COMMISSIONING OF A NEW STREAK CAMERA AT TLS FOR TPS PROJECT

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Abstract

Taiwan Photon Source (TPS) is a 3 GeV synchrotron light source which is being construction at campus of National Synchrotron Radiation Research Center (NSRRC) in Taiwan. A new streak camera equipped with a 125/250 MHz synchroscan unit, a fast/slow single sweep unit, and a dual-time sweep unit is prepared for beam diagnostics, especially for the TPS. An ultra short femtosecond Ti-Sapphire laser was used to evaluate the sub-picosecond temporal resolution of the streak camera and the first beam measurements of the streak camera using synchrotron light from the existing 1.5 GeV Taiwan Light Source (TLS) were performed. The commissioning results are summarized in this report.

INTRODUCTION

The Taiwan Photon Source (TPS) is a state-of-the-art synchrotron radiation facility featuring ultra-high photon brightness with extremely low emittance [1]. The latest generation diagnostic systems will equip to help TPS achieve its design goals. Streak cameras (SC) are one of the widely used diagnostic devices in synchrotron light source facilities for characterizing beam properties [2-3]. A dual sweep streak camera (C10910, Hamamatsu Photonics [4]) with one fast, one slow and two frequency of synchroscan sweep unit is used to perform temporal and transverse measurements. This model is a successor of C5680 universal streak camera to improve its performance and functionality. The beam motion in the longitudinal direction (phase information) could be observed by using the synchroscan unit (operated at 125/250 MHz). By using the fast single sweep unit the single shot bunch length can be measured in picosecond resolution. On the other hand by using the slow sweep unit it is possible to observe the stability of the beam over several milliseconds. The dual-time sweep unit allow the streak camera to operate in dual sweep mode. In this report, characterize the temporal resolution by the help of Ti-Sapphire laser and various measurements on synchrotron light from TLS storage ring are summarized.

EXPERIMENTAL SETUP

The commissioning of the streak camera is divided two parts. First, an ultra short femtosecond Ti-Sapphire laser is used to evaluate the sub-picosecond temporal resolution of the synchroscan units of the streak camera. Second, the synchrotron light under TLS is used to configure the system parameters for future study in TPS. The block diagrams and experimental setups are shown below.

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Femtosecond Laser Measurement

A femtosecond Ti-Sapphire laser provides a 850 nm near IR light with a repetition rate of 75 MHz and pulse length of 100 fs. This is used to evaluate the sub-picosecond temporal resolution of the streak camera. The laser passes through two neutral design filter (NDF) to reduce the intensity of the light and directly guides to the streak camera input. The synchroscan units of 125 MHz and 250 MHz are tested. As shown in Fig. 1, the synchronization clock for laser system is generated via a signal generator (R&S SMA-100A) with a home-made divider circuit which can provide a 75 MHz clock by divider a 3 GHz clock by 40. Another signal generator (R&S SMB-100A) can provide a 125/250 MHz clock for synchroscan sweep units which is phase locked with first signal generator by 10 MHz reference clock. Timing jitter between two signal generators output is in the order of 50 fs and is negligible in this application. The experimental setup is shown in Fig. 2.

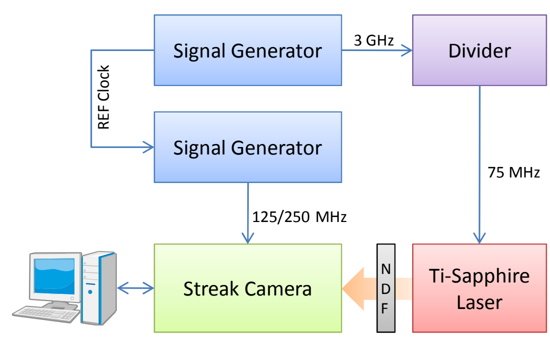
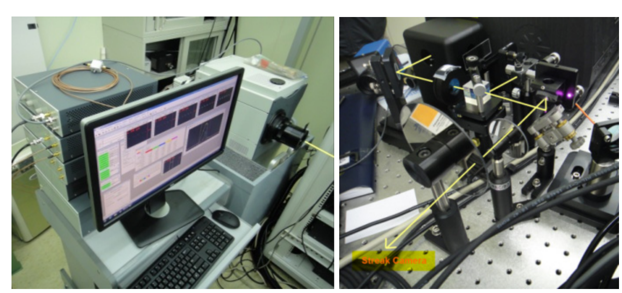


Figure 1: Block diagram of the laser measurement system.



