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PRELIMINARY RESULT OF PHOTON COUNTING ACQUISITION SCHEME FOR LASER PUMP/ X-RAY PROBE EXPERIMENTS*

J. He[1], Y. Zhang[2], Z. H. Gao[2], Y. F. Zhou[2], Y. F. Sui[1],J. H. Yue[1], J. S. Cao[1], Y. Tao[2]
[1]Division for Accelerators, [2]Beijing Synchrotron Radiation Facility, Institute of High Energy Physics, Beijing 100049, China

Abstract

R&D project has been initiated for a proposed ultralow emittance (~50pm.rad) synchrotron light source built in Beijing. The R&D includes the development of high repetition rate laser pump/X-ray probe for ultrafast dynamics detection in future source. In a typical laser pump/X-ray probe measurement, the X-ray pulse follows a laser pulse in adjustable delay. We are interested in the difference between laser on and laser off at different delay, which will snapshot dynamic process. To capture this trivial difference, it requires the acquisition system to single out the signal from this special X-ray pulse at adequate S/N ratio. For the R&D of high repetition rate pump-probe, we have set up a prototype counting acquisition system based on NIM modular electronics, which was tested in Beijing Synchrotron Radiation Facility (BSRF). The laser will be synchronized with a camshaft bunch at 124 kHz, a tenth of the revolution frequency. Avalanche Photo Diode (APD) was used to detect the X-ray pulse from this camshaft bunch due to its nanosecond response. Before the laser is delivered, we mimic the 124 kHz laser- on signal. The signals from APD are separated by power dividers into two Constant Fraction Discriminator (CFD) input channels. The signal in laser-on/off channel is gated out using the 1.24MHz timing signal divided from 499.8 MHz RF signal, while the mimic laser-on signal gated out at 124 kHz. Multiplied by ten times, the mimic laser-on signal counts should be consistent with the laser-on+off counts, if our counting modular works well. We carried out this test at 1W1B wiggler beam line to measure the Fe fluorescence signal. The performance of our system is demonstrated in the good consistency between mimic laser on and laser on+off signals.

INTRODUCTION

Synchrotron radiation characterization technology is developed with the advancement of the accelerator technology. There is a first generations light source Beijing Electron Positron Collider (BEPC) II in Institute of High Energy Physics (IHEP). It can be operated in either of two modes: SR mode for the BSRF (Beijing Synchrotron Radiation Facility) and Colliding mode for BES III (Beijing Spectrometer III) [1]. A third generation light source High Energy Light Source (HEPS) is in a state of pre-research [2]. Table 1 shows the main parameters of BEPCII and HEPS. After the development of different steady state analysis methods, dynamic information study is developed in many synchrotron light sources [3-6], which are called time-resolved detections using a method of Pump-Probe. To use laser excitation (pump) samples and synchrotron light to detected (Probe) the samples. The goal of the experiment is to detect the trivial difference between the ground state and exiting state.

The light source will provide synchronous photons with a special time structure in these experiments, which is called mixed (Hybrid) model, bunches current and bunches gap are not the same. There will be a bunch or some bunches which called camshaft bunch, which have a larger gap and a bigger current than the normal one. In order to make X-rays synchronized with laser spatially and temporally, there are some preliminary study are done for HEPS on BEPCII [7,8].

Synchrotron-based laser pump/x-ray probe experiments on an ns or faster time scale have typically used ultrafast lasers suffering from the limitation of low repetition rates on the order of 1-10 kHz. This severely limits the data collection efficiency, since the x-ray bunches repeat at a much higher rate. This is particularly critical for XAFS experiments, which require very large S/N ratios (~ 10^4 or better) to extract useful EXAFS far above the absorption edge. In order to set up a high frequency laser ultrafast time-resolved beam line on the HEPS, some preliminary test results will be introduced in this article.

