BEAM PARAMETERS MEASUREMENT WITH A STREAK CAMERA IN HLS*

J. G. Wang #, B. G. Sun, B. Y. Wang, H. L. Xu

NSRL, School of Nuclear Science and Technology, University of Science and Technology of China, Hefei 230029, P. R. China.

Abstract

In HLS streak camera system has been built. The system is used to measure some parameters of bunch like bunch length, longitudinal bunch profile and synchrotron frequency and so on, as it may report a direct derivation of fundamental machine characteristics. The system mainly consists of the synchrotron light extracting optics setup, the OPTOSCOPE streak camera and PC with a frame grabber interface card. The light extracting optics setup is used to extract synchrotron light at the bending magnet and the setup consists of the light extracting path and the optics imaging system. The streak camera realizes the functions of acquiring light and imaging. PC with a frame grabber interface card and ARP-Optoscope software package is used to monitor the light in real-time, acquire the image of light and analyze the data. The streak camera system operates with either synchroscan sweep mode or dual time base sweep mode. At present, some results are given, which include the bunch lengthening, the longitudinal bunch profile and the synchrotron frequency. These results are compared with the results acquired by using oscilloscope.

INTRODUCTION

HLS (Hefei Light Source) is an 800MeV electron storage ring with circumference about 66.13 meters in NSRL. The acceleration frequency (RF) of HLS is at 204.016MHz. The revolution frequency is 4.534MHz. A variety of filling patterns are possible: 45 bunches (full fill, 100~300mA) or single bunch. In full fill, the bunch space is 4.9ns. In single bunch, the bunch space is 220ns. The natural bunch length is 110ps [1].

As bunch length and its lengthening have very important influence on the machine performance in electron storage ring, these parameters measurements are very necessary. Because streak camera is a known instrument that can measure the profile of a picoseconds electron bunch, our streak camera system is set up in a beam diagnostic beam line in 2006. Recently some measurements have been made in HLS. In paper, we presented some results of measurements, which include the bunch lengthening, the longitudinal bunch profile and the synchrotron frequency. In addition, the result of the synchrotron frequency is compared with the result acquired by using oscilloscope.

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wangjg@ustc.edu.cn

THE STREAK CAMERA PRINCIPLE

The streak camera is a two dimensional camera. Used in combination with different input optics, it is possible to measure time variation of the incident light with respect to position. Figure 1 shows the operating principle and timing of the streak camera[2].

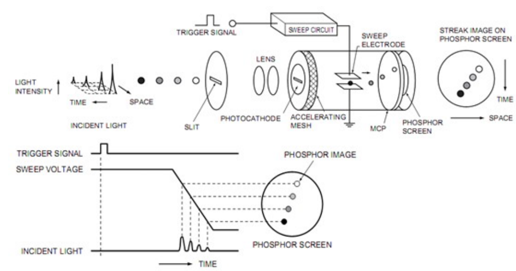

Figure 1: The operating principle (up) and timing (down) of the streak camera.

The incident light passed through a slit is formed by the input optics into an image of incident light on the photocathode of the streak tube. The incident light on the photocathode is converted into a number of electrons proportional to the intensity of the light, so that these four optical pulses are converted sequentially into electrons. They then pass through a pair of accelerating electrodes. As the electrons pass between a pair of sweep electrodes, high voltage is applied to the sweep electrodes at a timing synchronized to the incident light. During the high-speed sweep, the electrons are deflected in slightly different angles in the vertical direction, and enter the MCP (micro-channel plate). In the MCP, they are multiplied several thousands of times, and then impact against the phosphor screen, where they are converted again into light. On the phosphor screen, the phosphor image corresponding to the optical pulse which was the earliest to arrive is placed in the uppermost position, with the other images being arranged in sequential order from top to bottom. In this way, the streak camera can be used to convert changes in the temporal and spatial light intensity of the light being measured into an image showing the brightness distribution on the phosphor screen [3][4].

SYSTEM CONFIGURATION

Hardware Configuration

The streak camera system consists of the synchrotron light extracting optics setup, OPTOSCOPE streak camera, frequency divider circuit and personal computer (PC) with frame-grabber card. The system functional diagram is shown in Fig.2 [2] [5].

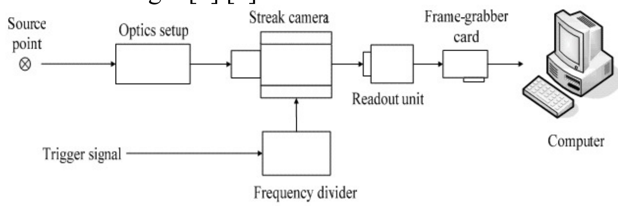

Figure 2: The system functional diagram.