(a) Streak camera (b) Laser system
Figure 2: Femtosecond laser measurement setup.

Synchrotron Light Measurement

The synchrotron light measurements in TLS were well demonstrated. These include bunch length measurements with different bunch current and RF gap voltage, synchronous phase investigation, instability observations,

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etc. The block diagram of the synchrotron light measurement setup is shown in Fig. 3.

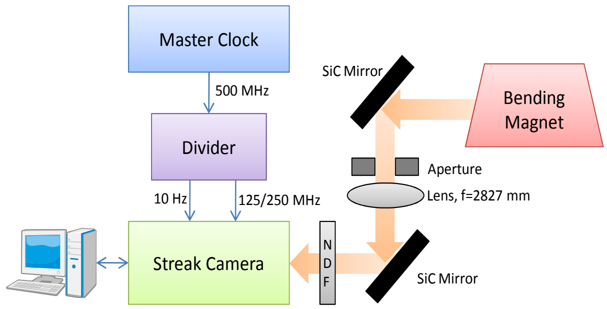
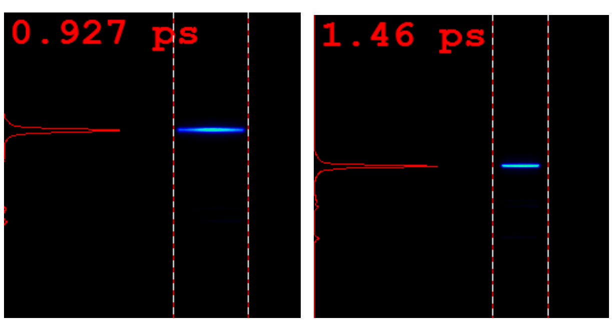


Figure 3: Block diagram of the synchrotron light measurement system.

RESULTS AND DESCRIPTION

Temporal Resolution

The temporal resolution evaluation of the synchroscan units of the 125 MHz and 250 MHz were carried out via ultra-short femtosecond Ti-Sapphire laser. The results show that it is in reasonable agreement with specification of the synchroscan units, shown in Fig. 4. It is less than 1 ps for the 125 MHz unit and less than 2 ps for the 250 MHz unit, respectively.



(a) (b)

Figure 4: The temporal resolution measurement of the synchroscan units (a) 125MHz < 1 ps temporal resolution, (b) 250MHz < 2 ps.

Time Resolution vs Light Intensity

The time resolution versus intensity of light input was studied with femtosecond Ti-Sapphire laser and fast single sweep unit. The streak camera parameters were kept constant, but the injection light intensity was adjusted. As shown in Fig. 5, the weak light can get higher resolution and the intense light can cause degradation to the temporal resolution and measurement accuracy due to space charge effect in the streak camera. It is important to notice that when one wants to push the system to few ps resolution, reducing the light intensity by adjusting the NDF is needed.

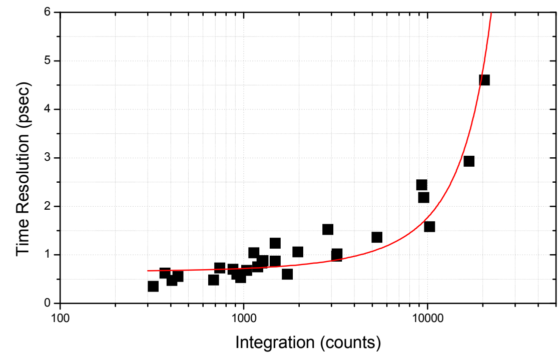


Figure 5: The time resolution vs intensity of light input.

Measurement on the TLS

For the bunch length measurement, the synchroscan unit of 250 MHz was used. As shown in Fig. 6, the average of 100 times of streak images resulted in the bunch length of the TLS storage ring around 60 ps in FWHM (25 ps in sigma), which is consistent with the previous studies [5].

