gauss produced at three different pulse lengths and at three different currents:

	0.6 μsec	1.4 μsec	2.0 μsec
500 A	24.4	25.7	24.8
1000 A	48.6	52.0	49.6
1500 A	74.2	75.2	74.8

The calibration of the magnet is thus set at .05 gauss/A. This agreed with the estimates made with POISSON.

Current measurements during operation is made with a permanently mounted current transformer in the discharge path. Since this transformer will detect all currents through the diodes and magnet capacity to ground, it does not display the true current wave shape and is not used as such. It is only used as a peak current detector to verify the correct operation of the kicker.

The true performance of the kicker was determined by its effect on the injected electron beam in the SXLS synchrotron, by moving the time of firing of the kicker relative to the incoming electron bunch, and measuring resulting displacement on a fluorescent flag downstream of the magnet. Figure 4 shows the result of these measurements.

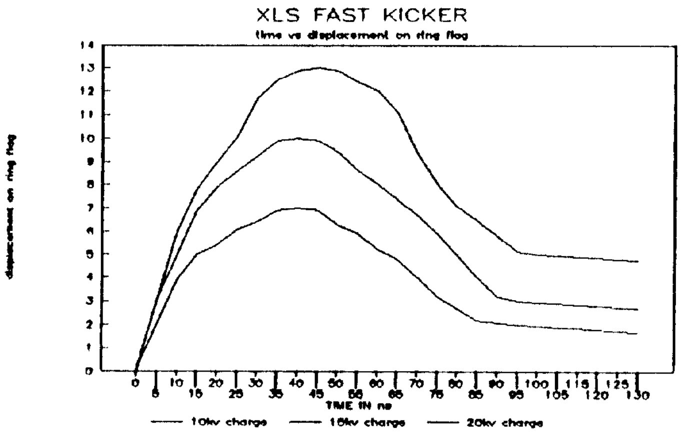


Fig. 4.

The kicker achieves 80% of its maximum value after 15 ns, has a "flat-top" of about 35 ns, and falls to 25% of its peak value in another 20 ns. The long, low-field tail, decaying in several hundred ns is probably flux "captured" in the beam pipe, and decays as the eddy currents decay. These small kicks do not harm the beam or the injected pulse. From a machine physics point of view, it is beneficial to have a slightly larger kick of the stored beam the second time; we normally operate that the first kick to the stored beam occurs at the 25 ns point, the second kick to the stored beam, and the first kick to the injected bunch then occurs at the 52 ns point. The third kick at ≈ 80 ns is not detrimental to the circulating beam.

V. CONCLUSIONS

A very difficult magnet needed to be developed to assure the successful performance of the compact synchrotron. This has been achieved, the maximum current injected into the SXLS machine has been in excess of 1200 mA, with injection rates of up to 10 mA per "shot", at a repetition rate of 0.67 Hz.

ACKNOWLEDGEMENTS

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REFERENCES

1. J.B. Murphy, et al., this Proc. (1991).
2. R. Heese, S. Kalsi, E. Leung, this Proc. (1991).
3. J.B. Murphy, et al., Proc. 2nd European Particle Accelerator Conference, p.1828 (1990).
4. Unitrode Applications Handbook, Unitrode Corp., Lexington, MA 02173 (1987-88).