Research and Development for the 8 GeV Booster Synchrotron

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Abstract

We present an R&D programme and its initial results for the 8Gev synchrotron which is to be used as a booster of the storage ring (SPring-8). The subjects are concerned with magnets, RF system, beam duct with vacuum system and beam monitors.

Introduction

The role of the booster synchrotron is to accelerate positron/electron beams of the energy of 1 GeV from the linac up to 8 GeV for the storage ring. Low emittance (1.9×10^{-7} m.rad) and short(1 ns) or long(1 μs) pulse beam are requested. The outline of the synchrotron has been shown in elsewhere,[1,2] The design policy is that the system should be reliable, capable of various types of operational mode at a minimum of manpower with automation and maintenance free. Under these conditions we are now designing the synchrotron. Devices for the R&D are under construction and a part of the experimental programme has been just started. The final design should reflect those investigation.

Magnet System

The magnet system of the synchrotron are composed of 68 dipole magnets, 80 quadrupole magnets and 64 sextupole magnets. The cores of those magnets are made from 0.5 mm thick, silicon steel laminations and stacked into end plates of stainless steel. We selected C-type yoke for the bending magnet. An end view of a dipole magnet with radial shims on the pole face is shown in Figure 1, as an example. Figure 2 shows the good field region of the dipole magnet which is calculated with a 2-dimensional code, LINDA. We find that the good field region covers enough the sagita of about 33mm. The coil is made from hollow copper conductor molded with epoxy resin.

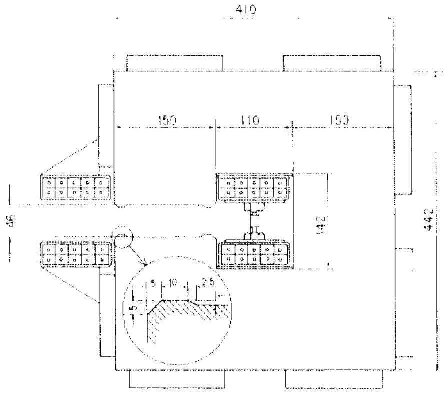

Figure 1. An end view of dipole magnet.

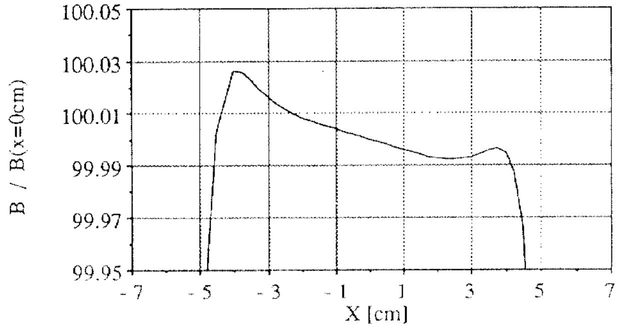

Fig.2. The transversal field distribution on the median plane calculated by LINDA. The field uniformity is requested to be better than ±0.05% in the region of x=±4.5cm. The yoke is in the minus direction.

The quadrupole magnet has a two-pieces structure of the core, which is more easy to achieve good field-gradient and takes less time to construct than the four-pieces structure. The coils, however, must be more compact to be installed and needs more current than that of four-pieces structure. The good field region is widened with radial shimming on the pole face. The sextupole magnet is also made of two-pieces core, but there is no radial shim on the pole face.

On the R&D plans we are making each prototype of dipole, quadrupole and sextupole magnets. The purpose of the research is to verify following points prior to the commissioning to the facility; 1) whether the designed magnetic fields are realized in the magnets, by comparing the computer calculations with measured ones and 2) whether the magnetic field distortion due to eddy current on the vacuum chamber in the ramp field of 1 Hz is reduced enough by using particular type of ducts: bellow type and/or reinforced thin ducts. We develop also easy and reliable methods of testing a lot of magnets before installation and see the reproducibility of the magnetic fields after reassembling of the magnets. For those measurements we have made hole probes, search coils, a harmonic coil, a long flip coil and a twin coils with their movement mechanisms.

