BEAM MONITORING SYSTEM FOR THE COMPACT SYNCHROTRON LIGHT SOURCE AURORA

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Abstarct

A beam diagnostics of AURORA the compact synchrotron light source requires a development of new kind of beam monitors because of the size and the shape of the storage ring which has no straight sections. In this paper a philosophy of the beam monitoring system for this compact light source is briefly described, and some detailed descriptions on particular instruments such as a Cerenkov counter using optical fiber bundles, specially developed screen monitors, and telescope systems for synchrotron lights are presented.

Introduction

The beam diagnostics of AURORA is carried out somewhat in different fashion from another conventional type storage ring. Since AURORA has no straight sections to achieve a possible smallest synchrotorn light source,[1,2,3] beam monitors typically placed on the straight sections need to be either modified or newly developed. We have to avoid these instruments to be irradiated by synchrotron radiation when it is placed at the bending sections. We are also concerned that the strong magnetic field may interfere these instruments. The high vacuum environment rises difficulties concerned with the housing of the instruments. A current transformer, for instance, typically used in the synchrotron is useless under the high magnetic field as well as under the synchrotorn radiation. We also found that button monitors are affected by the slit on the beam duct for extracting the radiation. The discussion of the beam monitoring system of AURORA is separated to two parts. One is on the injection microtron and the other is on the electron storage ring.

Beam monitoring system for the 150 MeV injection microtron

Commissioning of the 150-MeV racetrack microtron[4,5] is the process to optimize 50 steering magnets for 25-lap orbits in collaboration of powers and phases of 3 rf components. Difficulty in tuning this type of accelerator is of that the optimum values of these magnetic elements are changed by the rf-power split to the linac, single gap accelerator, and buncher, and by the phases between those. For the commissioning we have prepared the beam monitors as many as possible. However, after some experiences of operating the microtorn, we intend to select some of the most useful monitors utilized for the automatic tuning. For this purpose most of the beam data are taken through the computer system and linked to the central console.[6]

Destructive type profile monitors:

The beam monitors used for the microtron are the kind of standard one. The most convenient equipment to observe the beam profile and its center is a screen monitor made of alumina ceramics with 3% of chromium oxide ingredient. This screen monitor is used at almost every tuning points. In fact the thin gold plated screen is useful for even 30-keV electrons at the injection line. The reason for the difficulty in detecting low energy electrons was found so that the accumulated charges on the screen reflects the electron beam. The ceramics screens are viewed through compact CCD cameras, and the beam image was processed by Micro VAX II named the Central Intelligence System.[6] The image processor is operated in a real time refreshing mode, in an averaging mode, as well as in a real time summing mode which is useful to observe a faint beam. The image processor accommodates a function for making a projection of the beam profile in order to find the beam center and width. From the intensity of the integrated beam image, the beam current is also deduced. The combination of the CCD camera and the alumina screen improved the observable beam current to 0.1 μA peak at a few μsec pulse width and 10 Hz duty cycle. Screen monitors are also placed in the every turn of the microtron. A single camera manages the views of the 25 screens. Of course all these monitors are controlled from the central console as well as from the local panel.

Non-destructive type profile monitors:

A CCD camera to view directly the SR light from the bending section of the microtron is useful for the measurement of the turn separations and the beam profiles of all the trajectory at once. In Fig.1 typical SR lights from every turns are shown, although the visible light is available from the electron with energy higher than about 30 MeV (corresponding to the 4th turn). The spot at the most left(right) in the Fig. 1 is the synchrotron light from the 4th(25th) turn. Due to the refrection of the synchrotron light by the pole surfaces of the magnet the spot is seen as a triplet at the younger turn. The synchrotron light from the lower energy electron shows naturally more divergence.

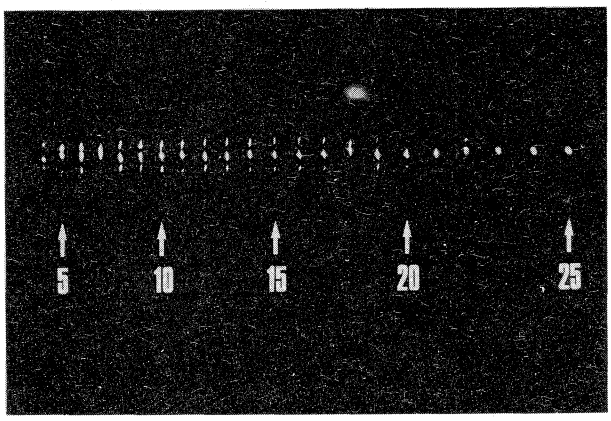

Fig.1 Syncrotron lights from the bending section of the microtron.

