RECENT EXPERIMENTAL STUDY ON ECI AT THE BEPC *

Q. Qin, Z. Guo, H. Huang, Y. Liu, J. Wang, J. Xing, Z. Zhao, IHEP, Beijing 100039, P.R. China
H. Fukuma, KEK, Tsukuba-shi, Ibaraki-ken, Japan

Abstract

From last APAC, some experiments on electron-cloud instability (ECI) have been carried out on the Beijing Electron Positron Collider (BEPC). These experiments focus not only the ECI detecting and measurement, but the beam effects due to the newly installed clearing electrode and solenoid coils. This paper will describe the instrumentation of the ECI experiments, the measurement and the results, and some discussions on the experiments.

INTRODUCTION

Since the ECI was first observed on the BEPC in 1996 [1], many experiments related on the characteristics of the ECI, the detection of the current of electron cloud (EC), and the effects on beam performance have been carried out for years [2]. Analyses and simulations on the ECI happened in the BEPC storage ring were also done to help us understand further [3]. More photon-electron detectors were installed on the storage ring of the BEPC to compare the measurement with the first one installed on 1999 [4]. To curb the ECI and to get much beneficial information for the BEPCII, the upgrade project of BEPC, we did some more experiments on ECI measurement, clearing electrodes effect using both special kind and BPM buttons, and solenoid coils wound over almost all the straight section regions around the ring in recent years. Experiment results are compared with the simulation results [5] in a wide range.

In this paper, experiments on photon-electron detectors, clearing electrodes and solenoids will be introduced sequentially, together with the results of experiments. At last, some discussions on the results are given.

ELECTRON CLOUD OBSERVATION

The first EC detector was installed on the BEPC storage ring in 1999 [4]. With this detector, we got some information on PE energy distribution, secondary electron creation, dependences of beam parameters, etc. From 2002, other 4 detectors were designed and manufactured, and installed on different positions of the storage ring. Fig. 1 gives the positions of all 5 detectors.

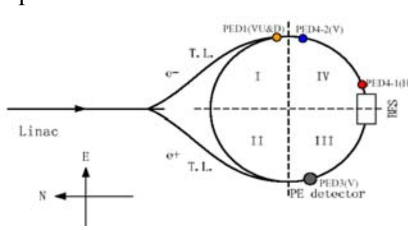


Figure 1: Positions of the 5 EC detectors around the ring.

* Work supported by the Chinese National Foundation of Natural Sciences, contract 10275079

Shown in Fig. 1, two detectors (PED1V) were installed on the same longitudinal position, but up (PED1V-U) and down (PED1V-D) on the vacuum chamber, respectively. The PED1V-D can be used as a clearing electrode. Fig. 2 shows the variation of PE current, I_c, as the bias voltage, V_b, changes on the PED1V-U and PED4-2V. Fig. 3 gives the variation of I_c as a function of bunch current I_b.

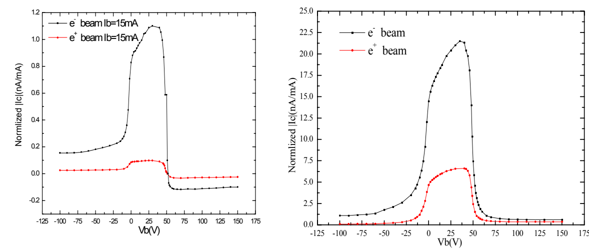


Figure 2: EC current I_c as a function of the bias voltage V_b (right: PED1V-U, left: PED4-2V).

