EXTRACTION SYSTEM DESIGN FOR THE CSNS/RCS*

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Abstract:

The CSNS extraction system takes use one of the four dispersion-free straight sections. Five vertical kickers and one Lambertson septum magnet are used for the one-turn extraction. The rise time of less 250 ns and the total kicking angle of 20 mrad are required for the kickers that are grouped into two tanks. The design for the kicker magnets and the PFN is also given. To reduce the low beam loss in the extraction channels due to large halo emittance, large apertures are used for both the kickers and septum. Stray magnetic field inside and at the two ends of the circulating path of the Lambertson magnet and its effect to the beam has been studied.

INTRODUCTION

The China Spallation Neutron Source (CSNS) consists of a combination of a linac and a RCS to achieve the beam power of several hundreds kW [1-3]. The H- beam pre-accelerated in the linac will be injected into the RCS via stripping method, accumulated via phase space painting and accelerated further to 1.6 GeV.

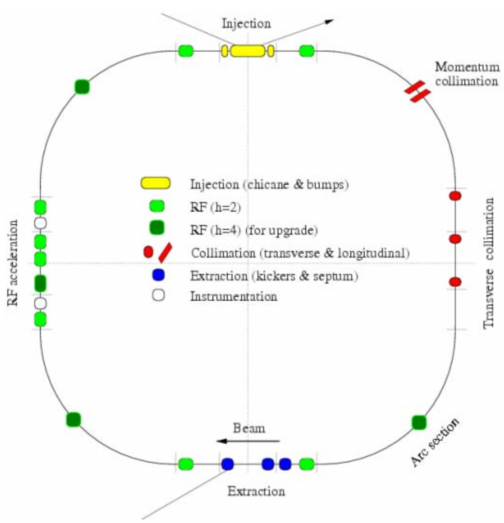

Figure 1: RCS layout and functions

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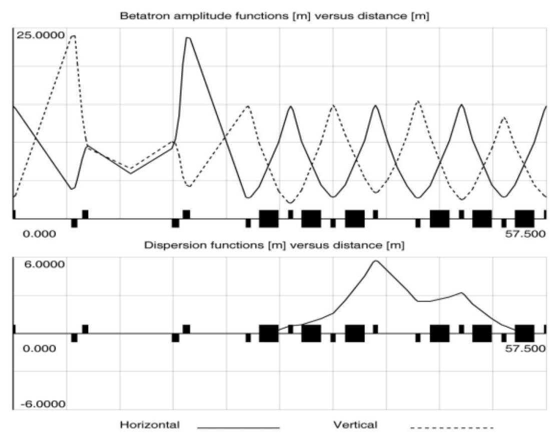

Figure 2: The lattice functions for one RCS super-period

Single turn extraction method is required to extract the beam from the RCS, and then the beam of short pulse is transported to the Spallation target. Taking the advantage of the RF harmonic number of 2 and the bunch shrinking during acceleration, about 300 ns time gap between the two circulating bunches can be used to excite the kickers.

LAYOUT OF EXTRACTION SYSTEM

The RCS lattice has been optimised by taking account of the design of the injection and extraction systems. The extraction system design is based on one of the four long straight dispersion-free sections. The anti-symmetric lattice favours kicking in the vertical plane, therefore, a group of vertical kickers and a Lambertson septum magnet are used to extract the beam and guide it into the ring to target beam transport line (RTBT) [4]. Five kickers are grouped into two tanks on the two sides of a doublet quadrupoles, and the space for one more kicker adjoining to the fifth is reserved. This is a compromise between the kicking strength and the additional requirement to the quadrupole apertures. Figure 3 shows the layout of the extraction devices.

Though the emittance of beam core is shrunk to less 80 πmm.mrad during the acceleration, it is uncertain how the halo portion is. As the beam loss is a key issue in the accelerators like CSNS/RCS, the design of the extraction system should avoid the loss of the halo particles. Therefore, the acceptance of the extraction channel is taken to be 350 πmm.mrad defined by the ring collimation acceptance. The apertures of the kickers and intercrossed quadrupoles should take into account both the circulating beam and the extracted beam.