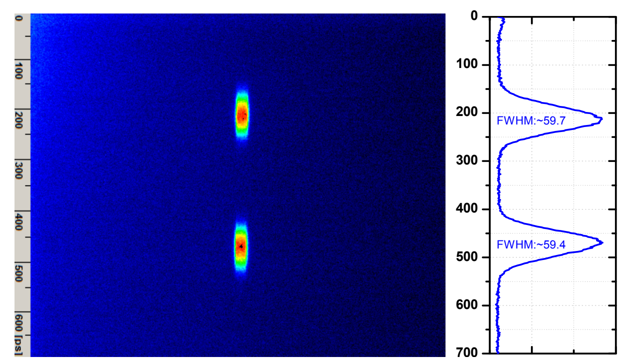


Figure 6: Bunch length measurement at TLS storage ring, vertical scale is 700 ps.

The filling pattern of the storage ring can be observed by the synchroscan unit and the dual-time sweep unit. The harmonic number of TLS storage ring is 200. As shown in Fig. 7, in user's shift, about 165 buckets were filled and a gap of 35 buckets (70 ns) were empty. Bunch intensity can be measured from the image and bunch length vs intensity can be correlated.

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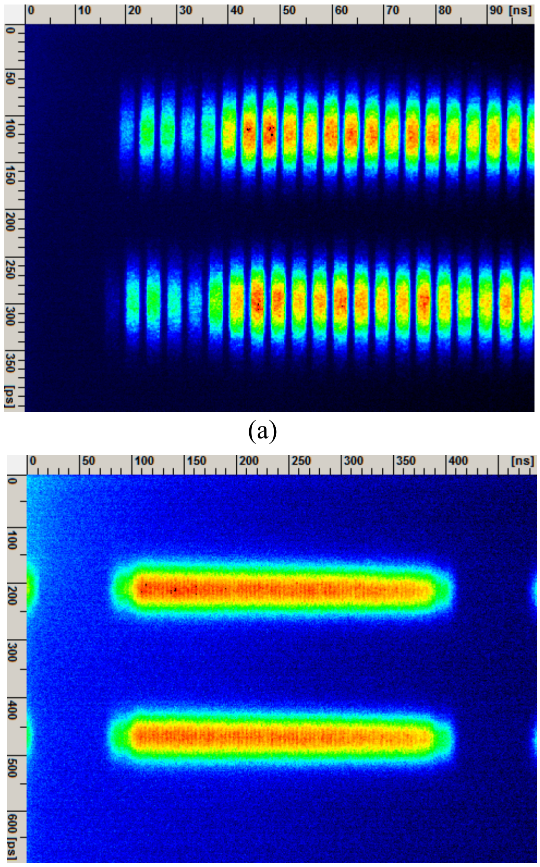
(a)
(b)

Figure 7: Filling pattern of the TLS storage ring (360 mA) in user's shift, (a) vertical scale 400 ps, horizontal scale 100 ns, (b) vertical scale 700 ps, horizontal scale 500 ns.

TLS Synchronous Phase Measurement

The TLS synchronous phase can be observed by streak camera synchroscan unit with dual-time sweep unit. The result is shown in Fig. 8. It is around 3.5 ps lag comparing the first bunch with the last bunch due to the wake field effect.

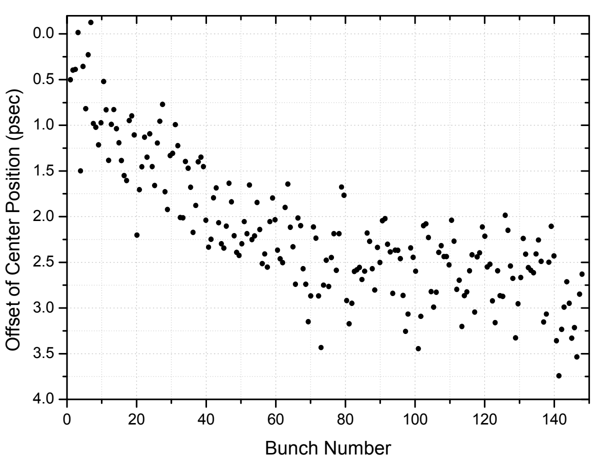

Figure 8: The synchronous phase measurement of the TLS storage ring.

