IMPROVEMENT OF THE SPS MACHINE PERFORMANCE

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Abstract

Ever since the first successful storage of electron beam, work for improving the machine performance has been performed on the Siam Photon Source (SPS), the modified SORTEC machine.

The majority of the problems to be overcome are inherent in a used machine. Apparent features were unstable operation of the machine control system caused by electrical noise, the energy fluctuation of the linac electron beam, low injection efficiency to the storage ring, the frequent strong beam instability of the storage ring, large COD and the nonuniform distribution of the betatron function with anomalously large values at some quadrupole magnets. Noise has been removed. The origin of the serious beam instability is the short circuit in some of the quadrupole magnets. Renewal of four very defective coils significantly improved the machine performance. A maximum stored current of 216 mA and the beam lifetime of 6 hrs at 100 mA have been attained. We are writing a program for the easier setting of the required operating points.

INTRODUCTION

The Siam Photon Source has been built using the components of a used machine, SORTEC. The machine components were transferred from the SORTEC Laboratory to the National Synchrotron Research Center (NSRC). The accelerator complex comprises a 40 MeV injector linac of the re-entrant type, a 1 GeV booster synchrotron of the FODO lattice and a light source storage ring of the DBA Double Bend Achromat) lattice [1]. The LBT (Low energy Beam Transport) line connects the linac and the synchrotron. The HBT (high energy beam transport) line connects the synchrotron and the storage ring. In the Siam Photon Source, the linac, the synchrotron and the LBT line of the original SORTEC machines were used without modification. The storage ring and HBT line were rebuilt and modified to have a more advance structure for the utilization of synchrotron radiation. The work of the machine reassembly, the commissioning and the performance improvement included a lot of repairing. The machine control system is described elsewhere [2, 3]. The first electron storage was achieved in December 2001.

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BEAM INSTABILITY PROBLEM

Many defects have been found. They were caused by the degradation of various components in electrical power supplies and controllers [1-7]. Ever since the first storage of the electron beam in the storage ring, efforts to improve the machine performance have been carried out. The problems we had to solve were the low injection efficiency, short lifetime and the beam instability. They are related to each other to some extent. We have spent almost two years to settle the serious parts of the problems. In this report, the problems described above and their cures are presented. They appear to be quite distinctive of the accelerator complex of the Siam Photon Source.

MEASUREMENS OF MACHINE PARAMETERS

In the early stage, most of the efforts of the machine performance improvement were focused on the removal of noise [6-7]. The power supplies of the linac and the synchrotron are great sources of noise. The noise affects various parts of the control system, power supplies and controllers. The details of the noise trouble-shooting are not described here. Serious noise has been removed up to the present.

The beam instability is defined as the change of the beam intensity and the beam location. The beam instability of the storage ring had long been puzzling, since long-lasting investigations provedthat there was no defect in the power supplies and controllers of magnets and the microwave system for the RF acceleration. We eventually measured the machine parameters such as the tunes, the betatron functions, the dispersion function and momentum compaction factors. Among others, the measured data of the distribution of the betatron functions along the electron orbit is very astonishing.

The betatron functions at the quadrupole positions have been measured. The functions can be obtained by measuring the tune shift, as the magnetic field is charged [8]. Figure 1 shows the measured values of the betatron functions. The x-axis indicates the position of quadrupole magnets along the central orbit. The points show the values obtained by the measurements. The lines connecting the measured points are the calculated betatron functions obtained by the data fitting. The program, Beam Optics, was used in the.