As to the fast acting magnets, i.e. for injection and extraction sections, we consider there still remain difficulties because of its rapid rise time of the magnetic fields. The problem on the septum magnet is to minimize the leakage field out of the septum plate. For the kicker magnet, both rise and fall times of 100 ns should be achieved in order to kick selected bunches. So we have to test and develop the septum magnet and the kicker magnet with their power supplies. At the same time we will establish a method of measurement of such fast varying magnetic fields.

RF system

In the R&D plan for RF system we first make a full-scale model which is made of aluminum and test basic characteristics of the cavity at low power level. The subjects are ; 1) the resonant frequency, 2) Q values of each mode, which are compared with calculated ones and to be used to estimate conditions of the cavity surface, 3) measurements of the distribution of electromagnetic fields in the cavity, 4) shunt impedance from those measurements and an estimation of necessary power, 5) characteristics of the antenna, 6) performance of the tuner which enables to get best of the field distribution with automatic frequency control, 7) development of a computer control and data taking system. The results from the cold experiments should be reflected to the design of the next test cavity which is to be used in high power tests. Using a klystron test stand we will proceed high power experiments. The main subjects on the high power test stand as well as those of mentioned above are 1) a ceramic window which is capable of CW 250 kW, 2) thermal distortion of the cavity especially of the nose cone, 3) method of cooling and its efficiency. The parameters of the RF system are summarized in Table 1 and Figure 3 shows a photograph of the cold model.

Table 1
RF System Parameters

Type of Cavity Slot coupled	5 cells
Cavity Length	170 cm
Cell Length	29.5 cm/(λ/2)
Radius	21.5 cm
Effective Shunt Impedance	21 MΩ/m
Cavity Power (Peak)	250 kW
No. of Cavity	8
Frequency	508.58 MHz
Harmonic No.	672
Klystron Power (peak)	1.2 MW
No. of Klystrons	4
Accel Voltage at 8 GeV	17.1 MV
Accel Voltage at 1 GeV	1.8 MV
Over Voltage Factor	1.48
Synchrotron Freq at 8 GeV	32.4 kHz
Radiation Loss per One Turn at 8 GeV	1.6 MeV
Cavity Material	OFC

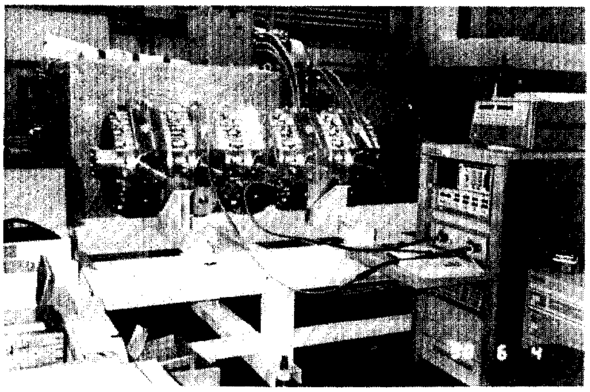

Fig.3 RF test stand for 5 cell cold model.

Vacuum

The design of the vacuum system is determined from the duct size, allowable pressure of the residual gas and allowance of the field distortion, which are related to the beam dynamics, beam life time and eddy current due to dB/dt, respectively. Because of 1 Hz operation of the synchrotron, we will prepare against eddy current applying a particular ducts: a bellow type or a thin tube reinforced by ribs. As mentioned above, effect of such particular duct against eddy currents is to be tested as R&D. The shape of the duct is ellipse with horizontal radius 36 mm and vertical radius 17 mm. The planned vacuum pressure, with beam, is lower than 1×10^{-6} Torr in everywhere by means of 4 ion pumps a cell (about 10 m long). For the simplicity we prepare no baking system. For this purpose the pre-treatment of the duct surface is a subject of R&D.

For the R&D we made two test stands. One is a prototype beam duct with a pumping system, which is equivalent to that of a unit cell of the synchrotron. A set of dummy button position monitor and a window port for visible light observations are also mounted. The study plan on the model duct are; 1) to know the reality of the pressure distribution, by varying pump power and distribution and to compare measured one and calculated one, 2) with a combination of model magnets, to see spatial problems and accessibility around the duct for the construction and maintenance works.