Table 1: Main Parameters of BEPCII and HEPS

Parameters	BEPCII Collide mode	BEPCII Synchrotron mode	HEPS [2]
Energy E_0 (GeV)	1~2.1	2.5	6
Circumference (m)	237.531	241.129	1296.14
RF frequency (Mhz)	499.8	499.8	499.8
Harmonic number	396	402	2000
Revolution frequency (Mhz)	1.264	1.243	0.2315
Revolution Period (ns)	792	804	4320

EXPERIMENT

As shown in the Table 1, the revolution period of the electron is 804 ns and the harmonic number is 402 for synchrotron mode. There are many normal bunches and a

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special bunch which in the middle of a 154ns gap. In order to get the signal of the camshaft bunch, we generated a gate signal with a width of 10 ns as shown in the Figure 1. There are three gate signals for different purposes. The frequencies of gate 1 and gate 3 are the same with revolution frequency, to synchronize with the camshaft bunch through 2 different APD detectors. Gate 2 is only tenth of it, to synchronize with the camshaft bunch and laser pulse, when we assume that the frequency of laser is 124 kHz.

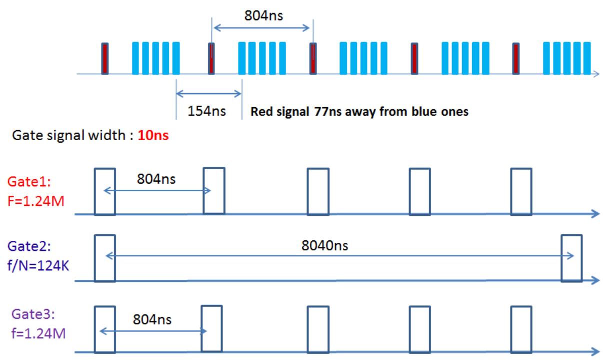

Figure 1: Laser on and laser off gate signals used for selecting the camshaft pulse.

Figure 2 shows the timing diagram of the gate signal and synchrotron X-ray. The oscilloscope is working in the infinite remainder sheen mode. The pink line is the timing signal generated by a timing sub-station which is consisted by an event generator (EVG) and an event receiver (EVR). This signal is synchronized with high frequency system. The grass green line is the signal of APD detector. The rise time of the output signal of the APD is several ns and the amplitude is several hundred mV. The yellow line is the gate signal which used to be designated the camshaft bunch. The insert picture of Figure 2 is the result of bunch current monitor (BCM) system, which can give the bunch current of whole ring. The current of each bunch is determined by the total current divide by sum signals of 4 beam position monitor (BPM) pick up electrodes. As shown it the Figure 2, there are two bunch strings, a longer one and a short one. The bunch gap is 4ns in a string, there is an isolate bunch in the #360 bucket which is the camshaft bunch.

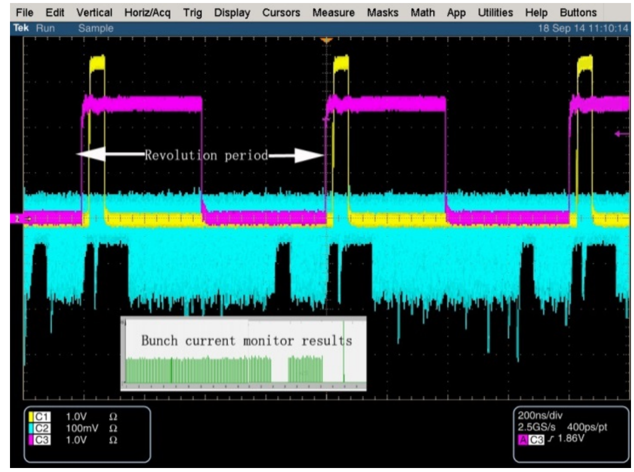

Figure 2: Gate signals used for synchronization with the camshaft pulse. The oscilloscope is working in the infinite remainder sheen mode.

Figure 3 shows a schematic of counting acquisition system based on NIM modular electronics, which including the photons signal processing, synchronization and delay control gate signals. There are four independent channels of the CFD (ORTEC model 935) which each channel accepts a negative, fast NIM logic signal to gate the respective constant-fraction timing output. If the signals come from APD exceed the threshold of the CFD, there will be a fast negative NIM output signals when we disable the gate controlled function. The four channel counter (ORTEC Model 974) will record the numbers of the pulse which present the intensity of the X-ray. Only when the X-ray and gate signals arrive at the same time, there will be output signal after we enable the gate controlled function. With that, we can get the X-ray signals of the camshaft bunch. To make the gate signals overlap with the special bunch temporal, a digital delay generator (SRS Stanford research system DG645) is used, which is working in the extra trigger mode to control the delay. If the delay time of DG645 is bigger than the period time of the trigger signal, the frequency of the output of DG645 will be a half of the input. When the delay is bigger than two period times will be third. That is the way we get the frequency of f/N, where f and N represent the revolution frequency and integer, respectively. If the laser frequency is124 kHz, the N is ten. The gate 2 will be used to get the laser on signal as shown in Figure 1. Both gate 1 and gate 3 is to going to be overlap with the special bunch, because they are used to gate different APD detectors, they have to use different time delay generators. The different function of APD detectors is shown in Figure 4.

