DESIGN OF THE TPS INJECTION SYSTEM

C. K. Chan#, C. H. Chang, P. J. Chou, C. S. Fan, Y. H. Liu, C. S. Yang, G. Y. Hsiung
NSRRC, Hsinchu, Taiwan.
J. R. Chen, NSRRC, Hsinchu; NTHU, Hsinchu, Taiwan.

Abstract

We present the vacuum designs of the injection section and the transport line (BTS) from the booster to the storage ring at the Taiwan Photon Source (TPS). The specifications and parameters of the ceramic chambers for the injection kicker are described. An iterative simulation program is utilized to calculate the pressure profile of the injection section; the simulation result indicates that an average pressure 4.2×10^{-10} mbar is obtained after a conditioning period 100 A·h.

INTRODUCTION

The 3-GeV Taiwan Photon Source is the third-generation synchrotron facility to be built at the National Synchrotron Radiation Research Center (NSRRC) in Taiwan. The design of the TPS is aimed to provide a low-emittance and highly brilliant beam with operation in the top-up injection mode. The storage ring and booster ring are concentric, i.e. in the same tunnel, and require a short transfer line for interconnection. The BTS has a septum magnet at each end for extraction of the electron beam from the booster and injection into the storage ring. A 12-m long straight section in the storage ring is reserved as the injection section in which the beam-diagnostic components, four injection kickers, and one septum magnet are located. The parameters specifying the pulsed elements are given in this proceeding [1].

INJECTION STRAIGHT SECTION

Figure 1 depicts the layout of the TPS injection section, in which four kickers (K1~K4) and one pulsed septum magnet are equipped for off-axis beam injection horizontally. The out-of-vacuum design for the TPS storage-ring injection septum is chosen based on

- successful and reliable operating experience at the Taiwan Light Source (TLS);
- available fabrication techniques and ease of maintenance, and
- avoidance of much outgassing and trapped air from the laminated core of the in-vacuum magnet, which would seriously degrade the vacuum condition in the storage ring [2,3].

Although many advantages can be gained, the compromise requires a beryllium (Be) window and a Kapton foil, as shown in figure 2, to separate the vacuum regions between the BTS and storage ring. The emittance of the injected beam expands a little (horizontal emittance $\varepsilon_H \sim 2 \times 10^{-8}$ mrad) after the injected beam penetrates the Kapton foil and Be window. A curved stainless-steel (SS) tube of thickness 0.25 mm is developed for installation inside the septum magnet to conduct the injected beam. With the downstream end of the SS tube sealed with Kapton foil, the ultimately attainable pressure is 2.3×10^{-7} mbar with an ion pump (speed 150 L/s) in our test

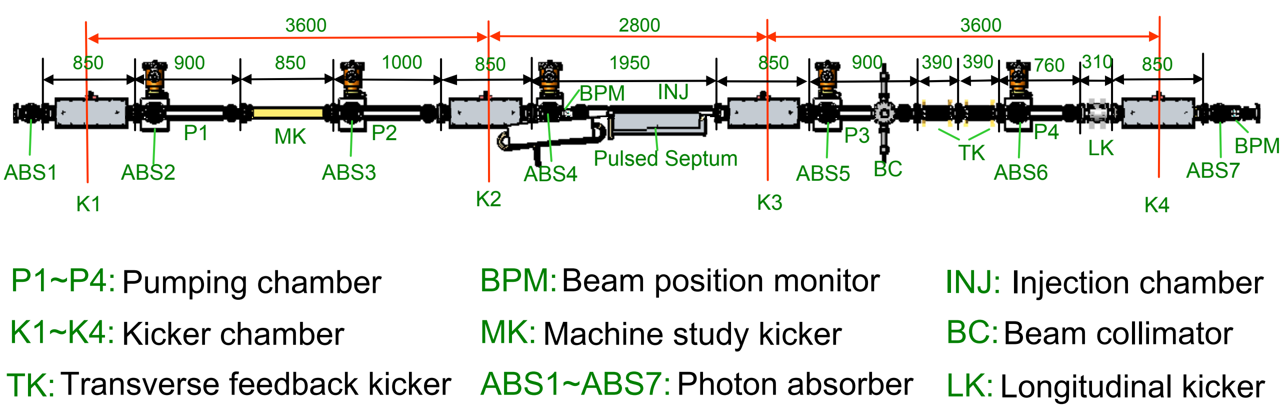

Figure 1: Layout of the TPS injection section with diagnostic components and pulsed magnets.

