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Application and development of the streak camera measurement system at HLS-II*

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Abstract

The dual-axial scan streak camera plays an important role in the super-fast optical measurement and the beam diagnosis of the accelerators. Indeed, the development of the synchrotron light measurement system by virtue of the streak camera provides an effective tool and research platform for the accelerator physics and the super-fast optical phenomenon. In this paper, the configuration of the streak camera measurement system is described. And the experimental researches are simultaneously performed, including the bunch lengthening, the potential-well distortion, the longitudinal bunch oscillations, and the beam evolution during the single bunch operation mode in HLS-II. Moreover, the effects of the RF modulation on the beam lifetime and longitudinal bunch beam dynamics are carried out.

Introduction

It is well-known that the streak camera [1-4] is a powerful diagnostic and measurement tool with remarkable merits of high temporal and spatial resolution, good stability to measure ultra-fast light phenomena. As a consequence, it has been widely employed in accelerator, super-fast optics, and laser-plasma physics. Generally, the bunch length in the synchrotron radiation (SR) light source is on the order of tens to hundreds of ps, whereas below 10 ps down to the magnitude of fs in linear accelerator and free electron laser. For the reason that, the streak camera are usually applied for observing longitudinal distribution and measuring bunch length owning to the accurate and intuitive measurement compared with other beam diagnostic instruments. At present, it is regarded as an indispensable measurement device by many laboratories.

Similar to many storage ring light sources, our OPTOSCOPE streak camera purchased in 2006 was primary implemented for measuring bunch length and longitudinal bunch distribution of the Hefei light source (HLS) and upgraded HLS-II [5, 6]. However, it is worthwhile to note that a part of recently extended applications based on the streak camera were also carried out, such as the observation of potential-well distortion, bunch lengthening phenomena, and longitudinal bunch oscillations [5], the investigation of radio-frequency (RF) modulation effect [7, 8], and the study of beam instability [7, 8], etc. In this paper, we mainly review and summarize the important applications of the streak camera in HLS-II. The major machine parameters of HLS-II are summarized in Table 1.

Table 1: Machine parameters of HLS-II storage ring

Parameter	Symbol	Value
Beam energy	E	0.8 GeV
Circumference	C	66.13 m
Radiation energy loss per turn	U_0	16.73 KeV
Beam current	I	360 mA
Natural rms energy spread	σ_ε/E_0	4.7×10^{-4}
Momentum compaction factor	α	0.0158
Natural beam emittance	ε_0	~40 nm•rad
Beam lifetime	τ	7-8 h
Natural rms bunch length	σ_τ	~50 ps
Revolution frequency	f_{rev}	4.534 MHz
Harmonic number	h	45
Main RF frequency	f_{rf}	204.030 MHz
Synchrotron frequency	f_s	20.0-21.5 kHz
Main cavity gap voltage	V_c	123 kV

Conclusions

In this article, we have summarized some current longitudinal beam dynamics studies on the HLS-II storage ring based on the streak camera measurement system. It mainly contains the bunch lengthening, potential-wall distortion, and longitudinal bunch oscillation, RF modulation, and beam instability. These experimental investigations have certain physical significance for the operation and debugging of HLS-II.

