RACETRACK MICROTRON - 150 MEV INJECTOR FOR COMPACT SR RING

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A 150 MeV racetrack microtron is under construction. This machine will be used as an injector for a superconducting SR-Light source system "AURORA". All the components have been manufactured and tested. The individual components satisfy the design specifications. The injection system provides 120-keV electrons. The rf system supplies pulsed 2-MW power to the 6-MeV accelerating column at 2856 MHz. The 180° bending magnets generate the magnetic field strength of 1.3 T with a sufficient uniformity. The permanent quadrupole magnets are used for beam focusing on each lap. The field gradients are distributed from 1.5 to 8.5 kG/m.

1. Introduction

A 650 MeV compact superconducting synchrotron radiation light source system, named "AURORA", is being constructed by Sumitomo Heavy Industries, Ltd. (SHI).[1-4] This system is optimized especially for X-ray lithography. A 150 MeV racetrack microtron was designed[5] and is also being developed as an injector of AURORA. The microtron has advantage in compactness and economization over linacs and synchrotrons as the injector.

The microtron consists of an injection system, a linac system, two 180° bending magnets (main magnets) with reverse-field magnets, beam focusing elements, a vacuum system, several beam monitors, and a control system. All the components have been manufactured, tested, and are undergoing assembly. The status of the microtron is presented in the following sections.

2. Injection System

The injection system shown in Fig.1 consists of an electron gun, a single-gap cavity (SGC), two bunchers, focusing magnets, beam monitors, and a chicane magnet. The electron gun supplies 20-keV electrons. The maximum peak current is 800 mA and the pulse width varies from 0.5 to 3.5 µsec. A repetition rate of the pulses is adjustable up to 180 Hz. The vacuum system for the electron gun is separated from the downstream part by means of a 2-mm diameter slit, and the pressure is kept to be below 1×10^{-7} Torr.

The SGC boosts the electrons from 20 keV to 120 keV. The SGC has a geometry similar to the accelerating cell of the linac (discussed later) and a movable inductive tuner at a side of the cavity. The tuner position is controlled automatically by a feed-back system in order to continuously generate an adequate electric field. The two bunchers have an identical conventional re-entrant shape. The upstream buncher is made of stainless steel and has a loaded Q-value of 280. The downstream one is made of cupro-nikel and has a loaded Q-value of 850. The SGC is located between the two bunchers. The focusing elements are two solenoids, two pairs of X-Y steerers, and two doublets of electric quadrupole magnets.

3. Linac System

The conventional side-coupled-structure accelerating column which is operated at 2856 MHz accelerates electrons by a field gradient of 15 MeV/m. This 0.5-m column shown in Fig.2 has 80-MΩ/m effective shunt impedance and gives 6-MeV energy to the electrons accompanied with a wall loss of 1.3 MW. The high power test has been successfully done by feeding more than 2-MW peak power into the column without beam loading. An operating frequency is tuned by an automatic frequency controller according to the drift of the linac resonant frequency. The feed-back system works well.

The SGC follows the operating frequency by using a motor-driven tuner. This system works fairly well, but a little more precision in the phase adjustment is needed for the feed-back system. This system is being improved to obtain precision of a phase angle less than 5°. The SGC boosts the electrons up to 120 keV, spending 2-kW power on the wall. No problem arises when such levels of power are fed into the cavity.

The high power rf system transmitting 5 MW and 100 kW from a klystron amplifier to the accelerating column and the SGC, respectively, where waveguides pressurized by SF_6 gas are used, has been fabricated and tested satisfactorily.

