

A BEAM DIAGNOSTIC SYSTEM USING SR FOR JLC-ATF

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Abstract

Development of a beam diagnostic system using SR light is in progress at the Institute for Nuclear Study (INS), University of Tokyo, for the JLC-ATF project. The system employs two key devices: one is a double-sweep streak camera, allowing to stack the many streak images on the phosphor screen, for bunch length measurement, and the other is an image-intensifier with a high-speed gate function for beam profile measurement. The system will be installed into the JLC-ATF damping ring for measuring the fast time evolution of the beam bunch length and profile next year.

Introduction

The JLC-ATF damping ring (DR) is under construction as a main facility of the JLC-ATF project at KEK. The major task of the DR is to investigate and to actually prove the possibility of producing a stable multi-bunch beam with very small emittances and a very short bunch length. The design parameters of the DR are briefly summarized in Table 1.^[1] The actual beam sizes corresponding to the emittances listed in the table are the order of 100 μm in the horizontal plane and 10 μm in the vertical plane, and the bunch length is 15 ps in time.

To study the performances of the DR, it is very essential to measure the time development of the beam profile and the beam bunch structure. For this purpose, a beam diagnostic system using SR light is being developed at the INS by using the SR light emitted from the 1.3-GeV electron synchrotron (INS-ES), which is operated with the repetition rate of 21.5 Hz and whose maximum top energy and the beam intensity is 1.2 GeV and typically 2.5×10^9 electrons/bunch, respectively. These operating parameters are similar to those of the DR.

The system consists of a double-sweep streak camera whose fastest streak time is 200 ps and the time resolution is better than 1.5 ps, an image-intensifier with a high-speed gate function of 3 ns and a UNIX work station (W.S.). The system is to be installed into the DR when the DR is completed.

On the other hand, the beam dynamics of the INS-ES has been studied by means of the measurements of bunch length

with the single photon counting method and beam profile with a slow-gate CCD camera, so far.^{[2],[3]} The newly-developed beam diagnostic system is used to measure the beam characteristics of the INS-ES before the installation to the DR, by which, it is expected that the study of the beam dynamics of the INS-ES is made more progress.

This paper describes the system configuration and its performances. The first results of a preliminary test using the SR light of the INS-ES are also reported.

Table 1
 Design Parameters of the ATF-DR

Beam energy	1.54	GeV
Repetition rate	25	Hz
No. of bunch trains	5	
No. of bunches / train	20	
No. of particles / bunch	$(1-3) \times 10^{10}$	
Damping time		
horizontal	6.9	ms
vertical	9.2	ms
longitudinal	5.5	ms
RF frequency	714	MHz
Normalized emittance		
horizontal	4.49×10^{-6}	m-rad
vertical	3.00×10^{-8}	m-rad
Bunch length	4.33	mm

System Description

Double-Sweep Streak Camera

In the DR, the bunch length is kept to be around 15 ps during the damping period of 40 ms. To observe the evolution of the bunch length of the period, the measuring system is composed with a double-sweep streak camera and a high-speed work station to control the whole measuring system

and to analyze data. Figure 1 shows the system configuration schematically.

The double-sweep streak camera has two sets of electrodes crossing each other at right angles in the streak tube as shown in Fig.2. The set of "streak-sweep" is to make an ordinary streak sweep, and the other set, "horizontal sweep", is to shift the image position of the streak sweep one by one. Then, this tube enables us to observe several-ten streak images emitted, for example, from the same bunch along with the damping process in a same picture, which is also shown conceptually on the phosphor screen in the figure. The main characteristics of the double-sweep streak camera for the system (C5680 by Hamamatsu Photonics) is listed in Table 2.

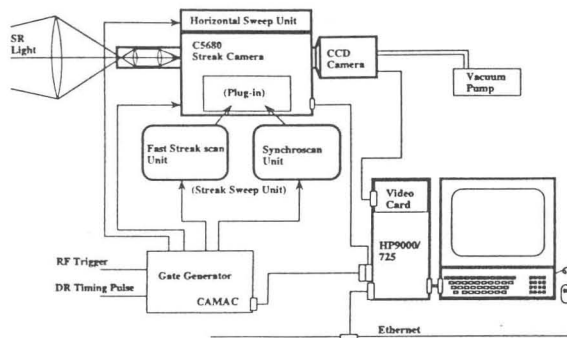


Fig.1 Block Diagram of the System Configuration for the Bunch Length Measurement

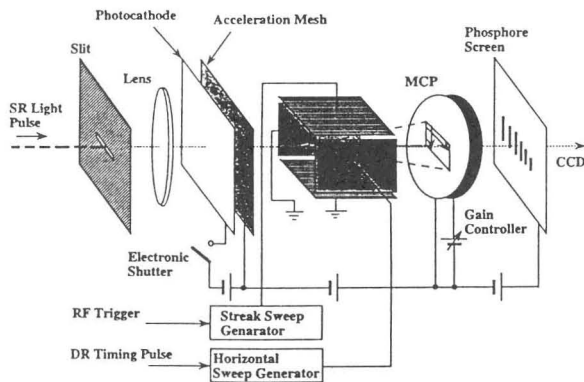


Fig.2 Conceptual Diagram of the Double-Sweep Streak Camera

The camera control, data acquisition and data analysis are done with the W.S. (HP9000/725 by YHP). For this purpose, a software and hardware have been developed. The CAMAC modules to generate timing signals for the streak camera are developed, and they are also controlled by the W.S. A short

fiber cable is used to make the connection between the streak camera and the optical axis of the SR light easy.

