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FEASIBILITY STUDY OF USING MULTIPOLE INJECTION KICKER (MIK) AND SEXTUPOLE FOR TPS INJECTION

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Abstract

Feasibility of applying MIK/sextupole injection at TPS is evaluated in this study. This study adopts layout similar to MAX IV injection scheme and their collaboration project with SOLEIL for MIK. Although the light source service fulfills present user needs, yet the increasing demands for a transparent injection is inevitable in the foreseeable future. This preliminary study is constrained under routine user operation, where we choose the optional pinger ceramic chamber between existing injection kicker-3 and kicker-4 for the MIK. We calculate the MIK kick strength requirement with minor trajectory adjustment upstream at the booster to storage-ring transfer line. Since the realization of MIK fabrication takes time, a fast-built sextupole is used to study the proposed injection scheme. This report describes the test result.

INTRODUCTION

Transparent top-up injection using multipole injection kicker (MIK) or sextupole has been well evaluated and implemented at a couple of synchrotron light sources [1-4]. In order to test the MIK injection at TPS storage ring, a sextupole has been designed, fabricated and is planning to install it at TPS for testing purpose. This report summarizes the design requirements, field constrain at TPS storage ring, technical consideration of fabrication, and preliminary measured B_y field profile of the sextupole. The result indicates that this sextupole, prepared for its test-run at TPS, should provide useful and practical information for future implementing the MIK injection at TPS.

BEAM INJECTION ANALYSIS

The present 4-kicker bump scheme is illustrated in Fig. 1 [5, 6]. To facilitate the proposed MIK injection from the booster-to-storage ring (BTS) transfer line, the last septum field strength relaxed to about 0.95 of its original setting. The proposed injecting trajectory intercepts storage ring at a pinger ceramic chamber with sidestep of 15 mm relative to the beam centerline. The planned sextupole at present pinger location provides proper kick strength to guide the injection beam onto the allowed acceptance to accomplish the capture process, shown in Fig. 2. Simulation of the capture process is shown in Fig. 3. The kick strength required, at various sidestep, using a 0.2 m sextupole, and the needed pulser drive current are summarized in Table 1 for checking purpose. Notice that the magnet gap of the sextupole is constrained by the height of the ceramic chamber. In order to test the MIK injection at TPS storage ring, a sextupole has been made and is planning to install it at TPS for testing purpose.

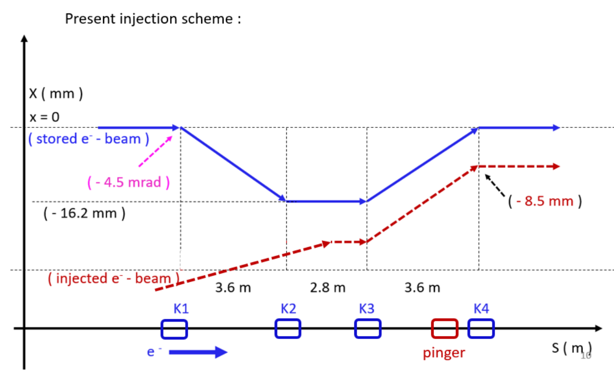

Figure 1: The present 4-kicker injection scheme parameters and the pinger location.

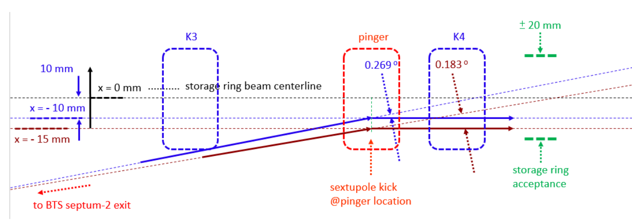

Figure 2: The proposed sextupole injection strength required at pinger location. The pinger will be re-installed at section-8 in September leaving the ceramic chamber for MIK and sextupole injection test-run.

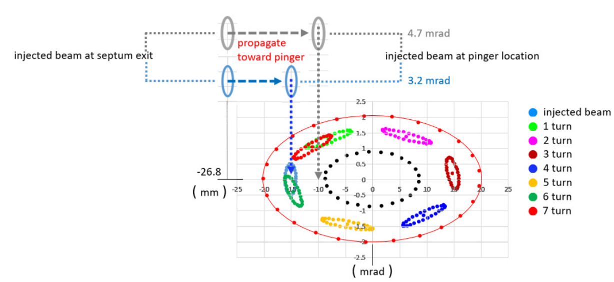

Figure 3: Configuration of the sextupole strength at various sidestep with respect to the storage ring acceptance.

