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Construction of SPring-8 injector system

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Abstract

The SPring-8 injector system composed of a linac and a booster synchrotron is under construction on schedule. The performances of the linac preinjector were proved to satisfy the requirements. Many components were fabricated and tested their performances. Construction of the injector building was completed in April 1995 and installation of the accelerators was started from May 1995.

1 INTRODUCTION

The SPring-8 is a third generation synchrotron radiation X-ray facility with a main accelerator of 8 GeV storage ring. The injector [?] for SPring-8 consists of a 1Gev linac and a 8 GeV booster synchrotron, as shown in Fig. ??. The positrons are used for the operation particle in the storage ring as well as the electrons. Fabrication of the accelerator components began in 1990. Construction of the injector building began in 1992 and was completed in 1995. Installation of the accelerator was started in 1995. General feature of the injector system will be explained in section 2, and status of the linac and the booster synchrotron will be presented in sections 3 and 4.

2 GENERAL FEATURES

The 1GeV linac consists of a 250MeV high current linac and electron/positron converter, and a 900MeV main linac. The electron beam is able to be accelerated up to 1.15GeV by means of extracting the target of the electron/positron converter from the beam line. The linac is able to produce various kind of the pulse width from 1nsec to 1μsec, which are requested by the storage ring operation modes; a multi-bunch operation and a single-bunch operation. The linac rf-frequency is 2856MHz and its operation rate is 60Hz at the maximum. The tatol length from the electron gun to the end of the linac is 140m followed by a 39m long beam transport line to the synchrotron.

The booster synchrotron is able to accelerate the beam injected from the linac from 1GeV to 8GeV which is the operation energy of the storage ring. The operation rate is 1Hz. The synchrotron has a racetrack shape with a FODO lattice containing 40 cells, which consists of 30 normal cells and two straight sections including 5 cells each. This straight section has 3 dispersion-free cells and 2 dispersion-suppressing cells with missing bending magnets. One cell is ~10m long, and circumference of the synchrotron is 396.12m. The natural emittance is $2.3\text{x}10^{-7}$ m·rad at 8GeV, and that is expected to be satisfactory for subsequent injection into the storage ring. The horizontal and vertical tunes are 11.73, and 8.87, and the natural chromaticities are -14.4 and -11.5 for the horizontal and vertical direction, respectively. The beam transport line between the synchrotron and the storage ring is 310m in length, climbing up by 9m in height.

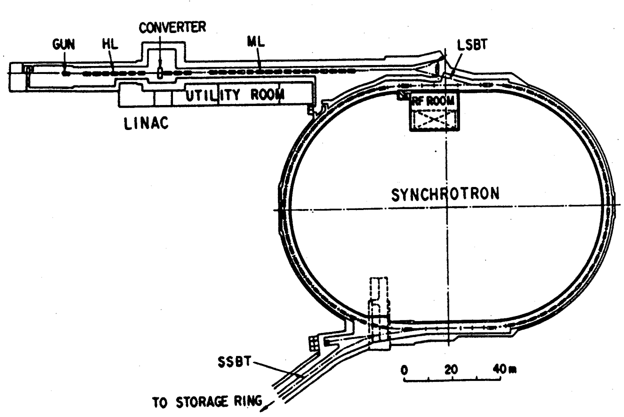

Figure 1: **Layout of the SPring-8 injector system.**

3 LINAC STATUS

3.1 *Preinjector*

The preinjector of the linac consists of the electron gun, two prebunchers, a buncher, several beam monitors, etc. This was fabricated in 1992 and temporarily installed in Tokai site to examine its performances. The performances of a thermionic cathode assemble were observed in many cases of changing parameters such as the high-voltage, grid-voltage, heater-power. The maximum beam current was obtained 22A at the condition of the high voltage of 200kV. The stability of the beam current was measured to be less than ± 1.5%. The pulse shape was adjusted by changing the three different types of the grid pulsers. The pulse width less than 1nsec was achieved by means of using a 4kV rapid rise-time