Current monitor:

A current transformer(CT) is useful to measure non-interactively the beam current as well as the beam time structure. We have installed the CT in the major portions of the beam line. The CT was made of a SEMPERMAX core wrapped with a glass tape. The core size is 10(width) x 20(ID) x 35(OD) mm, and is winded with 0.5mm thick wire by 25 turns. The housing of the CT was made carefully to shield the rf noise which penetrates from the opening for the beam. As a result the sensitivity of the current transformer was improved to minimum 1 μA pulse beam with the help of amplifier. The response of the CT (without amplifier) is compared with the input pulse in Fig 2. The current reading is monitored through the Universal Device Controller[6] as well as through a digital oscilloscope which is linked to the Central Intelligence System via GP-IB. The reading of the current transformer is referred by the automatic tuning program for the 50 steerers.

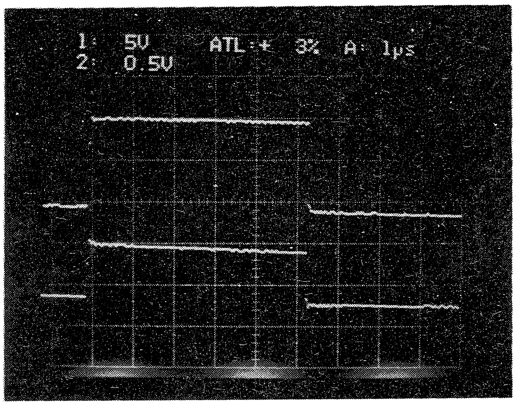

Fig.2 An output from the current transformer(bottom) is compared with the input signal(top).

Beam monitoring system for the storage ring

A beam monitoring of our electron storage ring faces to the special problems. Since there are no straight sections in the ring, and all sections of the beam duct have a slit on aside, a current transformer, for instance, typically used to measure beam current is not available. The reading of button monitors to measure the beam position is affected by the electromagnetic wave penetrate through the slit. Also the beam duct is in an environment of the high vacuum in the order of 10^{-10} Torr as well as the high magnetic field, then the materials to be used in the chamber must be specially concerned of magnetism and out gassing. Because of these facts we have designed the beam monitoring system which uses mainly the synchrotron radiation itself to observe the positions, profiles, and even intensities of the circulating beam. The betatron oscillation number can also be measured through the synchrotron radiation with a pin hole camera. The alignment of the injection line which is composed of two magnetic channels and one inflector is carried out by screen monitors and a Cerenkov counter using an optical fiber bandle. The overview of the beam monitoring system in the ring is shown in Fig. 3. Photo-multipliers are attached to the almost every light beam lines for the commissioning of the ring. It might be mentioned that the role of the beam monitoring for the ring is somewhat different from that for the microtron. The beam optics is rather simple in the case of the ring, since the number of the components to be adjusted is in the range of 10. Since the ring is made of the single-body of magnet, and the magnetic field is shaped so good as the theoretical requirement,[7] the correction of the COD is not so important. A study of the beam instability and the beam quality, and the observation of the resonances and the betatron tune number are the primary importance of the beam monitoring for our storage ring.

Screen monitors:

Screen monitors are placed between every beam tuning devices along the injection orbit in the ring magnet. Two magnetic channels modify the fringing field so to make suitable injection trajectory. The injection angle to the circulating orbit is determined by the electrostatic inflector. The screens are made of either the plate of a CaF_2(Eu) scintillator or the aluminum ceramics. We found the scintillator producing more than 5 times luminescence than the ceramics. The screens are viewed through the image fibers which are loaded in flexible bellows for protecting the vacuum. The image fiber made of pure quartz is quite stable against radiations, and, of course, functions without trouble under the strong magnetic field.

Cerenkov counter:

Tuning of the inflector voltage and position is carried out by looking at the reading of the Cerenkov counter arrays placed at the exit of the inflector. At the operation the monitor must be slided into the beam duct through the narrow slit to intersect the beam. The multi-wire monitor or the wire scanner is often used for this purpose, but since the large rf-noise is expected in the ring and the strong magnetic field disturb the reading, we have developed a Cerenkov counter, which is a fiber bandle composed of 8 of 1mm thick quartz fibers. The Cerenkov counter is set at 43° with regard to the beam direction to maximize the Cerenkov yield. The Cerenkov emissions are detected with photo-diods, and the converted charges are accumulated in 1000 μF condenser before they are read out through gate arrays. The gates are operated at 2 μsec interval and the accumulating time is variable in the range from 100 μsec to 1 sec. Depending on the beam intensity the accumulation time is changed. In this way the vertical profile of the beam is displayed on a digital oscilloscope, and the horizontal profile is observed by scanning the sensor.

Telescope system:

A special telescope has been developed to observe the beam profile, COD, as well as the betatron oscillation. It has a few mm deep focusing power and 10 μm of resolution power at the position of the circulating beam. We can select the eyepieces which provide either 5 or 10 times magnifications. We rather selected the telescope having the narrow depth of a focus to limit the well focused view to a specific region of the beam trajectory. In this way we hope to observe a sharp cross sectional view of the beam. This telescope is arranged so to provide 3 view ports by half mirrors. The first port is kept for a CCD camera to observe the beam profile, and the second is used for a pin-hole camera to measure the betatron oscillation number, and the third is not specified in this moment. The displacement of the beam position from the designed beam center can be measured with the CCD camera within the accuracy of 50 μm. The designed beam position is known by the laser placed in the opposite side of the telescope. We are planning to install a set of slits in front of the telescope to measure the beam emittance.