TLS Longitudinal Instability

There were two unstable longitudinal modes in TLS. These modes were suppressed by a longitudinal feedback system. Using streak camera could observe TLS instabilities as shown in [6]. Turning off the feedback systems will cause the beam unstable longitudinally as shown in Fig. 9. The synchroscan unit is working at half of the RF frequency, so the consecutive bunch will appear at upper sweep and down sweep trace respectively. From the streak image, oscillation of odd and even bunches are out of phase. Leading bunches are with small oscillation amplitude compared with the trailing bunches. This effect can be easily observed by average 100 frames of motion. The leading bunch motion envelope (~70 ps in FWHM) is smaller than that of the trailing one (~170 ps in FWHM). This unstable mode might come from resonance mode of vacuum components.

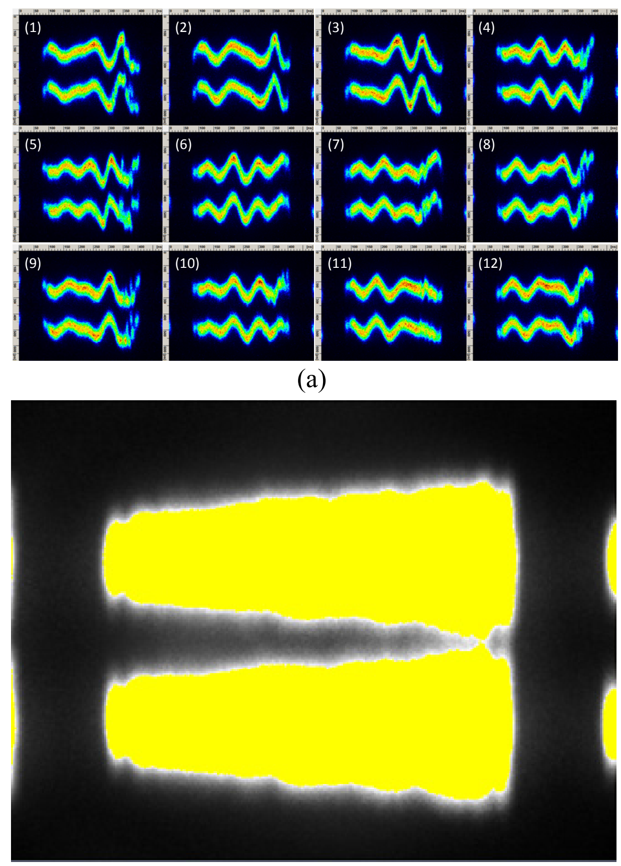
(a)
(b)

Figure 9: Longitudinal instability of the TLS storage ring (150 mA, decay mode) when turning off the longitudinal feedback system, vertical scale 700 ps, horizontal scale 500 ns, (a) 12 sequential streak images of motion, (b) average 100 streak images.

TLS Bunch Length vs Bunch Current

The bunch length as a function of bunch current was measured in multi-bunch mode. The streak image of fill pattern is shown in Fig. 10(a), there are 15 bunches storage, and beam current around 60 mA. The measurement result is shown in Fig. 10(b).

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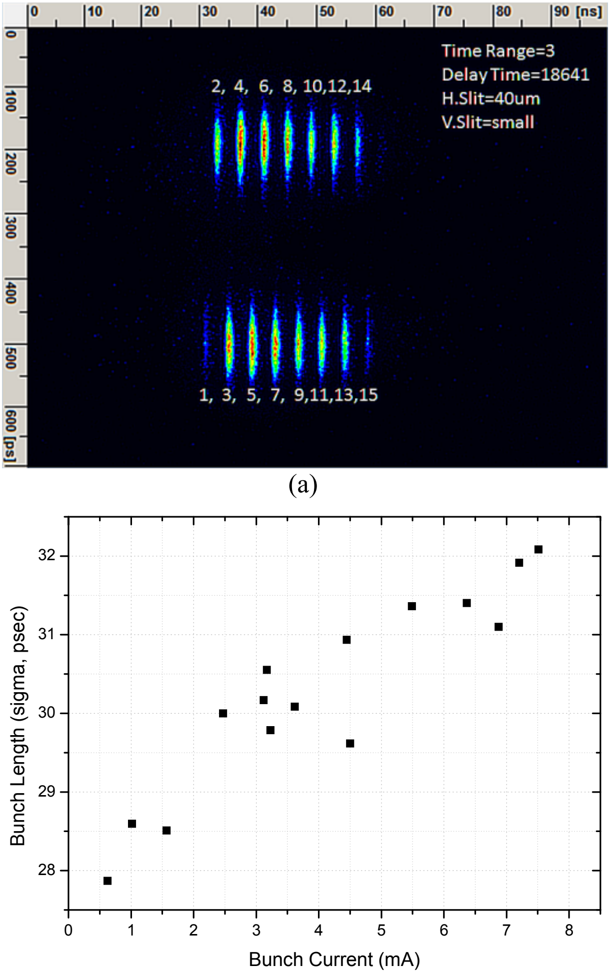