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Table 1: The Sextupole and Pulser Specifications and Required Strength at Various Conditions

MIK sextupole parameters			
specifications		sidestep (mm)	
		10	15
kick strength (mrad)	5	4.7	3.2
length (m)		0.2	
field strength (Tesla)	0.25	0.235	0.16
integrated field (T*m)	0.05	0.047	0.032
magnet gap (mm)		35	
inductance (µH)		2	
drive current (kA)	10	9.4	6.4

SEXTUPOLE PULSER PREPARATION

Since the realization of MIK magnet fabrication takes time, therefore a fast-built-sextupole is prepared to examine the proposed injection scheme beforehand. Design and fabrication of the fast-built-sextupole profile is constrained by the existing pinger ceramic chamber. Figure 4 shows the calculated B_y at middle plane using the software program POISSON [7]. The sextupole ferrite blocks are machined by using water-jet cutting and polishing with diamond cutter so that its machining precision is better than 0.1 mm. For the ease of sextupole assembling in dealing with fragile ferrite and tight coils arrangement, a couple of critical parts of the coils are adopting wire-EDM (Wire Electrical Discharge Machining) to ease its fitting consideration. Figure 5 shows the the assembled coils, and ferrite of the fast-built-sextupole.

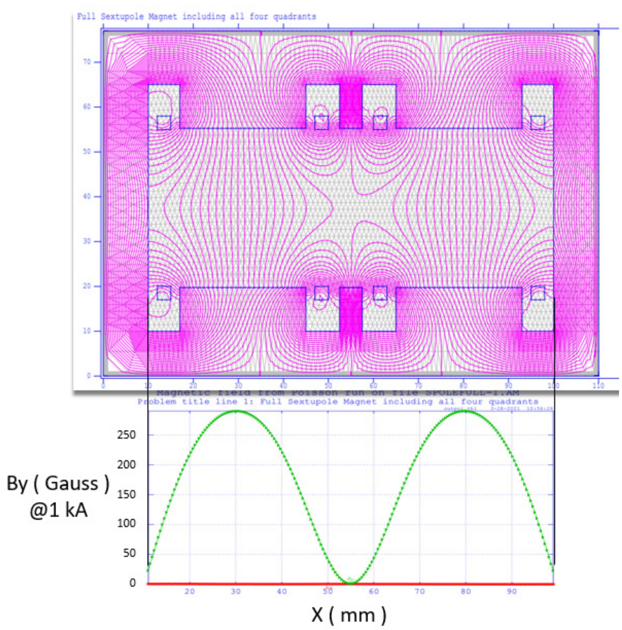

Figure 4. The cross-section of the sextupole together with its illustrative field lines and the calculated B_y using POISSON.

The sextupolar field distribution of B_y at middle plane is measured at DC-10 amperes for preliminary checking. The measurement results is shown in Fig. 6. Despite the poor measured statistics due to weak field-strength nature and unsettled mechanical precision, the B_y distribution falls along the calculated expectation.

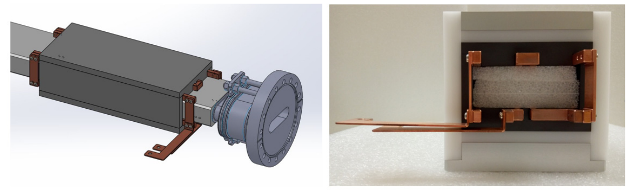

Figure 5: (L): sextupole and ceramic chamber; (R): the assembling sextupole.

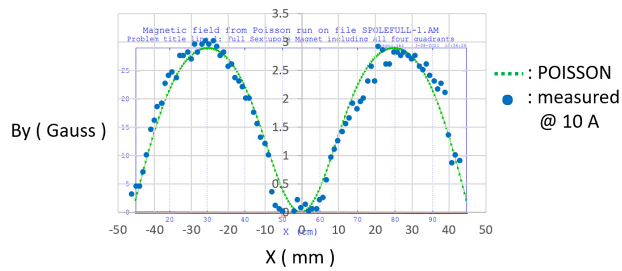

Figure 6: Sextuple B_y distribution along meddle plane at DC-10 amperes.