Other monitors:

Photo-multipliers(PM) directly coupled to the end of the every light beam lines might be useful to catch the first evidence of the captured electrons by the half resonance injection method. The PM will be used to measure the beam current as well.

We could find places for two button monitors, although the space is limited by another components such as the rf-cavity which could interfere the reading of the monitor.

Conclusion

The beam monitoring system for the 150-MeV racetrack microtron and for the unique electron storage ring has been developed. The system for the microtorn has already been tested, and we have successfully extracted 150MeV elctron beam. We are now commissioning the electron storage ring.

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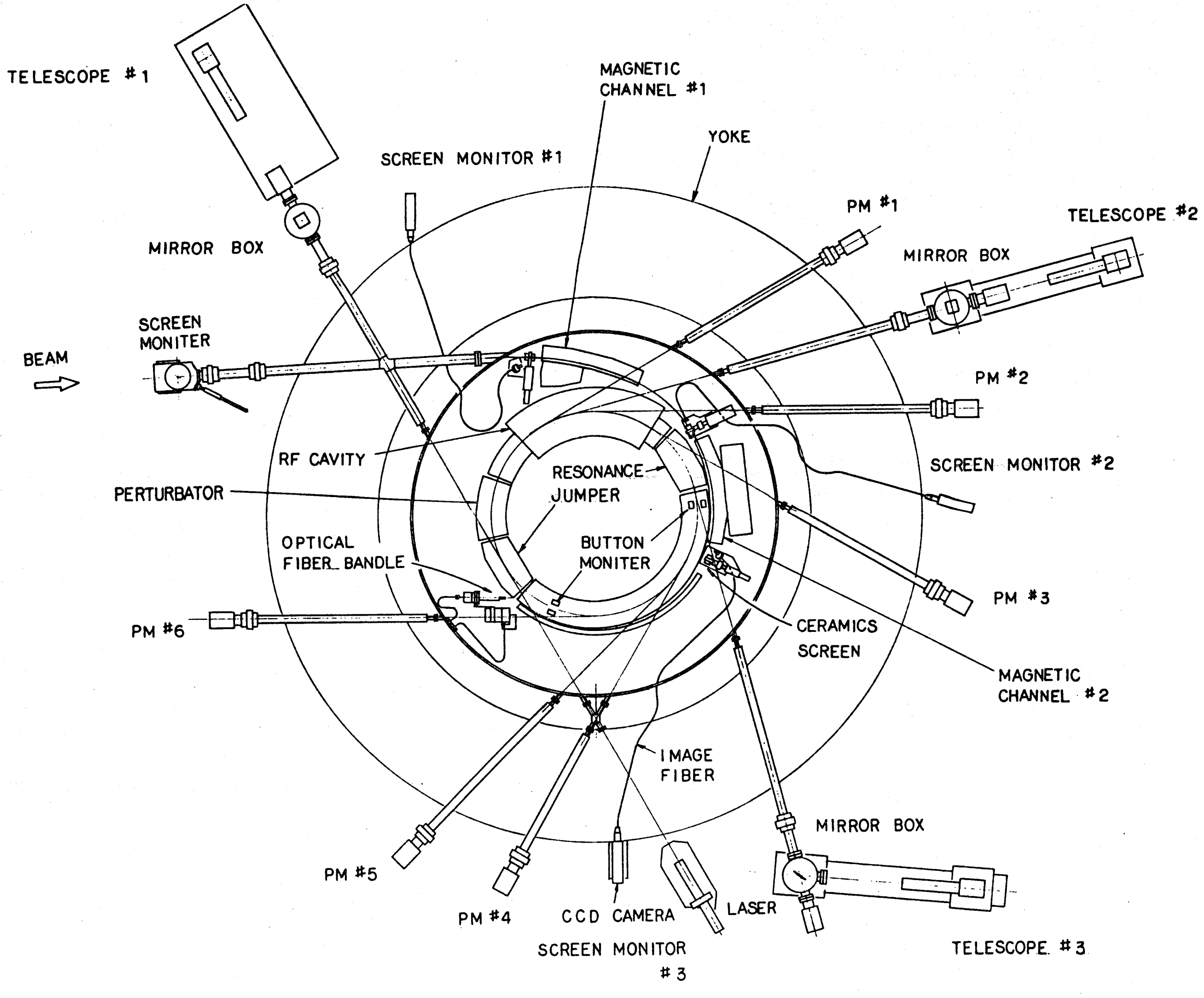

Fig.3 An overview of the beam monitoring system for the storage ring.