Experimental setup and results

1. Streak camera measurement system

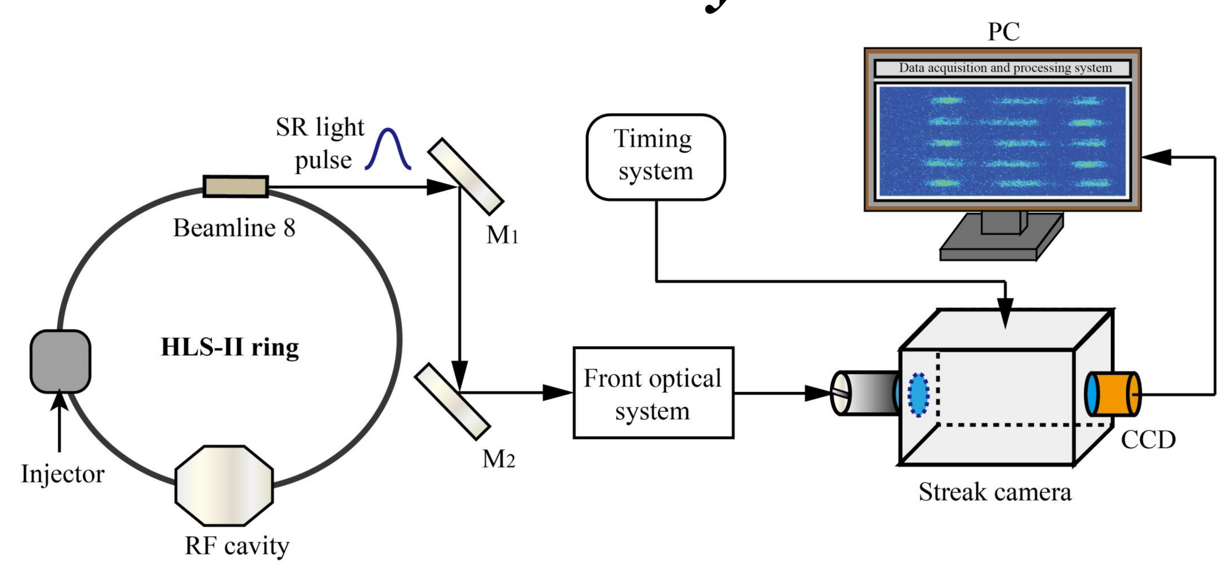

Figure 1: Schematic layout of the streak camera measurement system

The streak camera measurement system is mainly composed of a SR light extraction system, a front-end optical system, a timing system, and a data acquisition and processing system.