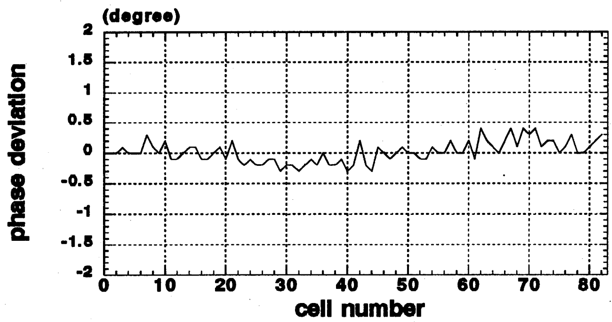

Figure 2: **Phase Deviation by Nodal Shift method**

pulser with a short circuit. The pulse transmission line between grid pulser and the electron gun was designed to have an impedance matched with the 1nsec grid pulser to prevent deformation of the 1nsec pulse. The bunching efficiency of the prebunchers and the buncher were 65% which is agreed with the calculation. The beam energy is 9MeV at the exit of the buncher and the energy spread was obtained to be less than ± 2%. The normarized emittance was measured to be about 130mm · mrad at the exit of the buncher.

3.2 Accelerator column

The linac has 26 accelerator columns. One accelerator column is 2.835m long containing 81 cells, and $2\pi/3$ traveling-wave constant-gradient type. They have three different type in a borediameter of an exit iris, which are 20.0mm, 20.5mm and 20.95mm, respectively. They are arranged in a manner to prevent multisection beam-breakup. The rf power is fed 26MW to each column, so that the average accelerating field is ~16MV/m, and the energy gain per each column becomes ~45MeV. The accelerator columns are designed to operate in the constant temperature of 30 ℃. The water cooling system is planned to have a capability of adjusting the temperature within an accuracy of ± 0.1 ℃. The disks and sylinders of the accelerator column are carefully machined with high precision and brazed in the vacuum furnace. The phase deviation of each cell, as shown in Fig. 2, are low enough within the specification of 2 degrees. The whole of the accelerator columns are already fabricated and stored on site enclosed with the dry nitrogen.

3.3 Magnet

The beam focusing magnets are composed of triplet-quadrupole magnets, which are placed in between accelerator columns. The steering magnets are utilized for beam position adjustment, which are used with the combination of the beam position monitors. These magnets were all fabricated and quadupole magnets were already installed in the machine room.

3.4 Klystron

13 klystrons are used for high power microwave amplifiers [2]. The klystron used in SPring-8 has the capabilities of the output-power 80MW, the pulse width 4μsec, the repetition rate 60pps. The klystron normally operates at the beam condition of 391kV and 474A. One klystron feeds the microwave to two accelerator columns. The fabication of klystrons are under way and now 8 klystrons were completed.

3.5 Modulator

The 190MW pulse modulator has a line type PFN with 4 parallel and 14 series condensors and inductors [3]. The ratio of the pulse transformer is 1:16, so that this modulator is required to produce the high-voltage pulse with 49kV. The voltage fluctuation was achieved to be less than ± 0.5% during the flat-top of 2μsec among the full width of 5μsec. The reproducibility of the output voltage was obtained to be good within ± 0.5%. The thyratron was selected F351; peak voltage 55kV and peak current 10,000A after the careful examination of several candidates.

4 SYNCHROTRON STATUS

4.1 Magnet

The magnets of the synchrotron are 64 dipole magnets, 80 qudrupole magnets, 60 sextupole magnets and 80 correction magnets. The core of these magnets is stacked with 0.5mm thick, silicon steel laminations. The dipole magnet has C-type core. The pole length is 2.870mm, and the maximum field strength is 0.9T. The pole width is 140mm with lateral shims 7.5mm wide by 1mm high. The good field region was obtained in the area of ± 40mm as shown in Fig. 3. The dipole magnets were all fabricated and started to be installed in the synchrotron tunnel since August 1995. The bore radius and the length are 70mm and 0.57m for the quadrupole magnets, and the maximum field strength is 15T/m. The bore radius and the length are 100mm and 0.15m for the sextupole magnets, and the maximum field strength is 200T/m^2. These magnets were all fabricated and measured their performances [4].