The trigger section controls the timing of the streak sweep. This section has to be adjusted so that a streak sweep is initiated when the light being measured arrives at the streak camera. The frequency divider circuit provides trigger signal with low temporal jitter for the requirements of the sweep units. We used the optics setup to extract the synchrotron light from the storage ring vacuum chamber at the bending magnet in the beam diagnostic beam line. The readout unit combines a high resolution and very sensitive CCD camera with a fibre optic taper to provide a universal and easy to use fibre optically coupled CCD camera. Analysis of streak images is done by transferring the images through a frame grabber card to a computer. The synchrotron light extracting setup is shown in Fig.3, in which the band pass filter optimizes the spatial resolution of the measurement and its centre wavelength is at 532nm [2] [3] [5].

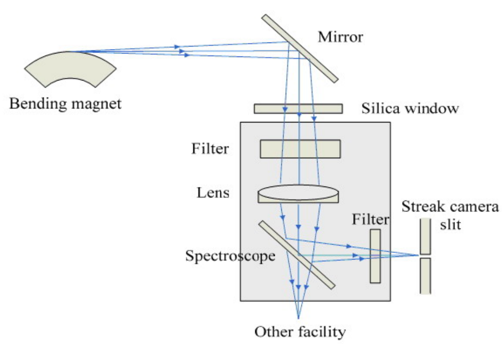

Figure 3: The synchrotron light extracting setup.

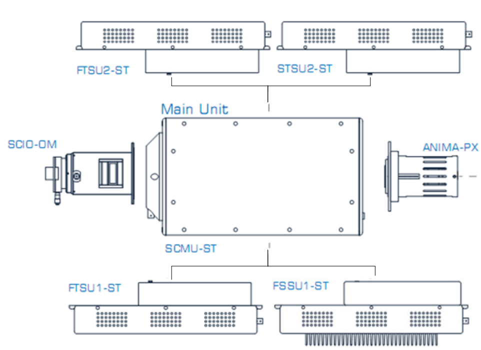

Figure 4: The streak camera main modules.

The OPTOSCOPE streak camera mainly consists of a camera main unit with input optics (SCIO-OM), a remote control unit, streak sweep unit (FSSU1-ST, FTSU1-ST, FTSU2-ST or STSU2-ST), a CCD camera readout unit (ANIMA-PX) and a power supply unit. The streak camera main modules are shown in Fig.4 [3].

Software Configuration

Controlling the streak camera and image acquisition is made by the ARP-Optoscope software. The software also allows controlling the operation of the streak camera system. It controls the streak camera through the RS232 interface. The software runs under Windows XP. For various application requirements, the software allows to be configured for different image acquisition modes. The captured images are displayed and processed for temporal or spatial analysis and stored in real- time. The stored files can be exported in ASCII, RAW, BMP, and TIF formats. Additionally, it includes basic functions for profile and image analysis like: axis calibration, uniformity correction, jitter correction, etc. [3][5]

THE RESULTS OF MEASUREMENT

We respectively made some measurements for beam parameters which include bunch length and the synchrotron frequency under synchroscan sweep mode (FSSU1-ST) and dual time base sweep mode (FSSU1-ST and STSU2-ST) [6] [8].

Single Bunch Lengthening Measurement

When the injection current range varied from 4.1mA to 7.7mA @800MeV, we respectively measured the bunch length by using streak camera system under synchroscan sweep mode (FSSU1-ST). Because Gaussian function can fit well the bunch profile, we may acquire the bunch length σ_τ from Gaussian fit value. The measured bunch length σ_τ is from 110ps to 127ps. The streak image of single bunch and the bunch lengthening are shown in Fig. 5 [7].

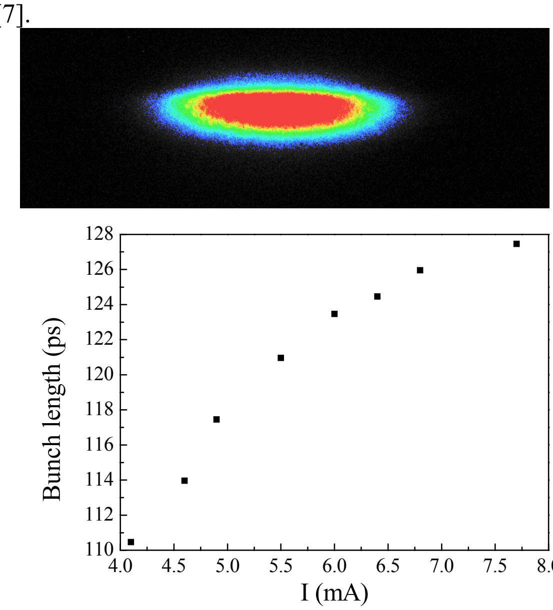

Figure 5: The streak image (up) and the bunch lengthening (down).