(a)

(b)

Figure 10: Bunch length vs bunch current of the TLS storage ring.

Bunch Length vs RF Gap Voltage

The bunch length vs RF gap voltage was measured at 360 mA total beam current and the RF gap voltage from 1000 kV to 1700 kV in 50 kV step. Taking 10 streak images for each measurement point to get average and statistics. The results is shown in Fig. 11. Eq. 1 shows the relationship between bunch length σ_z and the RF gap voltage V. The measured bunch lengths are in agreement with the theoretical values.

$$\sigma_z = \sqrt{\frac{2\pi\alpha_c E\sigma_E^2}{hV\cos\phi_s\omega_{rev}^2}} \tag{1}$$

,where σ_z is the bunch length, α_c is the momentum compaction factor, E is the beam energy, h is the harmonic number, V is RF gap voltage, ϕ_s is the synchronous phase, and ω_{rev} is the angular revolution frequency.

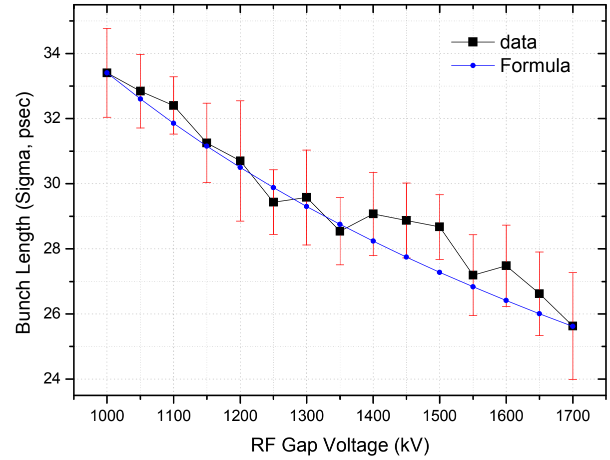

Figure 11: Bunch length versus RF gap voltage in the TLS.

SUMMARY

A new streak camera equipped with 125/250 MHz synchroscan units, fast/slow single sweep units, and dual-time sweep unit was commissioned with femtosecond laser and TLS storage ring. The results show that it is in reasonable agreement with specification of the synchroscan units. It is less than 1 ps for the 125 MHz unit and less than 2 ps for the 250 MHz unit, respectively. The sub-picosecond temporal resolution of the streak camera has been confirmed. The first beam measurements of the streak camera using synchrotron light from the existing 1.5 GeV TLS were performed. We practiced various operating modes of the streak camera to observe beam properties in longitudinal and transverse planes. This system will be used for the TPS project in the coming years.

ACKNOWLEDGMENTS

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REFERENCES

[1] TPS Design Handbook, version 16, June 2009.
[2] K. Scheidt, "Review of streak cameras for accelerators: features, applications and results", Proceedings of EPAC 2000, Vienna, Austria, p182 (2000).
[3] Bingxin Yang, "Streak Camera 101: Visualizing Charged-Particle Beam Dynamics", AIP Conference Proceedings. Vol. 868. (2006).
[4] Datasheet of Hamamatsu C10901 streak camera, (2012).
[5] P. J. Chou *et. al.* "Collective Effects in the TLS Storage Ring after the Installation of Superconducting RF Cavity", PAC'05, Knoxville, Tennessee, (2005), MPPP034, p. 2360.
[6] M. H. Wang, *et. al.*, "The Observation of the Longitudinal Coupled Bunch Motion on Streak Camera at SRRC", Proceedings of PAC1995, p. 2971.

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