BUNCH PURITY MEASUREMENT FOR BEPCII

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Abstract

The bunch purity measurement is very important for time-resolved experiments. It is determined by the quality of the injection system and Touschek effect. The Beijing Electron-Positron ColliderI (BEPC II)was constructed for both High Energy Physics (HEP) and Synchrotron Radiation (SR) researches. It can be operated in the colliding mode and synchrotron radiation mode. It is planned to measure the beam bunch purity in a short time of several seconds by using a time-correlated single photon counting method. The method has a time resolution of 600 ps and a dynamic range of five orders of magnitude. In this paper, we describe our experimental setup and give a series of test results for colliding mode. We plan to set up a system which can kick out the unwanted bunches in the next stage.

INTRODUCTION

BEPC Ⅱ 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). There are dozens of bunches running around BEPCII electron storage ring, each bunch including about 10^{10} electrons. They are travelled through a linac, transport lines, kicker system, and captured by high frequency stable region at last. Electron beam from linac can be injected into the ring in a specified bunches through controlling the kicker by the timing system, bunches became stabilized because of the damping effect, gradually. The circumference of the BEPCII storage ring is about 240m and the RF system is 499.8M. There are 396 (Synchrotron mode is slightly different) stable regions. The number of electrons in the bunch is monitored by BPM signal which normalized by the DCCT (the principle of bunch beam current monitor), BCM system can only measurement the current in order of mA, which cannot meet the requirements of a more precise control.

A high signal to noise ratio of the short pulse light is required in order to study the process of rapid change in material, which means empty bunch have no photons emission. The bunch space is generally 8ns or 6ns in the colliding mode, because of the internal scattering in bunches, also called Touschek effect, some scattering of electrons captured by an adjacent stable region. General fluorescence lifetime testing needs 10^3 bunches purity and time-resolved Mossbauer collection needs more than 10^6 bunches purity. In order to achieve high purity bunch, the bunch feedback system must be introduced.

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Several light sources laboratory have established their bunch purity measurement systems [1, 2]. Kicker makes its amplitude oscillation increased, and finally hit the scraper. Before the establishment of a dedicated feedback system, a high-precision the bunch purity measurement system has been set up, using the time-correlated single photon counting (TCSPC) method [3, 4, 5].

EXPERIMENT

The schematic diagram of the entire system is shown in Figure 1. The system is built on optical platform of BEPCII electron storage ring synchrotron radiation monitoring laboratory. The synchrotron radiation visible light was introduced to H7422-40 type PMT detector through an optical transmission system. The single-photon pulse output signal's amplitude is only a few mV; it must be amplified in order to be identified. A Hamamatsu's C5594-44 high-speed amplifier was chosen, the frequency bandwidth and amplification gain are 50K to 1.5GHz and 36dB, respectively.

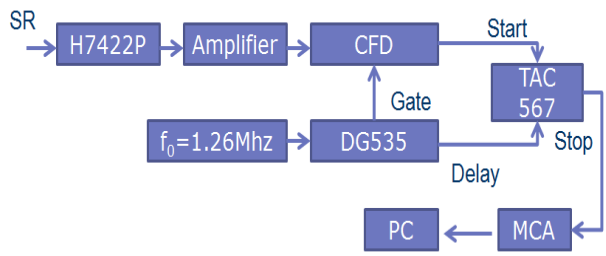

Figure 1: Schematic diagram of Bunch purity measurement system.

The output signal of amplifier's amplitude is several hundred mV and the rise time is about 1ns. In order to determine the arrival time accurately, we use the constant ratio screening method (Constant Fraction Discrimination, CFD ORTEC935), which the time jitter caused by the pulse height can be reduced as much as possible. CFD's output signals are used to generate a start signal triggering a time-to-amplitude converter (TAC, ORTEC 567). A timing signal from the BEPCII (1.26 MHz for colliding mode, 1.24 MHz for SR mode) can be used for TAC Stop signal directly, or used to trigger DG535. By adjusting the delay and width of the DG535 output, the CFD will only accept a signal excited from the special bunches which we concerned. TAC output is input into a multi-channel analyzer (MCA, ORTECTRUMP-PCI-2k) to count in different channels. After adequate accumulation, photon probability distribution P(t) curve which reflects the storage ring bunch distribution N (t) is restored.

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RESULTS

Figure 2 shows purity measurement results of BEPCII on collision mode, from top to bottom three are: (1) normal operation, (2) in two adjacent buckets injected 2 small bunches behind the third train, (3) condition of (2) after 9 hours. In the nine hours, the other colliding bunches were recharge continually, the two small bunches had not been recharge. There are three bunches queues, which including bunches of 25, 27, 28, respectively. The bunch is separated by 8ns in a queue and the queue is separated by 56ns, 48ns. The two small bunches' nominal current intensity is 4mA, BEPC II injection system cannot inject smaller current intensity bunches, Figure 3 shows the detail of the two bunches.