#ckchan@nsrrc.org.tw

INJECTION CHAMBER

The injection chamber (INJ) is an aluminium-alloy chamber, which consists of three major parts – the pumping chamber, the aluminium-alloy (A6061) extruded tube, and a special flange. At the interface between the SUS-tube and INJ, part of the chamber wall of the extruded tube is machined from 3 mm to 1 mm to provide space for the arrangement of the septum coil (thickness 1.7 mm) and the magnetic screening sheet (thickness 0.5 mm). The special flange is machined from one piece of aluminium alloy (A2219) material and a Be window is welded to the special flange with an electron beam. The pumping chamber, the extruded tube, and the special flange are assembled using tungsten-inert-gas (TIG) welding.

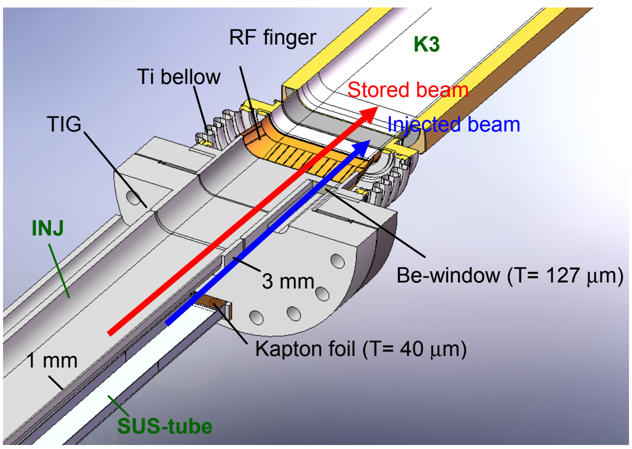

Figure 2: Cutaway view of the assembly of K3, INJ and the SUS-tube.

CERAMIC CHAMBER

The ceramic chambers are utilized and placed inside the kicker magnets to avoid the shielding of the rapidly varying kicker field by the metallic chamber wall. Figure 3 shows photographs of the TLS ceramic chamber. The TPS ceramic chamber is similar to that of TLS, which consists of a ceramic tube of size 650 mm × 90 mm × 33 mm, two titanium flanges and two titanium bellows with Be-Cu RF fingers inside, as shown in figure 4. The narrow racetrack aperture (68 mm × 20 mm) of the ceramic tube facilitates decreasing the power consumption of the kicker power supply.

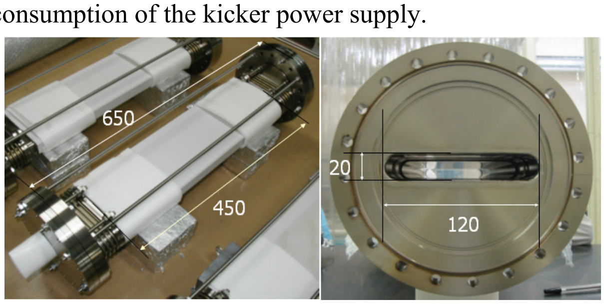

Figure 3: TLS ceramic chamber.

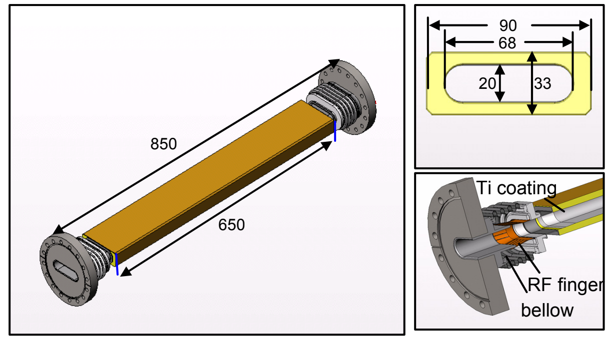

Figure 4: Configuration of TPS ceramic chamber.

The ceramic tube produces large coupling impedances that produce heating due to the beam-image currents. To solve this problem, a titanium coating on the inner surface of the ceramic chamber is adopted to carry the beam-image currents, but the interior coating film not only deforms the external kicker field [4] but also generates heat induced by eddy currents when the kicker field is applied. For a compromise between decreasing the deposited power and minimizing the waveform deformation of the kicker field, the surface resistivity of titanium film is optimized at 0.21 ohm/square [5]. According to the TLS experience, the coating uniformity can be controlled within 10 % and the corresponding curves of waveform attenuation, relative to the kicker field (5.18-μs half-sine pulse), are shown in figure 5. The results of calculation indicate that a peak delay 234 ~ 285 ns and amplitude attenuation 1.01 ~ 1.29 % are obtained.