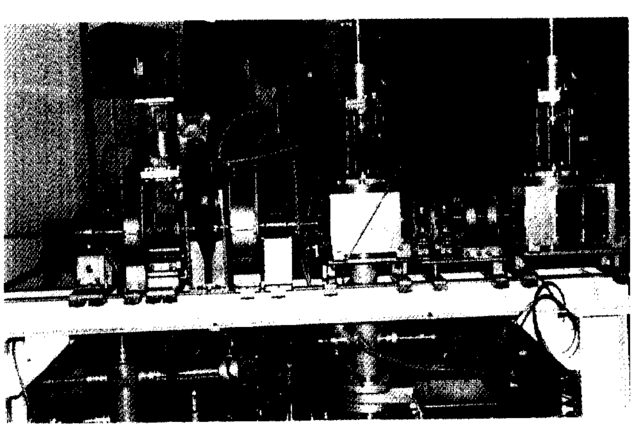

Fig.1. The injection system

Fig.2. The 6-MeV accelerating column

4. Magnet System

The magnet system of the microtron is composed of two main magnets, reverse-field magnets, permanent quadrupole magnets, vertical steerers, and an extraction magnet. The field measurements for all the magnets have been successfully completed.

The main magnet shares a yoke with the reverse-field magnet as shown in Fig.3. The pole of the main magnet has a size of 1100-mm width and 530-mm length. The pole gap length is 10.00 mm at the entrance and 10.56 mm at the opposite side. This gap difference gives a field gradient in order to obtain vertical focusing force for further turns. This pole gap, about one order narrower than conventional ones, requires high precision in flatness and smoothness for the pole surfaces. The poles were manufactured with a high-precision surface-glinding machine. The surface flatness attained is $\pm$ 2 μm while the surface roughness is $\pm$ 3 μm. The sensor used for field measurement was a Hall probe. The size of the Hall probe is 2.2 mm in width and 3.5 mm in length. Throughout the measurement the temperature of the Hall probe was detected to calibrate the output voltage of the probe. The measurement error is estimated to be $\pm$ 0.6 G. Observed uniformity of the magnetic field strength in the direction parallel to the entrance line results in $\pm$ 5 G over almost the whole area. At the corners of the entrance, however, the magnetic field becomes slightly higher. The uniformity on the line near the entrance is about $\pm$ 8 G. This is caused mainly by the effect of magnetic saturation at the corner of the pole. The measured field gradient is 0.14 T/m, which is consistent with the result of calculation by TRIM.

The reverse-field magnet has 25 pole gaps for 25 orbits. The dimensions of the pole size are 15 mm in width and 20 mm in length. The pole for the linac line has a different width of 40 mm. The poles have shims of 1.5 mm width and height at both the side edges. The magnet is operated at the field strength of 0.133 T. The measured maximum strength is 0.2 T. The field strength is varied within $\pm$ 100 G independently for each gap.

A pair of doublets of the quadrupole magnets are placed on each turn. Each quadrupole magnet except one doublet on the linac line is composed of eight or four pieces of $SmCo_5$ permanent magnets as shown in Fig.4. The permanent quadrupole field was measured by the rotation coil.[6] The center position of the quadrupole field was determined in an accuracy of 30 μm. The strengths of the higher order components are also derived at less than 2 % of the quadrupole one, which presents no problems in beam dynamics. The effective length of the quadrupole field can be continuously