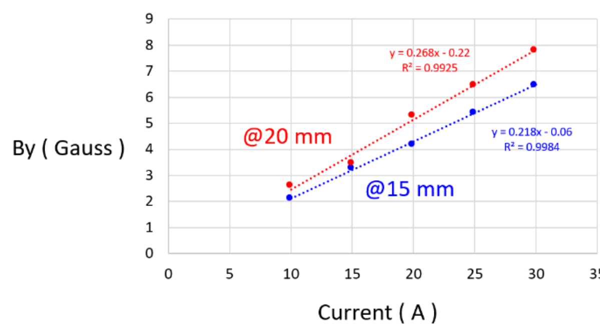

Figure 7: Linearity check of the B_y at sidestep of 15 mm and 20 mm at small drive current.

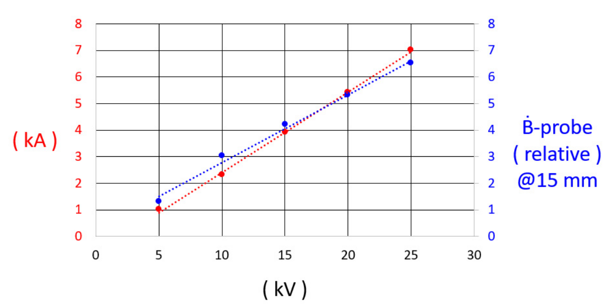

Figure 8: The measured pulsed drive-current and the response of Ḃ-probe at kA region.

A quick check on the linear increase of the measured B_y of putting Gauss meter at 15 mm and 20 mm, respectively versus varying drive current of 10, 20, 30 amperes, are

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shown in Fig. 7, where B_y shows steady increase as expected at small drive current region. A current transformer to measure the drive current at kA range and a $\dot{B}$-probe to measure the pulsed B_y field response are used to examine their linearity at the high B-field region, shown in Fig. 8. The straight-line tendency of the $\dot{B}$-probe response implies that the sextupole has not yet saturated at the region of interest and thus it is usable for the experiment.

SEXTUPOLE INJECTION TRAJECTORY VERIFICATION USING KICKER-4 TO TEST ON-AXIS INJECTION

Since appropriate machine-time is not available for testing sextupole injection under present routine user operation, a preliminary sextupole injection trajectory tuning is performed instead to verify that guiding of electron beam to arrive at sextupole location is doable with existing hardware layout. This major guideline of sextupole injection design is further confirmed by making use of the kicker-4, in Fig. 1, for on-axis injection check-up. This experimental verification process is carried out during the available machine shift in May. The injected electron beam successfully stored in the storage ring shot-by-shot, as shown in Fig. 9, indicates that the proposed guiding trajectory is doable for later on sextupole injection test-run.

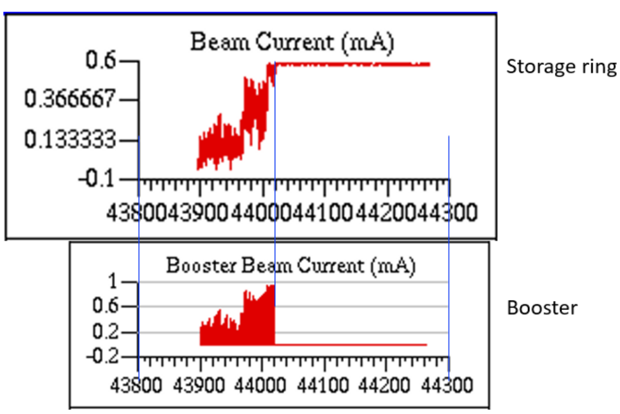

Figure 9: After kicker-4 on-axis injection tune-up, the injection process terminated. The storage ring stores with the one-shot beam current of 0.6 mA.

While carrying out the kicker-4 on-axis injection test-run, beam tuning shows an optimization kick strength of 2 mrad is given. This explains well for the observed shot-by-shot stored beam with the acceptance illustrated in Fig. 3. In addition, the success of kicker-4 on-axis injection indicates that upstream steering of the injected beam trajectory is adequate and useful for sextupole injection study. The pinger is planned to re-install at section-8 of the storage ring in September 2021, and the sextupole installed at section-1 for the injection testing.

SUMMARY

Feasibility of applying MIK/sextupole injection at TPS is evaluated in this work. A fast-built sextupole is fabricated and is planned to install for the test-run in September. The drive current pulser is tested to the specification required and estimation of sextupole strength gives satisfactory result. The designed injection beam trajectory at upstream of the BTS transfer line has been put for examination using storage ring kicker-4 to perform on-axis injection. The achieved shot-by-shot stored electron beam indicates that the injection trajectory tuning acquires reasonable allowance for further MIK/sextupole injection exploration.

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