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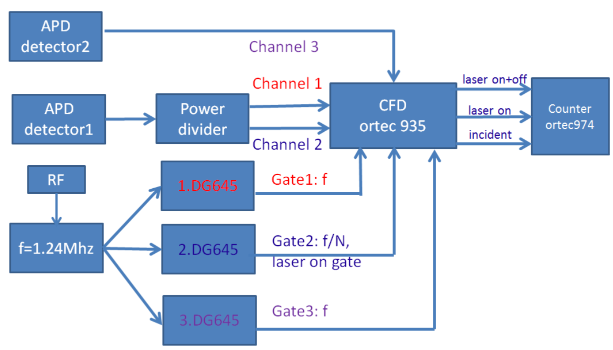

Figure 3: Schematic of channel consistency measurement.

Figure 4 shows a schematic diagram of XAS experiments. The experiments were done on 1W1B-X-ray Absorption Fine Structure of BEPCII. The normal XAS experiments were done with Ionization chamber (IC) to detect the light intensity. Two ADP (the commercial sensor with electronic developed by Y. Tao research group of BSRF) detectors were used to instead of the IC. The first APD is used to detect fluorescence signal of the sample and the second detector is to detect incident light intensity which is the same as the normal XAS experiments. Both DG645 and the Counter974 is controlled with computer through serial interface.

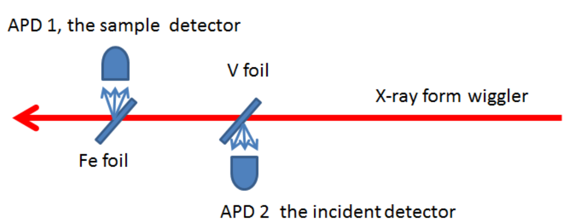

Figure 4: Schematic of XAS experiments.

Figure 5 shows the results of the X-ray absorb spectrum of Fe elements. The black and red lines are the absorb spectrums obtain from channel 1 and channel 2. The channel 2 represent the laser on signal and channel 1 represent the sum signal of laser on and laser off. To evaluate the consistency of the power divider and electronic which including the CFD and counter, the signal of channel 2 is magnified ten-fold. The ratio of the two signals is closed to 1 which means that the consistency of the system is good and the synchronization system works fine.

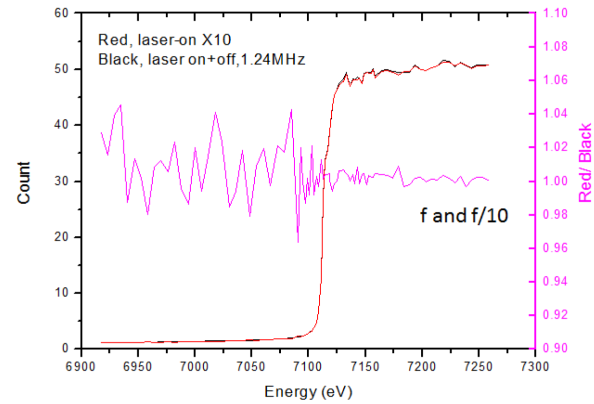

Figure 5: XAS results with different gate signal, presenting laser on (124 kHz) and laser on +off (1.24 Mhz), respectively.

CONCLUSION

It have been put on the agenda of built a third generation light source of 6 GeV with an emittance below 1nm rad. Development of high repetition rate laser pump/X-ray probe for ultrafast dynamics detection is one of the pre-research missions. A data acquisition system based on the NIM model is established. The preliminary result shown that the consistency of the system is good and the synchronization system works fine. The more work such as a laser pump system is under the way.

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