Table 2
Main Parameters
of the Double-Sweep Streak Camera

Streak sweep unit	
Fast single scan	
streak time	0.2 ns to 50 ns (/full screen)
temporal resolution	better than 1.5 ps
sweep repetition rate	max. 10 kHz
Synchroscan	
streak time	280 ps to 1/6f (/full screen)
temporal resolution	better than 2 ps
sweep frequency	75 MHz to 165 MHz
Horizontal sweep unit	
Sweep range	100 ns to 100 ms (/full screen)
Repetition frequency	max. 10 kHz
Input optics	200 to 1600 nm
Streak tube	400 to 900 nm
MCP gain	3000
Gate method	MCP + Photocathode gate
Gate time	50 ns to DC

Gated Image Intensifier

A very fast-gate image-intensifier (I.I.), whose fastest gate time is 3 ns and the maximum luminous gain is about 7000 (C2925-01 by Hamamatsu Photonics), will be employed to observe the beam profile in the DR. The main characteristics of the I.I. are listed in Table 3. The bunch separation in the bunch train (including 20 bunches) from an injector linac is to be 2.8 ns which corresponds to the time of 2 buckets of the RF acceleration voltage of the DR, then each bunch is injected into the RF bucket every other one. Therefore, the gate time of the I.I. is short enough to measure the profile of one bunch separately.

Table 3
Main characteristics of the I.I.

Gate time	3	ns
gate rise time	2	ns
gate fall time	3	ns
Gate jitter	better than	200 ps
Repetition frequency	10	kHz
Luminous gain	7000	ft-L/ft-C
Cathode sensitivity	47	mA/W
Equivalent background noise (at max. gain)	4×10^{-11}	lm/cm ²

Data acquisition and data analysis are also done with the W.S. A special sampling controller has been developed to control the I.I. and the W.S., which generates the trigger pulse

every a few periods of the damping cycle with adding a fractional delay time from one trigger pulse to the next. The observation of the evolution of the beam profile along with the damping period is available every a few seconds by means of the sampling controller.

In the DR, the errors due to the effects of diffraction, field depth and orbit curvature are seemed to be comparable to the vertical size ($\sim 10 \mu\text{m}$) in the last stage of the damping period. Therefore, the design of the SR light transport line for the profile measurement is in progress by taking account of these effects. [4]

First Results of A Preliminary Test

The system is now under test with the SR light from the INS-ES. The configuration of the optical system is, now, tentative.

Figure 3 shows the typical picture of the analyzed result of the measured bunch length on the display of the W.S. The upper left shows the evolution of the bunch structure of the same bunch observed every 0.5 ms along with the acceleration of the INS-ES. The vertical axis indicates the bunch length and the relative bunch position. The rightmost bunch image on the picture shows the dramatic change of the position, which corresponds to the end point of acceleration. This is due to the fact that the beam is moving to the inside of the synchrotron orbit rapidly after finish of acceleration. The graph on the right-hand side indicates the time structure of the 8th bunch from the right side, in this case. The bunch length (1.235 ns) and the relative peak position are also indicated at the upper part of the graph.

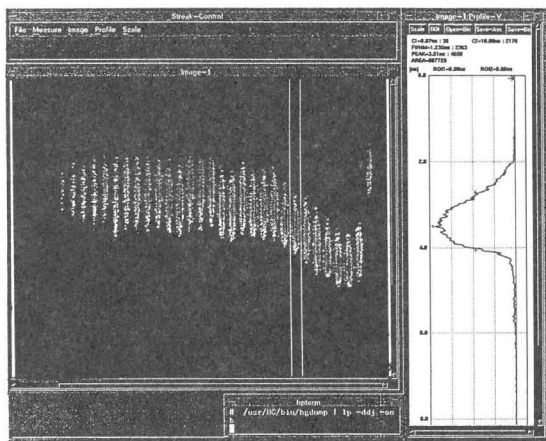


Fig.3 Analyzed Result of the Measured Bunch Length

Figure 4 shows the result of the profile measurement with the I.I. at the gate time of 8 ns, which is slightly over the bunch separation of the INS-ES. The horizontal and vertical axes on the picture correspond to the horizontal and vertical sizes of the beam, respectively. In this picture, these are 1.60 mm and

1.67 mm in FWHM, respectively. The spatial resolution is about $20 \mu\text{m}/\text{pixel}$ on the CCD element.

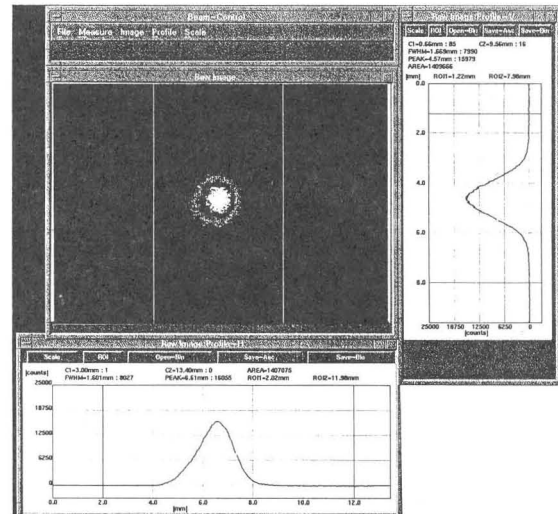


Fig.4 Analyzed Result of the Measured Beam Profile

Conclusion

The test of the beam diagnostic system using the SR light is in progress at the INS. The first measurement of the beam bunch length and the beam profile was carried out successfully. It is expected that the further development of the electronics and the design of the optical system will be finished in near future. At present, the repetition rate of the data acquisition and data analysis of a full screen is about 5 Hz. It is under study to increase the rate up to 10 Hz.

The detailed study on the characteristics of the circulating beam in the INS-ES will be started soon.

References

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