Magnet, Power Supply and Alignment

Noritaka KUMAGAI
Koji TSUMAKI

Magnet Group has responsibility for magnet design, field measurement, girder design, power supply provision, magnet installation, and alignment.

Magnet

The storage ring of SPring-8 has 88 dipoles, 480 quadrupoles and 336 sextupoles. All these magnets are constructed with laminated silicon steel plates of 0.5 mm in thickness. For closed orbit correction, 569 steering magnets are used. Four bump and septum magnets are installed for beam injection.

Dipole magnet: The dipole magnet has a C-shaped rectangular configuration with 64.04 mm gap width. The field strength is 0.679 T. The pole is flat over a horizontal range of 120 mm and has radial shims of 1.5 mm in thickness at both radial ends to obtain a good field region of 60 mm.

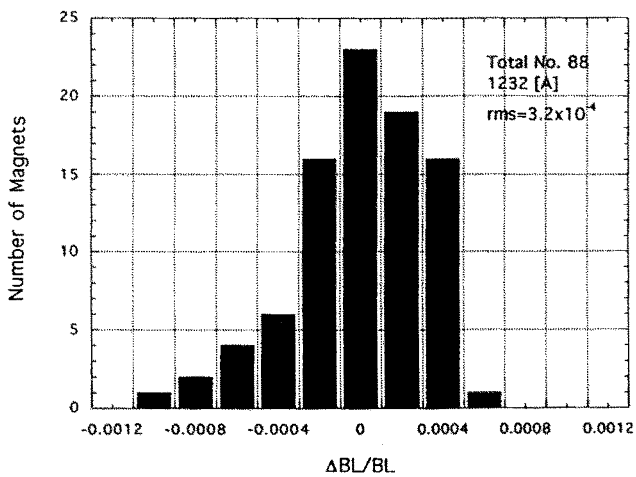

Fig. 1 Integrated field strength of dipole magnets.

Quadrupole magnet: Two types of magnets having different yoke structure have been designed to avoid interference between magnet yoke and vacuum chamber or photon beam line. All magnets have the same pole contour with four different length. Bore diameter is 85 mm and the maximum field gradient is 18 T/m.

Sextupole magnet: Magnets with two different exterior size has been designed for the installation of vacuum chambers and beam lines. Yoke structure is completely symmetric. Pole contour and yoke width are the same for all magnets. Bore diameter is 92 mm and maximum field strength is 420 T/m^2.

Steering magnet: Closed orbit is corrected by 286 horizontal and 283 vertical steering magnets. The maximum integrated field strengths of horizontal and vertical steering magnets are 0.0267 T•m and 0.0133 T•m, respectively.

Injection magnet: The synchrotron ejects electron or positron beams with the repetition rate of 1 Hz or 10 Hz. The beams are injected into storage ring through three DC and one pulsed septum magnets. The bump orbit is formed by four bump magnets. DC septum magnets are operated in the air and a stainless steel vacuum chamber is installed in the magnet gap. The pulsed septum magnet is in the vacuum vessel. The stray field on the bump orbit are canceled by the fields generated by eddy current in the septum wall. The core of the bump magnets is made of ferrite and the vacuum chamber at the magnet section is made of ceramic to avoid generation of eddy currents.

Fabrication of dipoles, quadrupoles and sextupoles have been almost completed and the field measurements are progressed. A long flip coil is used for the measurement of integrated dipole fields of dipole magnets. Measurement results are shown in Fig. 1. Integrated field gradient and multipole field of quadrupoles and sextupoles are measured by the harmonic coil. Magnetic centers of quadrupoles and sextupoles are transferred to the fiducial points on the magnets within the accuracy of 20 μm. These transferred fiducial points are used for the precise magnet alignment.

Final design of steering magnets and injection magnets was finished and the specifications were written. Fabrication of injection magnets will be completed by August 1996. Delivery of steering magnets will start in March 1996 and finish in September.

Girder

We place 5 or 7 quadrupole and sextupole magnets on a girder. After the placement of quadrupole and sextupole magnets, the girder positioning is done and the magnets on a girder are aligned very precisely on a straight line. Therefore the girder is required to have high rigidity and high position adjustability. We made a prototype girder and tested the performance. On the basis of the test results, we designed a new girder. Girders are now being fabricated in a company. Delivery of girders starts in April 1995 and finishes by the end of September.

Power Supply

Total electric power for all magnet power supplies is 7.2 MVA. All the dipole magnets are electrically connected in series and the power is supplied by a single power supply. The quadrupoles in the same family are connected in series and powered by the same power supply. Six families of quadrupoles which are faced to the straight sections have auxiliary power supplies to correct the β function distortion due to insertion devices. The quadrupole magnets in the four long straight sections have also auxiliary power supplies to adjust the β values. Each family of sextupoles is also connected in series over the 48 cells. Current stability of 1×10^{-5} is required for dipoles and 1×10^{-4} for quadrupoles and sextupoles. Steering magnets have individual power supplies. Three DC septum magnets are excited in series by a single power supply. The pulse shape of the pulsed septum magnet is half-sine-wave. Bump magnet power supplies also provide half-sine-wave pulses with 6 ms pulse width.

All the power supplies of dipoles, quadrupoles and sextupoles and half of the steerings were delivered. These power supplies will be installed in the four buildings which are distributed along the inside of the ring.

Alignment

We align the quadrupoles and sextupoles through two-step process. The first step is to align the magnets at each end of a girder and survey the girder position by a laser tracking system using these magnets as fiducial points. Smoothing is done on the basis of survey results. Survey and smoothing of girders are repeated two or three times. In the second step the quadrupoles and the sextupoles on a girder are aligned on a straight line using the high accuracy laser alignment system which consists of a He-Ne laser, a CCD camera and a computer (Fig. 2). Following the girder alignment, dipole magnets are aligned using the laser alignment system.

Survey network for girder alignment was optimized and girder alignment accuracy was estimated by computer simulation taking into account the measurement error of laser tracker. Simulated results showed that the relative alignment error between the neighboring girders was 0.04 mm and the absolute error was 0.9 mm. The laser alignment system for second step alignment was developed and the measurement accuracy was measured. The measurement accuracy strongly depends on the air flow and the temperature change. The stability of laser was 1 mm/(deg•m) without the air flow. It was enough accuracy for the second step alignment.

Magnet installation and alignment will be started in April and ended in March 1996 except the steering magnets.

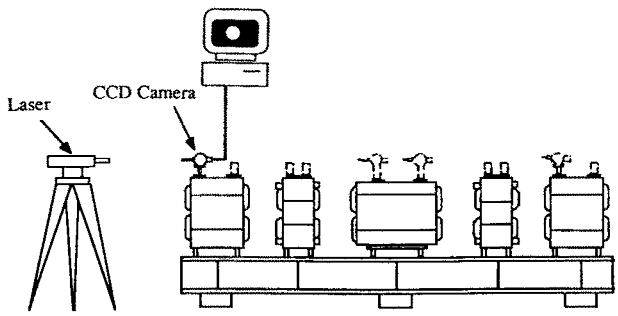

Fig. 2 Magnet alignment on a girder by laser system.