PULSED VUV SYNCHROTRON RADIATION SOURCE

S. H. Kim, Y. S. Cho, T. Y. Kim, K. H. Chung
Dept. Of Nuclear Eng., Seoul National University, Seoul 151-742, KOREA

Abstract

The conceptual design of the pulsed VUV synchrotron radiation (SR) source is reported. This machine has modified racetrack shape (diamond shape) and consist of two superconducting bending magnets, two normal conducting bending magnets, iron yokes, quadrupole magnets and injection system. Maximum magnetic flux density is 7 T. Injector is 100 MeV racetrack microtron and 100 MeV, 10 pps electron beam is directly injected to this SR source. The bending radius is 4.8 cm and critical wave length is 27 nm.

I. INTRODUCTION

Soft x-ray projection lithography using synchrotron radiation, more recently referred to as extreme-ultra violet lithography which has merits in optics is new technology that would lead to the mass production of high-density integrated circuits [1]. The increasing importance of SR for research and industrial applications call for the development of inexpensive and simple source. For this purpose compact superconducting SR rings with small bending radius have been worldwidely proposed and constructed during last several years [2],[3],[4]. Most of these rings use about 3-5 T magnetic flux density.

To study the feasibility of more inexpensive and compact SR source, pulsed VUV SR source which utilizes 100 MeV electron beam from the racetrack microtron which is under construction at Seoul National University is conceptually designed. There is no rf system hence life time of the beam is short, that is pulsed. Electron beam is directly injected to this machine at a field of 7 T. In designing the compact SR ring, nonlinear terms of equations of motion must be considered. Therefore complicated three dimensional magnetic field must be also considered. In this design we use 3-D magnetostatic code TOSCA. The present paper briefly describes the design feature of SR source considering magnet and beam dynamics.

II. INJECTOR

A 100 MeV racetrack microtron (RTM) is under construction. This machine will be used as an injector. Injection to this RTM is provided with 75 keV, 1 A electron gun. Pulsed 2 MW microwave power is delivered to the 5 MeV accelerating column at 2.998 GHz. The field strength of the 180 degree bending magnet is 1.048 T with sufficient uniform area. Its specification is summarized in Table I and figure 1 shows an RTM under construction.

Table I
Specifications of the RTM

Injection energy	45 keV
Final energy	100 MeV
Beam current	10 mA
Energy gain per turn	5 MeV
Accelerating cavity frequency	2.998 GHz
Maximum flux density of bending magnet	1.048 T
Pulse Width	3 μsec
Repetition rate	10 pps

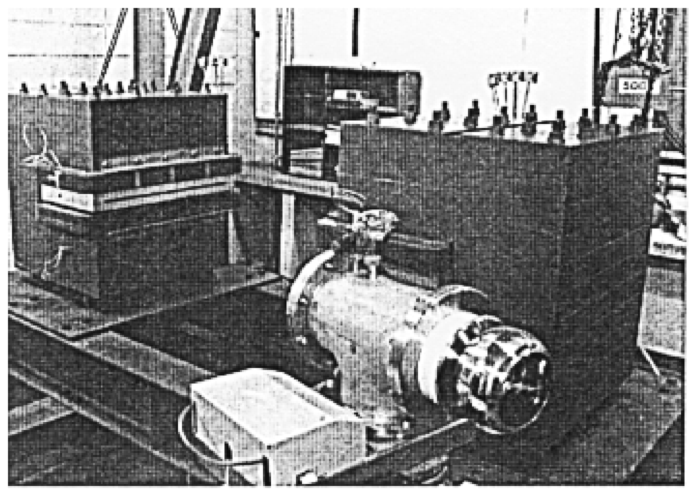

Figure 1. Racetrack microtron under construction

III. DESIGN FEATURE

Compact superconducting SR rings are classified into two types. One is the circular type with single bending magnet using weak focusing, and the other is racerack type with seperated magnet and long straight section using strong focusing or combined focusing.

In case of applying circular type to this design, it has merits of simple structure consequently more compact because the principle of weak focusing is applicable. So auxiliary magnet system is not necessary. But injection is almost impossible because the bending radius correspondence to 7 T magnetic flux density, 100 MeV electron beam is so small (4.8 cm) and fringing field region is wide.

Adapting racetrack type to this design, injection is possible. Because of iron yoke saturation however, electron beam is reflected before it reaches 7 T region. For the more there exists reverse fringing field region. In case of using this reverse fringing field, the orbit is like that of reflex microtron [5] so other optics is not applicable. In order to reduce the reverse fringing field, 'banana'-shape dipole coil which are turned up and away from the beam at each end, it has difficulty to make it small.