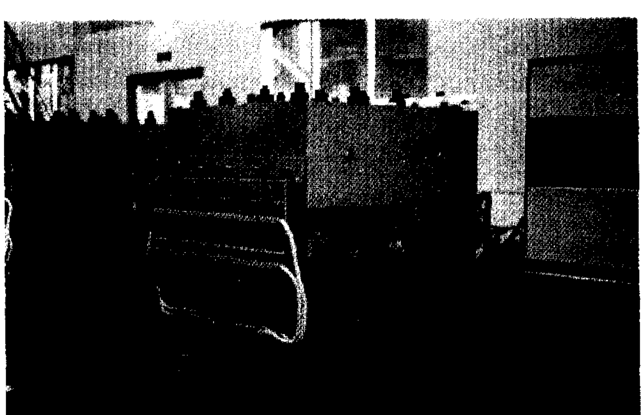

Fig.3. The main magnet and the reverse-field magnet

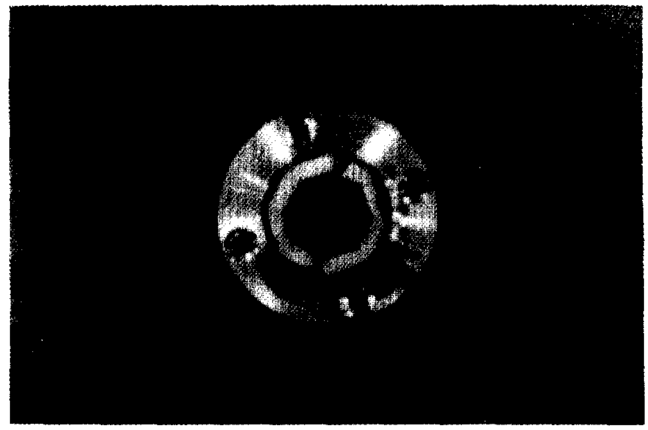

Fig.4. The permanent quadrupole magnet

varied within $\pm$ 15 % by a screw-in field clump.

The 150-MeV electron beam is extracted only by the extraction magnet installed on the last turn. This magnet bends the 150-MeV electrons at an angle of 10° with the magnetic field strength of 6.8 kG. A field clump of 6-mm thickness is added to the extraction magnet in order to avoid disturbing a beam on the 24th lap orbit by the fringe field of the magnet. Consequently, a measured fringe field strength on the 24th lap orbit is less than 1 G.

5. Vacuum System

The vacuum system of the microtron is separated into three sections; the injection system, an accelerating box, and the main magnet system. Turbo molecular pumps (TMP) and an ion pump (IP) are adopted in order to obtain a clean vacuum. One IP and one TMP are used in the injection system. The IP having a pumping speed of 20 ℓ/s achieved pressure of 3×10^{-8} Torr in the gun section. The 50 ℓ/s TMP is used for the remaining part of the system where the observed pressure is 1×10^{-6} Torr.

A 400 ℓ/s TMP is used for the aluminum accelerating box, where the accelerating column, a screen monitor, and a current transformer are installed. The first-five-lap beams pass through this box. The TMP is located just under the box, and the obtained pressure in the box is 3×10^{-7} Torr.

Another 400 ℓ/s TMP is used for the main magnet section which is composed of two vacuum chambers for the main magnets, beam ducts, and a movable screen monitor box. The pressure in the chambers of the main magnet is observed to be 1×10^{-6} Torr at the low energy side and 1×10^{-5} Torr at the high energy side. The pressure is good enough to avoid beam loss caused by scattering with residual gas molecules.

6. Control System

A control system of the microtron is contained within the total control system of the AURORA.[7] The system, based on computer control, has a three level hierarchical architecture. In the lowest level, local controllers, which are distributed over devices and control the devices directly, are linked by an optical fiber network. The local controllers, based on standard microprocessers and called Universal Device Controller (UDC), are originally developed by SHI in order to standardize the control of accelerators. Through the fiber network each local controller communicates with the second level controller, which monitors the status of the UDC's and sets parameters of the UDC's. The second level controller is connected with the highest level controller by Ethernet. Both the highest and second level controllers are configured by μVAX II. The highest level controller works as a man-machine interface as well as an intelligent control of the whole parameters.

Another feature of the UDC is that it operates standing alone. This specification is quite beneficial for maintenance of equipment. For example, the microwave controller consisting of several UDC's works well in local mode to control the rf system of the microtron.

The highest level controller works also as a beam-monitor processor linked by GP-IB and CAMAC lines. Two kinds of beam monitors are used for the microtron. One is a screen monitor, which is a profile monitor and whose data is image-processed through digitization by a CCD camera. The other is a current transformer type using a permalloy core, which can pick up a pulsed beam current. Data from the monitors are used to optimize the parameters of the microtron.

7. Summary

The 150-MeV racetrack microtron is under construction. All of the components have been manufactured and most of them have been successfully tested. The assembly of the microtron is almost finished and the test operation will start soon.

References

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