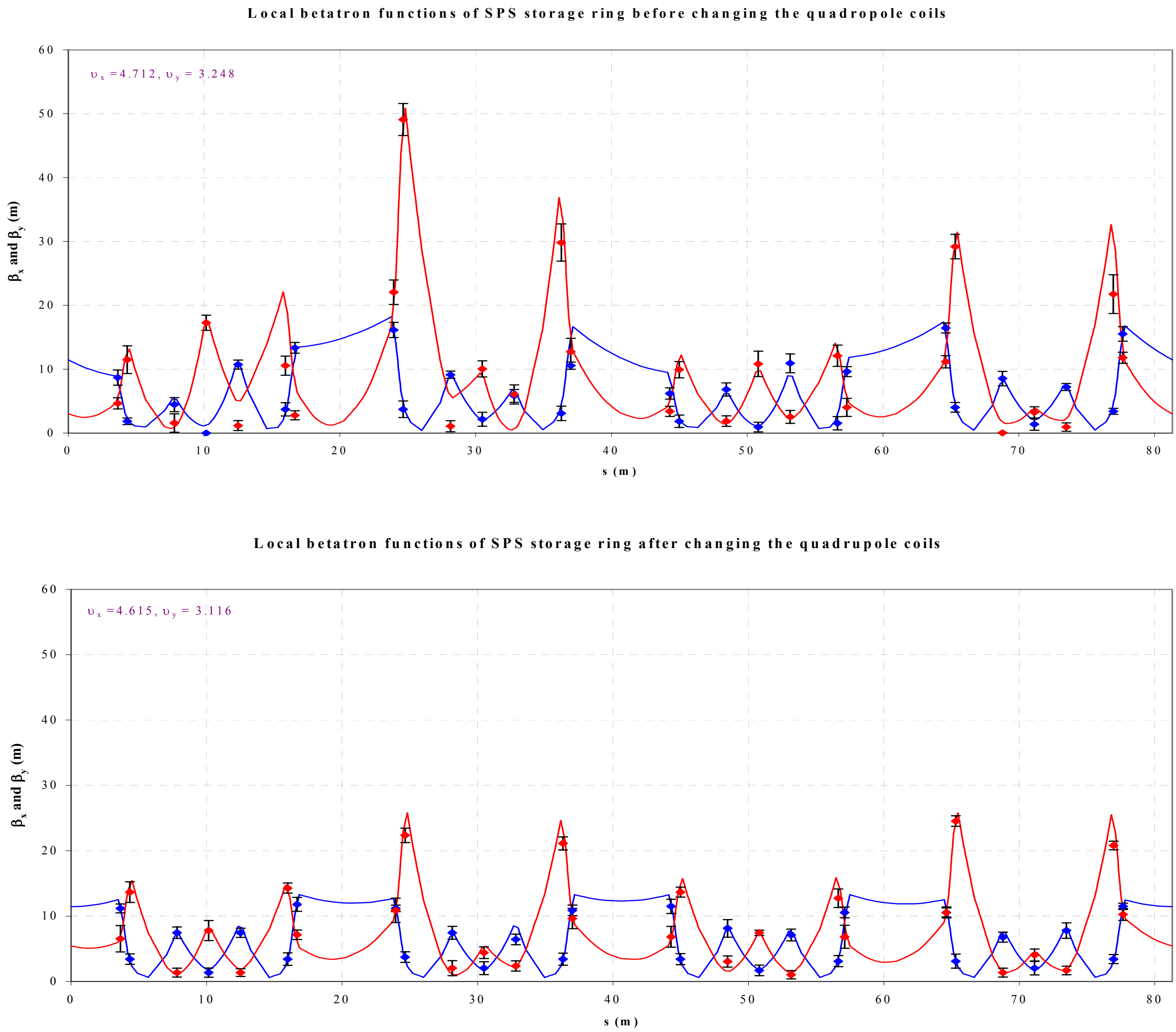

Figure 1: The measured horizontal and vertical betatron functions at the positions of quadrupole magnets before and after changing 4 quadrupole coils. Points indicate the measure value and lines indicate betatron functions fitted by Beam Optics

calculation [9]. In Fig 1, two curves of the distribution of the betatron function are shown. In the upper panel, the distribution curve before the magnet coil replacement is shown. In the lower panel the distribution curve after the coil replacement is shown.

At some locations, the values of the betatron functions were very large as is seen in the distribution curve in the upper panel. This fact is consistent with other pieces of observation: (a) We have to give strong fields to some steering magnets to have the beam stored in the ring. (b) Strong γ rays are emitted in the forward beam direction in some quadrupole magnets upon the beam injection. (c) The beam lifetime is short. (d) The maximum stored current does not stay at the high level. (d) The COD is large and cannot be corrected. The beam scraping may occur because of the large beam size and COD.

DEFECTS IN QUADRUPOLE MAGNETS

To investigate the problems, we monitored the voltage drop across each coil of the quadrupole magnets. It was found that many coils from SORTEC's quadrupole magnets had incorrect and unstable ampere-turn numbers.

Two very interesting things were found: (a) Some of the coil resistances were much less than the others. (b) In some coils, the resistance fluctuates with time. The behavior found here strongly suggest that the short-circuit occurs between the coil layers and its state changes with time as the temperature of the coil is changed. The short-circuits were found only in the quadrupole magnets previously used in the SORTEC storage ring. The recent "autopsy" of the problematic coils showed that the insulation between layers was not maintained with the materials used there.

We have temporarily replaced the seemingly worst 4 coils in 4 quadrupole magnets with new ones. This drastically changed the machine performance. The maximum stored current reached 216 mA. The beam lifetime at 100 mA was increased to 6 hrs. These values are those of the design goal. The beam lifetime has been increases drastically. The asymmetric distribution of the betatron functions has not yet been corrected completely. This is obvious in the distribution curve in the lower panel. Although the values of the betatron functions have decreased considerably, the distribution curve is still asymmetric. By investigating a defective coil, we found the causes are too low temperature for the heat treatment of the coil and the use of improper insulation materials.

BEAM INSTABILITY IN THE INJECTOR PART

The beam instability of the injector linac manifests itself as the occasional fluctuation of the beam intensity. We found that this is attributable to the fluctuation of the beam energy. This fluctuation arises from the degradation of the components in the microwave electrical circuit. The problems were also attributable to the inappropriate circuit design and the use of improper circuit components. The adjustment of the control circuit was not very well done. Large noise arising from the breakdown discharge in the high voltage circuit prevented the proper operation of various monitors and the fine tuning of the controllers and power supplies could not be implemented. Up to the present, the degraded components have been renewed; the fine tuning of the controllers and the power supplies was carried out; a voltage amplifier has been installed at each beam current monitor; the emission current from the electron gun has been increased. These enhanced the injection efficiency. The fluctuations of the beam energy have been reduced to a level that does not affect the injection efficiency. However, some noise still remains.

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