To overcome above problems, diamond shape orbit configuration is suggested. The operation scheme is as follows. 100 MeV electron beam from the RTM is injected to this SR source. This

Table II
Designed parameters of Pulsed VUV SR Source

Beam energy	100 MeV
Injection energy	100 MeV
Maximum magnetic flux density	7 T
Critical wavelength	27 nm
Bending Radius	4.8 cm
Circumference	4.2 m

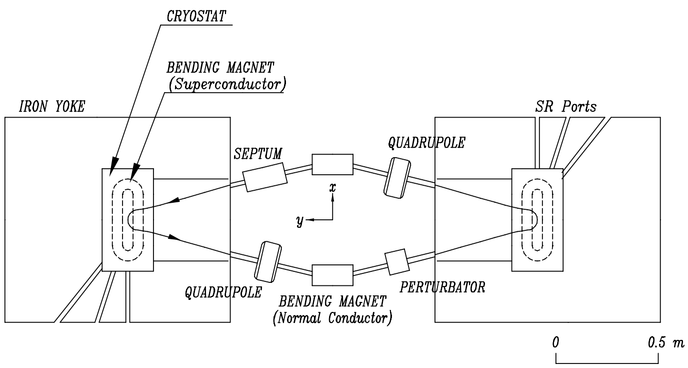

Figure 2. The Schematic Layout of the pulsed VUV SR Source

machine has no RF system, beam loses its energy continuously via radiating SR. Therefore successfully injected beam circulate for few msec. and then decay out. That is pulsed and the repetition rate of pulse is mainly governed by that of RTM. Table II is specifications of this machine and figure 2 shows a rayout of this machine. Located in straight sections are quadrupole magnets, inflector and pertubator. Its circumference is 4.2 m. Its footprint is 0.9 m $\times$ 3.2 m.

IV. MAGNET

The magnet system consists of superconducting bending magnets, normal conducting bending magnets and quadrupole magnets. The superconducting magnet have an iron yoke. The maximum flux density is 7 T. The roles of the iron yoke are to reduce magnetomotive force and to shield magnetic field at injection. The design principals of this superconducting magnet are to reduce the fringing field region and to let the field distribution uniform in x-direction (coordinate system is shown in figure 2)

To achieve the former, magnet width should be short. So sub lambda cooling (1.8 K) is selected. NbTi (easy to handle) is chosen as a superconducting material. And to achieve the latter racetrack shape magnet with long straight section is selected. Figure 3 is vertical field component at the center of superconducting magnet in x-direction, and shows good uniformity. Field components are calculated using TOSCA. Figure 4 is the field distributions of the superconducting magnet along the beam axis and figure 5 is schematics of superconducting coil and its cryostat. The location of the normal conducting bending magnet is determined by particle tracking. The bending field of this magnet is about 0.5 T and bending angle is 32 degree. This machine has fairly long straight section compared with bending radius. Therefore quadrupole magnets are necessary.

