STATUS OF PHOTON FACTORY STORAGE RING

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1. General description

The construction of a 2.5 GeV electron storage ring at KEK-PF began in April, 1978. The aim of the storage ring is to provide intense synchrotron radiations with a broad spectrum from 0.1 Å to 1000 Å for reseaches of matters. Synchrotron radiations generated from bending magnets have a critical wave length of 3.09 Å. This value is reduced to 0.62 Å by using a wiggler of 6 tesla. The accummulating current is expected to be 500 mA. There are 24 light exit ports, however, six beam channels will be provided in the first stage. The principal parameters of the storage ring are listed in the Table 1.

Table 1 Principal parameters of the storage ring

Energy	2.5 GeV
Accummulating current	500 mA
Mean radius	29.77 m
Radius of curvature	8.66 m
Field strength of bending magnet	9.63 kG
Length of bending magnet core	1.85 m
Number of bending magnet	28
Length of Q-magnet core	0.5 ∿ 1.0 m
Number of Q-magnet	58
Tune number	
horizontal	5.25 ∿ 7.25
vertical	3.25 ∿ 5.25
RF frequency	499.99 MHz
Harmonic number	312
Synchrotron radiation loss	510 keV/turn
Number of cavity and klystron	4
Output power of a klystron	180 kW
RF voltage per turn	2.1 ∿ 2.8 MV
Average pressure (with beam)	∿10^{-9} torr
Beam life time	∿10 hr.
Beam size	
horizontal	1.5 ∿ 3 mm
vertical	0.1 ∿ 0.2 mm

The total cost is 2.4×10^9 ¥ except buildings and civil engineerings. Now the construction of a buildings for the storage ring including an experimental hall is under way. Commissioning is programmed for April, 1982.

2. Orbit and Magnet

The storage ring is composed of 28 bending magnets, 58 Q-magnets, 8 medium straight sections of 3.5 m in length and 2 long straight sections of 5 m in length as illustrated in Fig. 1. Four medium straight sections are

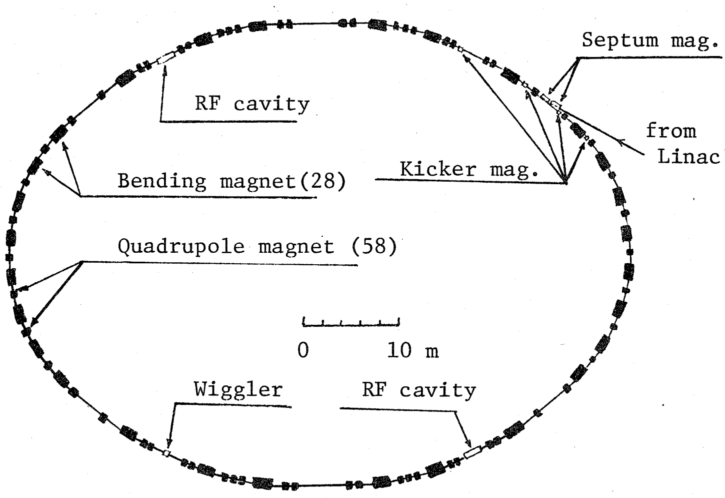

Fig.1 Plane view of the storage ring

used for the injection system and the RF cavities. Remaining six straight sections are dedicated to synchrotron radiation devices, wigglers as wave length shifters, interference undulators, etc. The momentum dispersion and β-functions in the normal operation are shown in Fig. 2, however, they are controlled by means of 12 independently powered Q-magnets. In the special operation mode, the beam size at the long straight sections becomes 0.14 mm× 0.45 mm, which makes possible to produce synchrotron radiations with high brightness providing a wiggler at this point.

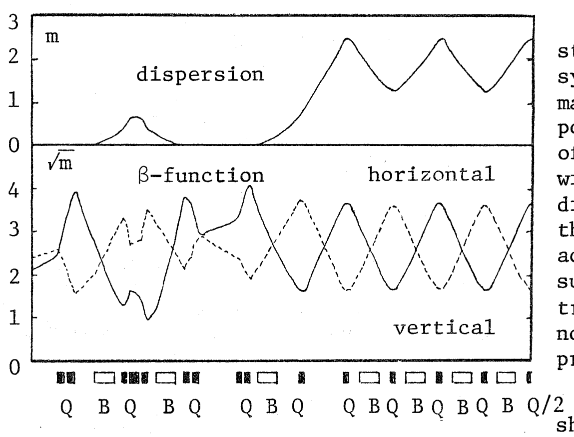

Fig.2 Momentum dispersion and β-function in the quater of the ring

The most important thing for a storage ring dedicated to the synchrotron radiation usage is to make the closed orbit as stable as possible. To do this, power supplies of all of magnets are stabilized within 2×10^{-4} and 42 electrostatic disc shaped position monitors measure the closed orbit position in an accuracy of 0.2 mm. All of power supplies of ring magnets are made by transisters to reduce electric noises which will give a serious problem for experiments.

The bending magnet is a C-shaped rectangular magnet with radial shims and pole end shims, and has a gap of 70 mm. Field measurements shows that the effective magnet length is uniform within $\pm 2 \times 10^{-4}$ along the radial position extending ±90 mm at 0.96 T, while it was ±20 mm at 1.2 T. This means that the accelerating storage up to 3 GeV will be possible.