Multi Bunch Lengthening Measurement

The multi-bunch mode is the standard operation mode with 45 bunches filled. As the injection current is from 67mA to 224mA @800MeV, we made the same measurement as that of the single bunch length. The bunch length σ_τ varied from 211ps to 298ps. The streak image of multi-bunch and the bunch lengthening are shown in Fig. 6 [9]. Comparing Fig. 5 and Fig. 6, the bunch length in multi-bunch mode is obviously larger than in single bunch mode.

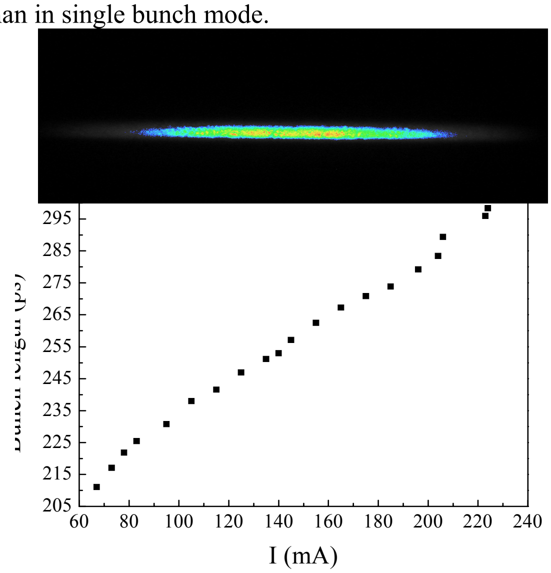

Figure 6: The streak image (up) and the bunch lengthening (down).

The Synchrotron Frequency Measurement

We measured the synchrotron frequency with multi bunch under dual time base sweep mode (FSSU1-ST and STSU2-ST). FSSU1-ST sweep speed is set to 100ps/mm and STSU2-ST sweep speed is set to 10µs/mm. So, horizontal deflection full screen range is 1.96ns and vertical deflection full screen range is 144µs. The streak image measured is shown in Fig.7. The result of measurement is also shown by using oscilloscope RSA6100A in Fig.8. The synchrotron frequency measured is about 35 kHz [7].

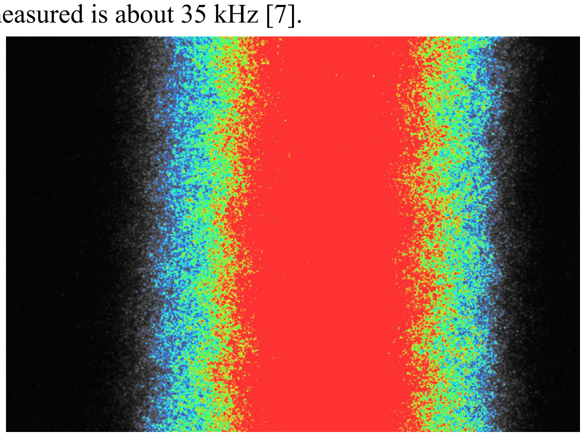

Figure 7: The streak image of multi bunch.

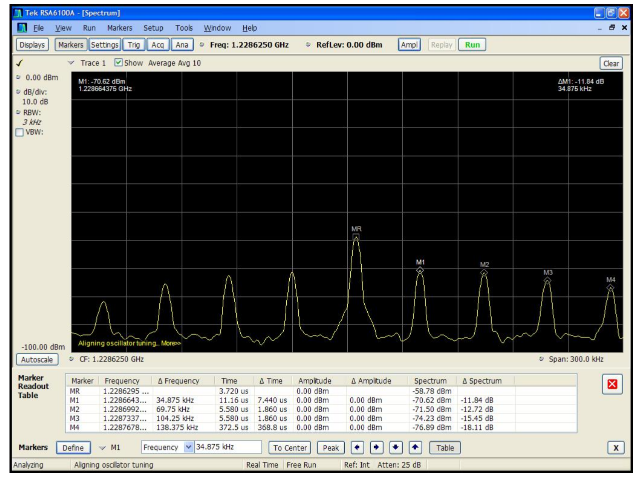

Figure 8: the measurement of synchrotron frequency with multi-bunch.

CONCLUSION

The above results proved that the streak camera system provided not only precise measurements but also visualizations of beam characteristics and behaviour. The experimental results proved that the bunch length will increases as the current increases and the synchrotron oscillation exists. The further work will measure the bunch lengthening under different RF voltage and momentum compaction factors.

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