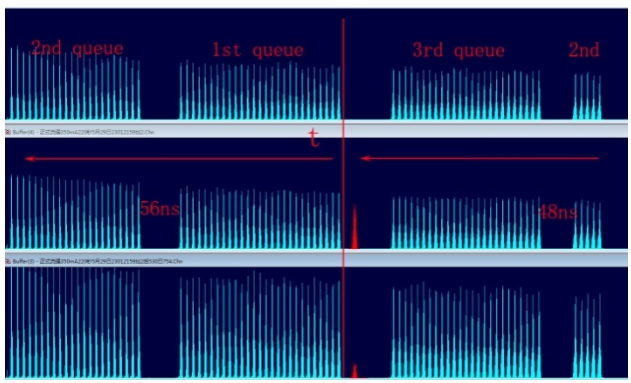

Figure 2: Bunch purity measurements of BEPCII Collider mode.

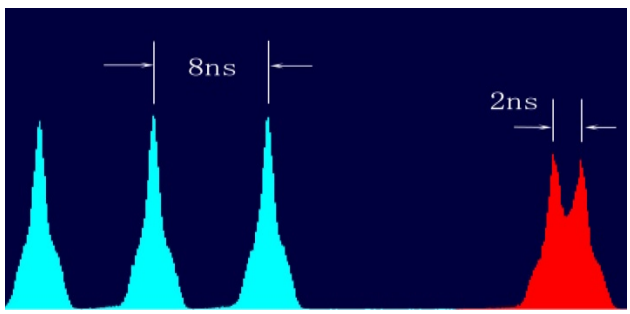

Figure 3: The detail of 2 small bunches which get adjacent intervals of 2ns.

The TAC select a range of 1000ns, multi-channel select a channel number of 8192 and the revolution period is about 800ns. The entire spectrum can be translated by adjust the delay of DG535. We put the two bunches signal in the middle of the MCA because of the linearity is better than the two sides. PMT's spectral response range is 300nm to 720nm and we select the center wavelength of 500nm. A reasonable light intensity means the multi-channel count rate within a reasonable range, the total count rate of counts per second is about 10^4 which is much lower than the repetition frequency of the selected pulse (1.26 MHz), so the pile-up effect is safely avoided. The Specific of count rate statistics is shown in Table 1. The two small bunches' continuous attenuation process has not been recorded because of the beam breakdown.

Table 1: Cps Statistics of Bunches

Bunches	cps	Current
Whole ring	1.5e4 (±120)	300mA (±10)
Single bunch	200 (±14)	4 mA(±0.5)
Two bunches	270(±16)	5.4mA (±0.4)
After 9 hours	60 (±8)	1.2 mA(±0.4)

After changing the channel addressed to the time and reversing the timeline, bunch purity measurement results are shown in Fig. 4, we can see that the bunch purity is better than 3×10^3. When the TAC selected a range of 50ns, the multi-channel indicates six bunches only, as shown in Fig. 5, the test bunch structure, the resulting bunch pulse FWHM is 600ps.This value does not represent the true width of the pulse bunches. It is determined by many factors, such as the bunch longitudinal length, TTD (Transit Time Discrete) of the PMT detector, the timing signal jitter, the delay and broadening cables. The longitudinal Gaussian width of the bunch is about 50 to 60ps; the PMT's TTD is about 300ps. The TTD of MCP-PMT is much shorter (only 25ps), a MCP-PMT has been bought already.

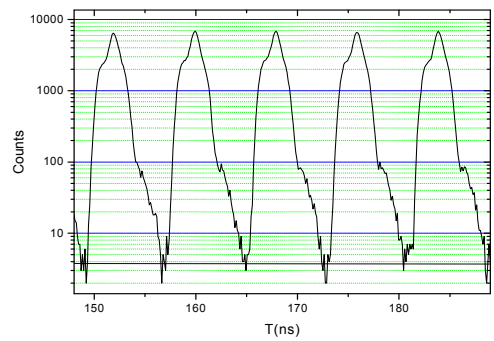

Figure 4: Bunch purity results(TAC range 1000ns).

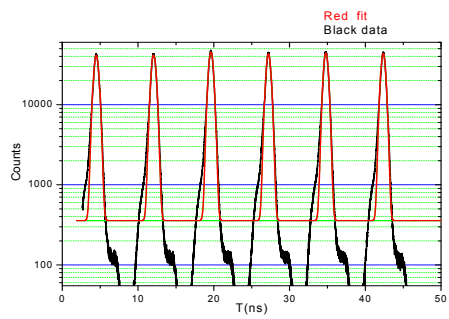

Figure 5: Data fitting results (TAC range 50ns).

The measurement results show that the BEPCII bunch purity is only 10^3 which does not mean that the real situation is at such a level but better than this. The test results depend on the features of the whole system. There are many important factors, detector dark counts, single-

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photon response curve, the precisions of electronics, a timing jitter of timing signal, experiment set up such as using Pockels box to control the photon transmission efficiency in an ns time scale [6].

CONCLUSION

A bunch purity measurement system has been set up in BEPCII storage ring using synchrotron light, it can give the bunch purity in tens of seconds. The Bunch purity measurement results show the purity of BEPCII is better than 3000, the system time resolution is about 600ps. The two parameters can be further improved by replacing the detector and electronics which are both underway. An Avalanche Photo Diode (APD) and an MCP-PMT detector have been prepared for the next experiments. A bunch clear system which based bands sweep kicker is under review also.

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