3. RF System

The frequency of the RF accelerating system was chosen at 500 MHz. Four single cavities with a total shunt impedance of 34 MΩ are independently excited by four klystrons each of which is rated to give 180 kW output.

The shape of cavity was optimized by calculations using a program "SUPERFISH" which also surveyed higher-order TM_0 modes. The first several HEM_1 modes which are not axial-symmetric and have a possibility to deflect beams have been surveyed by measuring field distributions with a test cavity. In order to avoid coupled bunch instabilities, several kinds of couplers which suppress these modes by about 30 dB have been tested.

Three 180 kW klystrons were already completed and the conversion efficiency was found to be 55 %. A crow-bar circuit which shunts the power supply of the klystron in case of emergency has been tested in success.

4. Vacuum

The vacuum system is requested to realize the pressure of 10^{-9} torr, carbon equivalent, in the full beam operation. Defining the desorption ratio, η, which denotes the number of gases released when one photoelectron hits the vacuum wall, the calculation shows that the η-value of 10^{-6} will be necessary to satisfy the condition. Vacuum ducts are made from extruded aluminum alloy (Al-6063-T3 or -T5), and are cleaned by argon discharge as well as bakeout. Laboratory test shows that η for light atoms were reduced less than 10^{-6}, while η for argon was not below 10^{-5}.

Pumping system consists of 52 ion pumps (128 ℓ/s), 28 distributed ion pumps (DIP) in the bending magnets and 6 roughing pump stations. Measured pumping speed of the DIP is 190 ℓ/s for N_2 at 6 kV and in the magnetic field of 1 T.

5. Beam channels

In the first stage, two beam lines for vacuum-ultraviolet (VUV), one for soft x-ray (SX) and three for x-ray will be provided. VUV and SX lines have a vacuum protection system with an acoustic delay line (ADL) and a fast closing valve. The ADL is a tube of 310 mm in diameter and 2 m in length loaded with an array of nine coned diaphrams each of which has a light path window of 15 mm × 55 mm. The measured delay time was 160 msec and 30 msec at the end point and at the middle of the ADL, respectively. X-ray beams are extracted through a beryllium window of 100 μm in thickness.

6. Beam monitors

Beam position monitors were already mentioned in section 2. The average current is measured by a DC current transformer with frequency response from DC to 500 MHz in an accuracy within 0.1 %. Synchrotron radiations will be used in measuring beam positions, profiles, intensities and the time structure of bunched beams.

7. Vertical wiggler

The wiggler magent consists of three pair of superconducting coils with iron poles and is set inside an iron magnetic shield. The magnetic fields of the central pole is 6 T in the radial direction, while that of outer poles 3 T. Eelctron beams are wiggled in the vertical plane by 10 mm and produce radiations which have an electric vector in the vertical direction. The vertical polarization is usefull for complex experimental apparatus set in a horizontal plane.

A beam pipe which has a shape like inverse T is inserted through the magnet. During injection, the wiggler is moved up so that electron beams having large spatial spread pass through a wider part of the pipe. After the beam size is shrinked to 2 mm × 1.2 mm due to radiation damping, the wiggler is moved down so that the beam can pass through the narrow magnet gap of 42 mm. In the case without any iron, the ratio between the field strength in the gap and that inside coils is 1.3. Due to the iron shield together with iron poles, this value is reduced to 1.1. In fact, in the model test, 6 T was easily reached without any training phenomena.

7. Control

The PF control system has to provide many function as: start-up and operation of machine, surveillance of operating parameters, real time data acquisition for experiments, machine and environment protection, access control, book keeping and program development.

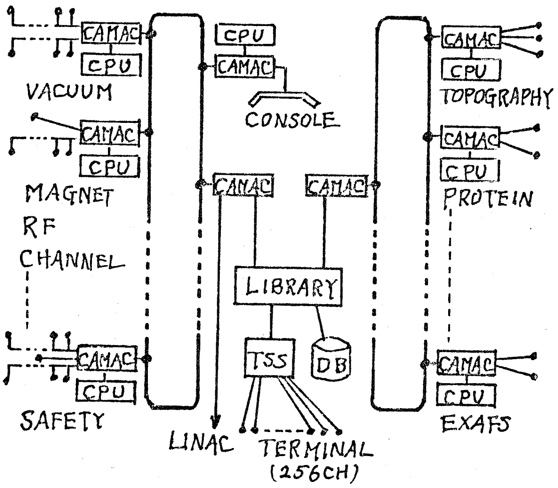

Fig.3 Diagram of the computer network
A: storage ring control loop
B: experimental data aquisition loop

In order to accomplish the above functions in a flexible way, the PF control system will be built around a network of computers as illustrated in Fig. 3. All the subsystems which have mini-computers or micro-processors are jointed by high speed data links through CAMAC modules. The library subsystem contains a complete record of the machine stauts, reference data and control programs of all subsystems. The library computer is a sophisticated midi-computer incorporating a large scale memory (6 MB), a large capacity disk (3.2 GB) and other peripheral devices.

The detail of the storage ring is described in the "Photon Factory Design Hand Book" and many "KEK-REPORT" written by members of the Department of Light Source, Photon Factory, KEK, who are acknowledged as following.

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