2. RF modulation effect

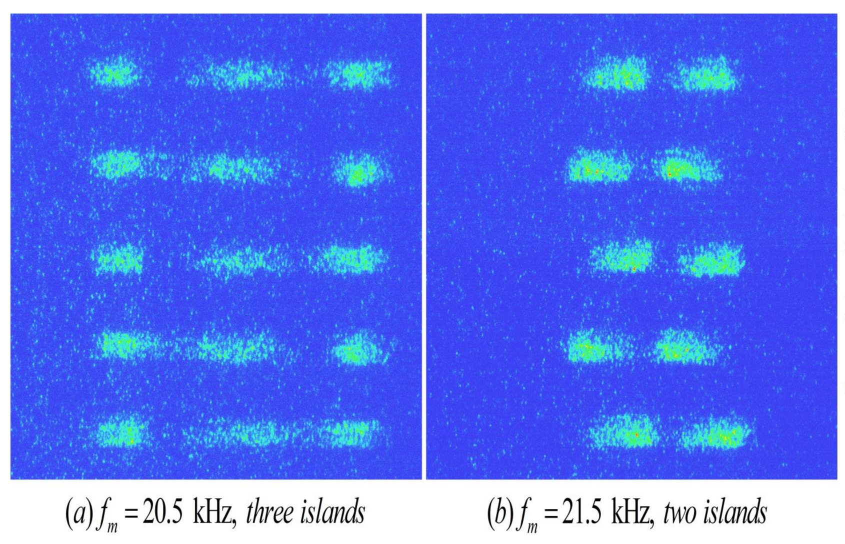

Figure 2: Observations of RF modulation phenomena

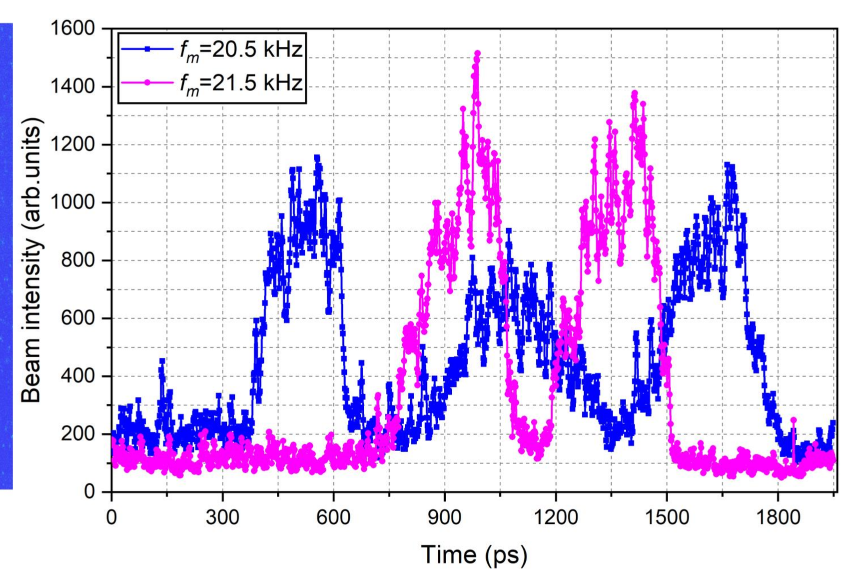

Figure 3: Longitudinal bunch profiles at different modulation frequencies

3. Bunch length measurement

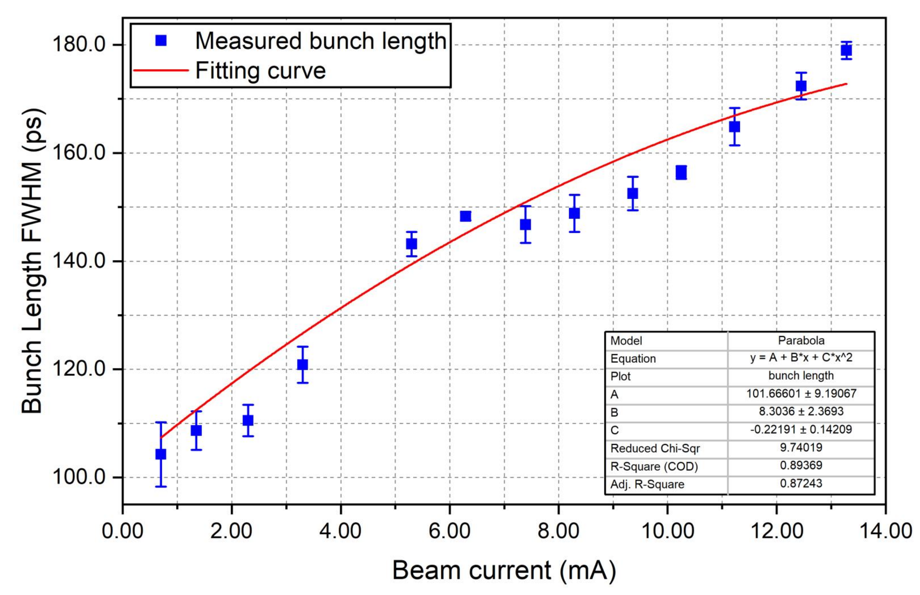

Figure 4: Bunch length via different beam currents

4. Potential-well distortion

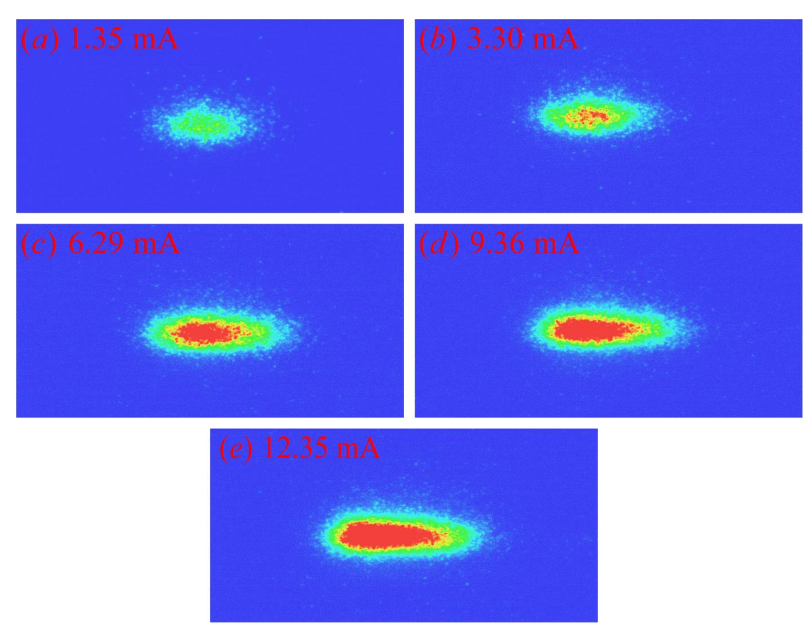

Figure 5: Observation of potential-well distortion under different beam currents

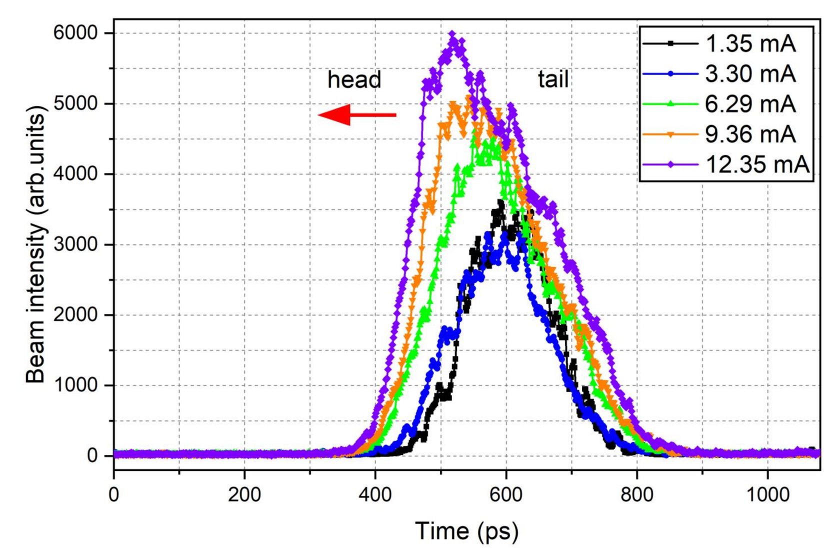

Figure 6: Longitudinal bunch distributions with beam currents

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