A total kicking strength of 20 mrad for the kickers will create about 130 mm central orbit displacement at the entrance of the Lambertson magnet, which is required by the separation of the extracted beam and the circulating beam and the septum thickness. The Lambertson magnet bends 15° in the horizontal plane and guides the beam into the RTBT. Figures 2 and 3 show the layout of the extraction devices and the central orbit displacement. Table 1 shows the main parameters of the extraction system.

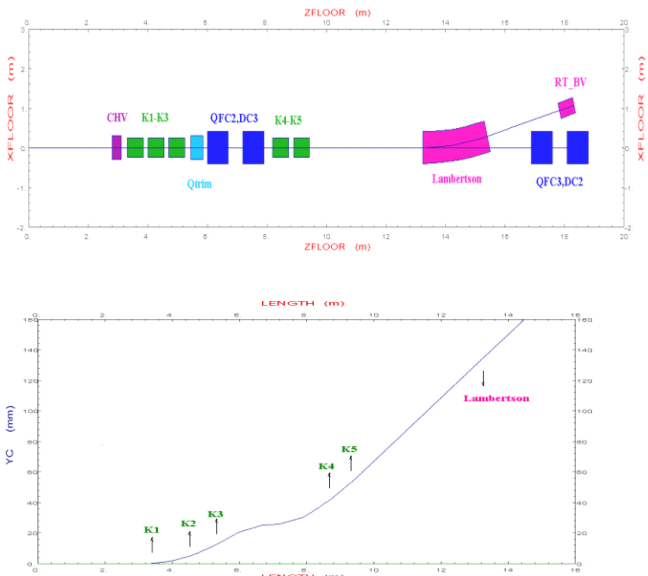

Figure 3: Layout of the extraction system and orbit displacement

Table 1: Main parameters of the extraction system

Extraction energy (GeV)	1.6
Beam rigidity (Tm)	7.8671
Acceptance (πmm.mrad)	350
Number of kickers	5
Rise time of kickers (ns)	<250
Total kicking strength (mrad)	~20
Kicker type	Lumped, twin-C, short
Length of Lambertson (m)	2.2
Field of Lambertson (T)	0.936
Angle of Lambertson (°)	15

THE KICKERS

Both lumped and transmission line types of kicker magnet have been considered, but the former is chosen for its simplicity. The kickers should satisfy the requirements of both the kicking strength (20 mrad) and the rise time (250 ns) of the magnetic field. Thus the length of the unit kicker is optimised after the rise time. Due to the space limitation and the preference of less number of kicker units, twin-C and short-ended type magnet is adopted. The lengths, widths and gaps of the five kickers have been optimised individually to have same inductance and exciting current, thus the rise time are the same. The ten power supplies are identical. The main parameters of the kickers are shown in Table 1.

CMD 5005 Ni-Zn type ferrite blocks are planned to construct the yokes of the kicker magnets. To the out-gasing rate and the secondary electron emission, TiN coating on both inner ferrites and conductors will be carried out. In-situ bake-out system is also planned to improve the local vacuum.

Table 1: Main parameters of kickers

	K1	K2	K3	K4	K5
Magnetic field (T)	0.063	0.059	0.052	0.052	0.052
Bending angle (mrad)	4.599	4.073	3.6	4.167	4.167
Length (m)	0.572	0.54	0.54	0.625	0.625
Width (mm)	168.5	191.4	217.6	187.2	187.2
Gap (mm)	115.9	123.5	139.7	139.7	139.7
Inductance (uH)	0.58	0.58	0.58	0.58	0.58
Field rise time (ns)	201	201	201	201	201
Effective current (A)	5832	5832	5831	5832	5832
PFN Voltage (kV)	36.4	36.4	36.4	36.4	36.4

The power supplies for the kickers consist of charge/discharge circuit with the deuterium thyratron as the main discharging switch. The lumped PFN is adopted for its robust. Blumlein circuit is used to reduce the PFN voltage by half. Four parallel cables of 50 Ω compose the characteristic impedance of 12.5 Ω. A parallel resistor of 12.5 Ω is added to reduce the beam impedance when the circuit is open, which is important for suppressing the beam collective instabilities. The thyratron type is selected as E2V CX1925X (hollow anode, deuterium- filled three-gap).