4.2 RF cavity

508.58MHz RF system for the synchrotron includes two 1MW klystrons and eight 5-cells cavities. The requiered RF voltage is 8MV at injection and 18.7MV at extraction, and the maximum RF power is 1.69MW. The effective RF voltage is changed by controlling the microwave phases between two klystrons

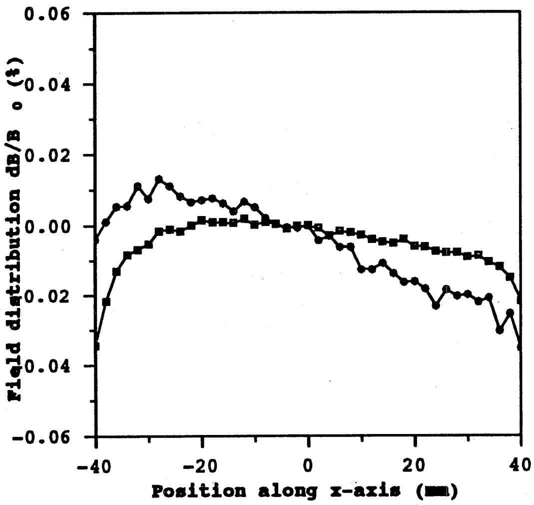

Figure 3: **Cross sectional field distribution. Circles at 1GeV and rectangulars at 8GeV.**

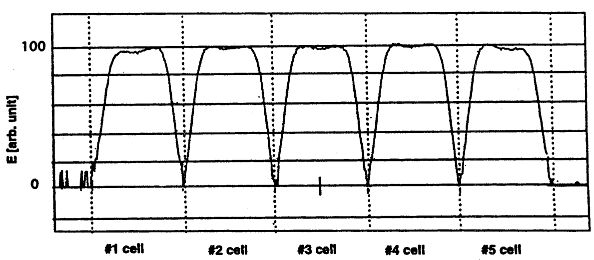

Figure 4: **Electric field distribution.**

from 131 degrees to zero degree, keeping the output power of the each klystron constant:845kW. The 5-cells cavity was selected to realize a high shunt impedance to reduce the wall losses. The effective shunt impedance was obtained to be ~21M Ω/m. The cavity has inductive coupling slots. A large coupling factor is required to stabilize the accelerating field against disturbances of the temperature rise. The total length 1640mm and the outer diameter is 492mm. Each cell of the cavity has a fixed tuner and a movable tuner to adjust the resonant frequency. The field distribution of 5 cells was adjusted to be constant as shown in Fig. 4.

4.3 Beam monitor

The synchrotron has several kinds of beam monitors; 3 current monitors, 80 position monitors, 14 screen monitors, a photon monitor, a RF-KO, 5 loss monitors. The beam position is measured at every quadrupole magnet by using a set of four button electrodes(BPM) mounted on the vacuum chamber. The signals from each BPM are transmitted through low-loss, high-frequency responce cables to the detector circuits via fast pin-diode switches. For real time measurements of the beam position during ramping, 4 electric circuits are independently processing data from 4 electrodes. BPMs were calibrated to obtain the exact beam position using the rf-antenna simulating the beam current [5].

4.4 Timing system

The integrated timing system is necessary to operate the accelerator complex such as SPring-8. Since the time width of each RF bucket is 2nsec, the timing accuracy required for beam transfer between two accelerators must be less than 100psec to suppress the beam loss due to the synchrotron oscillation at injection. Optical fiber of the transfer line, EO/OE transmitter and reciever and other compoments are required to be low jitter and low temperature dependence [6]. Several components were tested and the jitter of the electron beam produced by the linac preinjector was achieved to be less than 30psec using the high performance timing system.

5 CONCLUSION

The construction of the SPring-8 injector system is in progress, and many components were fabricated and tested to confirm their ferformances. The installation of the machine was started in the accelerator tunnel from May 1995.

6 REFERENCES

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