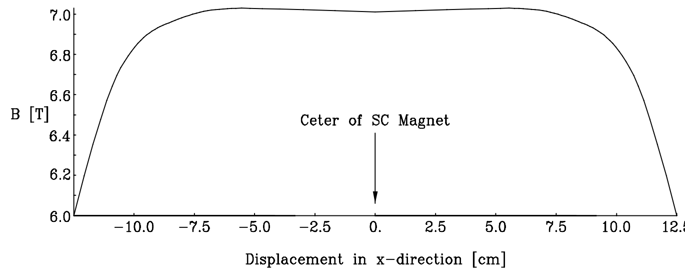

Figure 3. Field distribution at the center of SC Magnet

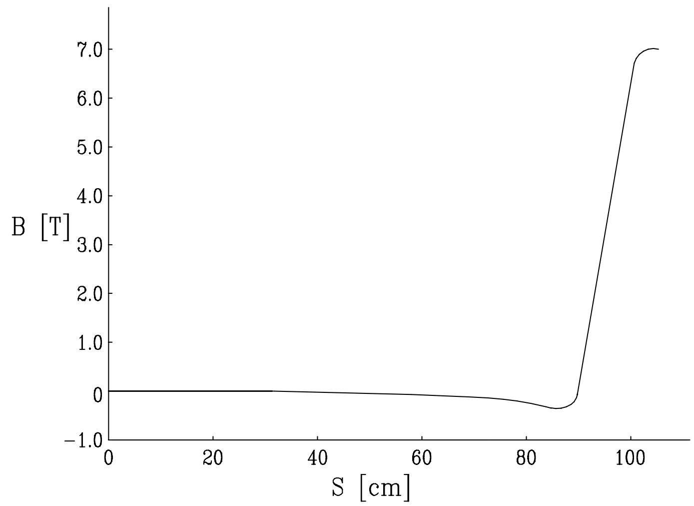

Figure 4. Field Distribution of the SC Magnet along the beam axis

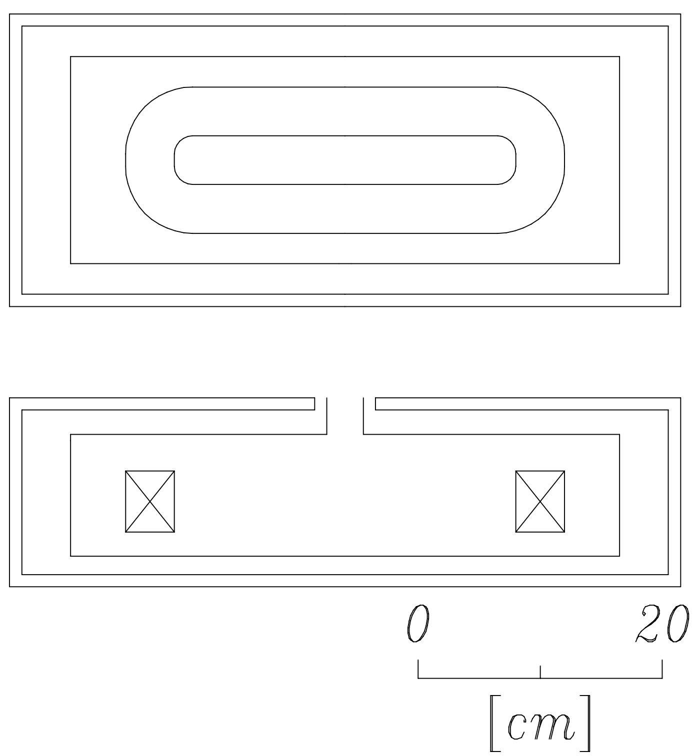

Figure 5. Schematics of SC Magnet and its Cryostat

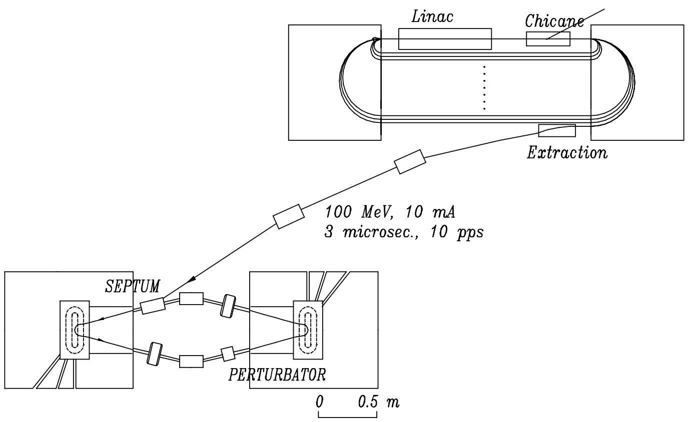

Figure 6. Schematics of Injection

V. INJECTION

In case of using usually used pulse magnet for injection there exist technical problems because of the short revolution time of electron. For recently resonance injection scheme is applied to electron and ion ring [6],[7]. Approximate radial tune of this machine is 1.43. Therefore small pertubation will be enough to create the half resonance condition. Detailed is under calculation. The schematics of injection is shown in figure 6.

VI. CONCLUSION

Pulsed VUV SR source is conceptually designed. It has diamond shape. 3-D magnetic field is calculated (TOSCA) and COD (closed orbit distortion) are determined by particle tracking. Half resonance injection sheme is selected. This paper presents partly calculated results. More presice analysis over the whole of this machine including injection is in progress.

References

[1] W.T.Silfcast and N.M.Ceglio, "Intronduction to special issue of Applied Optics on soft-x-ray projection lithography," Appl.Opt. vol.32 No.34, pp 6895-6900 (1993)

[2] T.Hosokawa et al., "NTT superconducting storage ring-Super ALIS," Rev. Sci. Inst. 60(7), pp 1783-1785 (1989)

[3] N.Takahashi, "Compact superconducting SR ring for x-ray lithography," Nucl. Inst. Meth. in Phy. Res. B24/25, pp425-428 (1987)

[4] U.Trinks, F.Nolden and A.Jahnke, "The table-top synchrotron radiation source ' klein erna'," Nucl. Inst. Meth. 200, pp475-479 (1982)

[5] R.E.Rand, "Recirculating electron accelerators," Harwood Acad. New York, pp 64-66 (1984)

[6] T.Takayama, "Resonance injection method for the compact superconducting SR-ring," Nucl. Inst. Meth. in Phy. Res. B24/25, pp 420-424 (1987)

[7] M.Tomizawa et al., "Injection method using the third order resonance at TARN II," 1993 IEEE Particle Accelerator Conference, Washington,D.C. (1993)