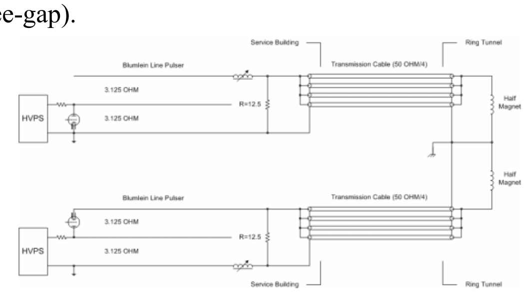

Figure 4: PFN circuit for the kickers

THE LAMBERTSON MAGNET

Compared with normal coil blade septum, the Lambertson type septum has the advantage that coils are away from the beam thus less exposed to the radiation and that more coil area can be designed to reduce the power consumption. However, there are also disadvantages: the different bending planes by the kickers and the Lambertson makes the dispersion suppression more difficult, here the vertical dispersion is left as it is until the target; the stray field at the two ends and inside the circulating channel has important to the circulating beam, especially to the beam at the injection energy, thus special magnetic field shielding is required.

The shielding method of the stray magnetic field similar to what the SNS [5] has carried out will be used here. The 3D OPERA/TOSCA [6] calculations of the magnetic field have been carried out to optimise the shielding design and verify the effectiveness. For example, the septum yoke is increased to 15 mm from 10 mm; the length of the magnet is increased from 2.0 mm to 2.2 m; the extension of the yoke at the two ends, the shielding iron tube to the circulating beam and iron caps at the tube ends are used to reduce the stray field on the path of the circulating beam. Finally, about 0.1% of the field integration on the circulating beam compared with the normal bending strength has been obtained, which can meet the requirement by the beam dynamics. Figures 5 and 6 show the 3D calculation model and the stray field after having taken the shielding measures.

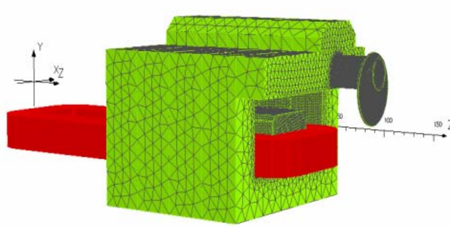

Figure 5: 3D OPERA model for the entrance end of the Lambertson magnet

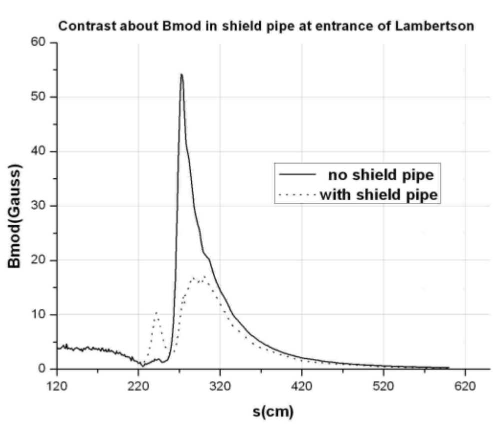

Figure 6: Stray field on the path of circulating beam with the shielding

CONCLUSIONS

Five kickers grouped into two vacuum tanks and a Lambertson septum magnet are to extract the beam from the RCS. The kickers are of lumped, Twin-C, short-ended magnet and of Blumlein lumped PFN power supply. The operation PFN voltage is within 36 kV. Special shielding to the Lambertson magnets has been designed to reduce the stray field integration within 0.1%. Further optimisation of the design will be continued.

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