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General Considerations on Beam Diagnostics for the 6 GeV Synchrotron Light Source

I. Introduction

Although the 6 GeV Light Source design is still in its initial stages, it is not too early to consider the requirements for beam measurement and diagnostic instrumentation. Preliminary planning is important since other facets of the light source design can have an impact on the diagnostic instrumentation design as well as vice versa. This note is intended to list very general diagnostic requirements and methods and to form a foundation for the final system configuration which will develop together with the other facets of the design. No detailed descriptions of the diagnostic instrumentation are provided, but references are included. The listed methods do not cover all possible systems, but only the primary ones in use or planned at other facilities and at this time, should in no way limit consideration of other methods.

II. Beam Position Monitors

The planned orbit correction system for the 6 GeV Storage Ring will minimize interaction between insertion devices and will require numerous accurate beam position measurements around the ring circumference. However, the other stages of the light source (accelerators, accumulator, transfer lines) will also require beam position measurements although with fewer monitors and not the same degree of accuracy. In a facility the size of the proposed light source, it is not unreasonable to have well over a hundred position monitors. Since some types of monitors could be used in all light source stages, there are advantages in considering these from the development cost, construction and signal processing aspect, although, the redundance provided by having additional different monitors cannot be neglected. Apart from providing the average beam position, the signal processing of the position monitor signals should be able to provide the closed orbit, beam trajectory, injection trajectory as well as both the integer and fractional components of the betatron tune.

A. Capacitive pickup button electrodes appear to be the most popular position monitors for electron machines. These monitors are in use at CESR,[1] PETRA,[2] Photon Factory at KEK[3] and are planned for ESRF[4] and LEP.[5] They have good high frequency response and can provide both horizontal and vertical information from a single set of pickups.

1. Advantages: Low cost, simple and accurate fabrication, good sensitivity, nondestructive, occupies little space, shielded from beam radiation.

2. Disadvantages: Requires complex signal processing, nonlinear position sensitivity.

B. Directional couplers (strip lines) are another popular position measurement pickup having high frequency response and able to provide intensity, bunch length and Schottky noise information. Strip lines are used or planned at Aladdin, SLAC,[6] CERN SPS,[7] and HESYRL.[8]

1. Advantages: Signals can be preprocessed at the pickup using passive networks, good performance with short bunches, non-destructive, can be used to "drive" the beam.

2. Disadvantages: Higher detector cost, more difficult fabrication, occupies more "real estate," hard to shield from beam radiation, limitations in bandwidth due to nulls in response (can be improved by using tapered strip line).

C. Synchrotron Radiation Monitors[1,8,9,10,11,12] make use of the synchrotron light emerging from bending magnets and are multi-use devices allowing observation of position, profile, bunch structure, tune parameters using TV cameras, photodiodes and other optical or optoelectronic devices.

1. Advantages: Synchrotron radiation can be directed outside the primary shielding enclosure, capabilities not limited by space, easily modified, nondestructive.

2. Disadvantages: Requires dedicated beam line from accelerator or storage ring dipoles, limited use in transfer lines.

D. Wall Current Monitors[13,14] measure the charge image induced in the vacuum chamber wall by the passing beam. They are primarily for longitudinal bunch information at high frequencies, but can be adapted for position measurement.

1. Advantages: Good high frequency response, nondestructive.

2. Disadvantages: Can occupy more "real estate" if high bandwidth is desired, requires outer vacuum chamber, complex fabrication.

E. Other Position Monitors

Movable fluorescent screens, segmented Faraday cups (SFCs), segmented secondary emission monitors (SSEMS) and moving wire scanners[15,16] all provide simple signal processing, but are to varying degrees limited in resolution as well as destructive. Therefore, their use is limited to transfer lines and observation of the first several turns in the circular machines.

III. Beam Profile Monitors

Monitoring of the beam profile/size can be accomplished by the devices listed in II.C. and II.E., however, only the synchrotron radiation monitor is capable of measuring the beam profile without any effect on beam in the circular machines.

IV. Beam Intensity Monitors

The intensity of the beam can be measured by the button, strip line and wall current monitors; however, most facilities rely on the beam current transformer (toroid)[8,17] for the intensity information. A "fast" toroid is used to monitor the charge and longitudinal shape of individual bunches. A "slow" toroid is used to measure the circulating current.

V. Beam Loss Monitors

Beam losses can be monitored by using ionization chambers or scintillation detectors and multipliers located within the shielded tunnel. Although loss monitors are unable to absolutely quantify a loss, they are a useful supplement to the other diagnostics by being able to localize the loss.

VI. Other Diagnostic Devices

In addition to the above mentioned "standard" diagnostic monitors, the need for other devices such as scrapers, collimators, specialized beam pickups for beam phase, commissioning and machine studies, experimental beam lines, etc., will have to be determined as the design of the 6 GeV light source progresses.

VII. Conclusion

The selection of the type and number of diagnostics to be used for the 6 GeV light source will have to be determined based on need, cost and benefits. Each type of diagnostic will be evaluated for compatibility with the expected beam properties, the required information, accuracies, resolution, dynamic range and frequency response, available space, signal processing requirements, interfacing to data acquisition systems and last, but not least, cost. Signal processing requirements and cost will also in part be affected by the physical layout of the light source complex and the number and location of data acquisition systems.

The diagnostic choices need not be made immediately, but should be considered during other facets of the preliminary light source design. Diagnostic requirements should be forwarded to the diagnostic group as soon as they are determined.

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