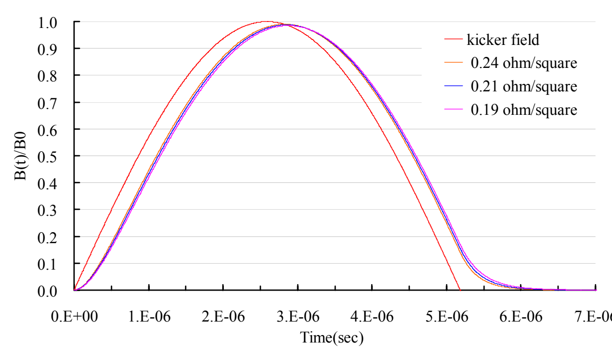

Figure 5: Attenuated fields inside the ceramic chamber relative to the external half-sine (5.18 μs) kicker field.

PHOTON ABSORBER

Because the four kicker chambers and most diagnostic components (the machine study kicker, the longitudinal cavity, and the beam collimator) in this straight section lack water-cooling channels, seven photon absorbers are arranged to protect these components from illumination by the synchrotron radiation. The absorber lengths are calculated according to the formulae in figure 6. An additional length 2 mm is reserved for the case of beam mis-steer; the necessary lengths ($b\tan\theta$ + 2) of the photon absorbers, ABS1-7 in figure 1, are hence 9.6, 7.9, 9.4, 5.0, 4.8, 5.4, 2.2 mm sequentially.

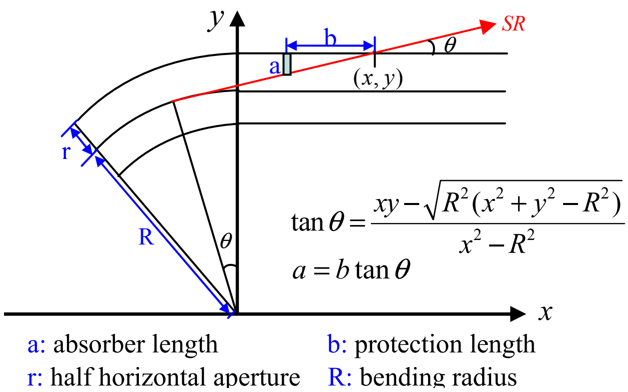

Figure 6: Sketch drawing of the synchrotron radiation emitted from the dipole magnet and blocked by the photon absorber.

PRESSURE PROFILE

The localized pumping configuration is adopted to handle the pressure of the injection section. Under each absorber, a lumped NEG pump (GP500 MK5 St707) combined with an ion pump (speed 400 L/s) are employed to evacuate the photon-stimulated desorption induced from the photon absorbers. According to the arrangement in figure 1, the pressure distribution, calculated with computer code and an iterative method [6], at an accumulated beam dose 100 A·h corresponding to desorption coefficient η= 5×10^{-5} molecules/electron [7], is displayed in figure 7. The simulation result shows that the average pressure can attain 4.2×10^{-10} mbar.

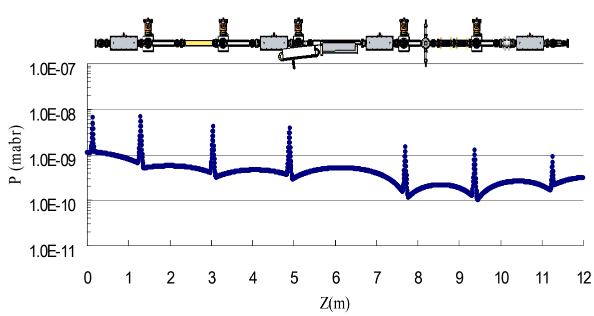

Figure 7: Pressure profile of the injection section at 3 GeV, 400 mA after a conditioning time of 100 A·h.

CONCLUSIONS

The vacuum designs for the TPS injection section are reported. The injection scheme adopts four injection kickers and one out-of-vacuum septum to perform off-axis multi-turn injection. A moderate titanium film (surface resistivity ~ 0.21 ohm/square) inside the ceramic chamber is determined as a result of a compromise between the waveform deformation and the power deposited from eddy currents and beam-image currents. An average pressure 4.2×10^{-10} mbar in the injection section, calculated with an iterative method, satisfies a requirement (< 1×10^{-9} mbar) for a 10-h beam lifetime at 3 GeV, 400 mA after a conditioning period 100 A·h

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