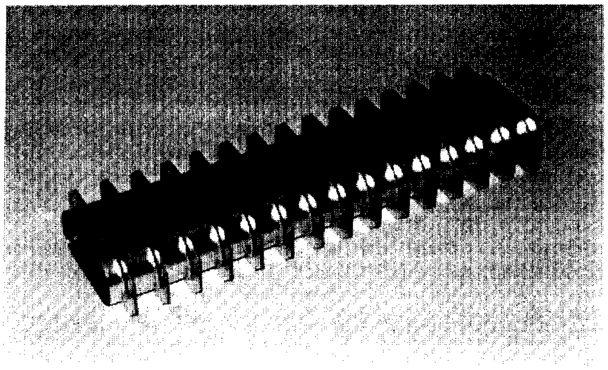

Fig.4 'Etude' of a rib-reinforced duct.

Another one is a test chamber which is to be used to evaluate outgassing rate of vacuum materials. Methods to lower outgassing rate is the dominant subject. A photograph of the test chamber is shown in Fig 5.

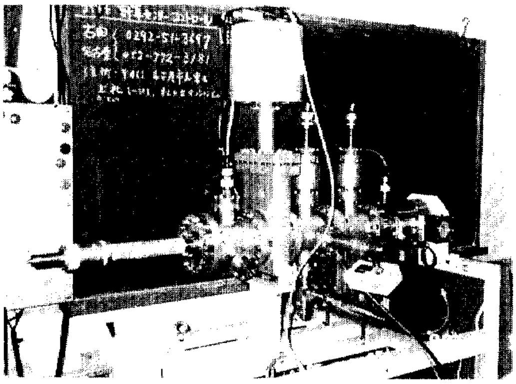

Fig.5 Test assembly for the measurement of outgassing rate.

Beam monitors

Various types of beam monitors have been proposed for the synchrotron and the beam transport line. Table 2 shows a list of those monitors to be used in the facilities. Although methods of those monitors have been established, we consider that each method has to be tested before application in order to avoid excess of the commissioning time. The synchrotron operation of 1Hz and 1 ns beam pulse seem to bring about a difficulty for us.

Table 2
Beam Monitors for Synchrotron and
Transport Lines between Synch.-Storage Ring

Items or Type	Synch	Transp. Line	Note
Button Position	80		
Fluores. Screen	7*	31	*injct/ext part
Current DC-CT	1		
Fast CT	1	5	amorph. core
Wall		15	
Multi-grid		6/X 3/Y	
Tune RF-KO	1/X 1/Y		
Visible Light	1 set		TV Camera Photo-diode Streak Camera
Beam Loss	40	9	Scintillator

Among those monitors we first test a multi-grid detector. The goal of this detector is to measure the beam emittance. Both of multi-wire and multi-plate type detectors, accompanied with a slit block, have been installed on a beam line of our linac.[3,4] We also mounted a fluorescent screen near those detectors in order to cross-check the beam shape. Figure 6 shows a very preliminary data obtained from the multi-wire. We saw an agreement of the beam size between this and the fluorescent screen but note that this does not represent a real profile. Because the present beam is not energy analyzed the peak moved on the grid during a 1 μsec pulse due to provably small energy change of the beam.

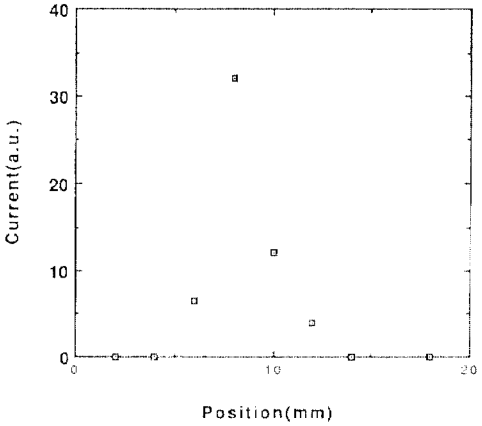

Fig.6 Peak plot of wire-grid signals during 1 μsec beam.

As other monitors, an amorphous core transformer for the fast current monitor, photo-diode arrays for the beam profile monitor and a scintillating fiber for the loss monitor have been prepared already and started to test on the linac or our compact ring (JSR).[4,5]

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