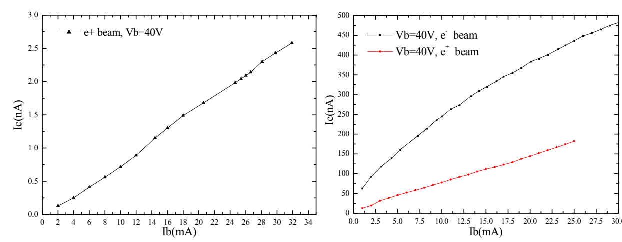


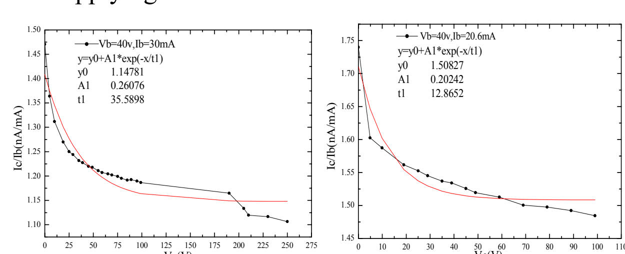
Figure 3: EC current I_c as a function of bunch current I_b (right: PED1V-U, left: PED4-2V).

Fig. 2 and 3 show the same behaviors of the EC current as we observed on the first detector. The I_c reaches its maximum value at V_b≈40V, which is also consistent with the previous results. No any saturation of I_c was observed in Fig. 3.

CLEARING ELECTRODE

EC Detector as an Electrode

One of the newly installed EC detectors, PED1V-D, can be used as an electrode to clean the EC with a properly DC voltage given on an extra grid inside the detector. The PED1V-U, which locates just above the PED1V-D on the top chamber, can be used to measure the change of EC after applying the electrode.



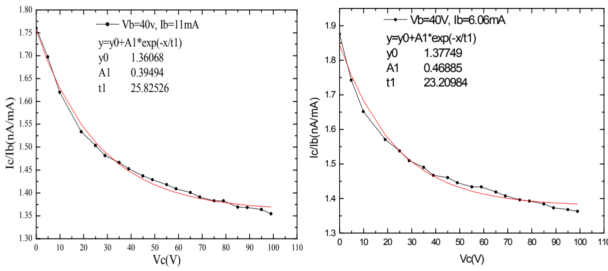


Figure 4: Normalized I_c as a function of clearing voltage at different bunch current.

With a V_b=40V on the detector of PED1V-U, we measured the I_c from the collector of PED1V-U as a function of the clearing voltage V_c on the PED1V-D.

In Fig. 4, the red lines are the fitting results from the measured values, the black lines. Fig. 4 shows the effect of the clearing electrode on PE. Since the grid used as the electrode is not close to the bottom of vacuum chamber, the electrode reduces only 15% EC current. Thus, the electrode was modified to the one with three-parallel plates, which are on the same level of the chamber bottom, shown in Fig. 5.

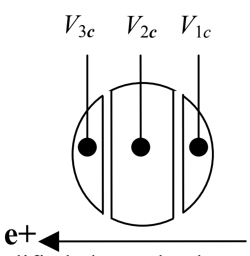


Figure 5: Modified electrode plates in the chamber.

The DC voltage can be applied to the electrode plate by plate or in a series. As an example, Fig. 6 shows the normalized I_c varies as the electrode voltage V_{3c} changes in different energies.

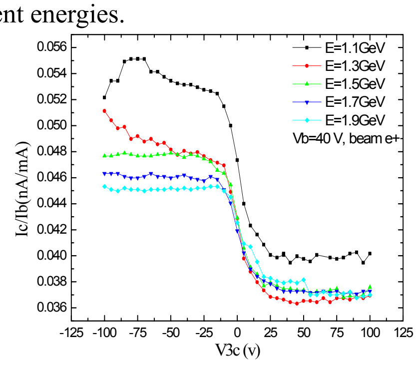


Figure 6: Normalized I_c changes with V_c in different energies.

BPM Buttons as Electrodes

32 BPMs are used around the BEPC storage ring. With a special switcher, total 128 circular BPM buttons can be applied DC voltage in the same time. In each BPM, the 4 buttons are labelled as A, B, C and D, shown as Fig. 7. All 32 buttons of A or B or C or D can be as different groups to be applied DC voltages. DC voltages from –600V to +600V were applied to the different patterns of buttons.

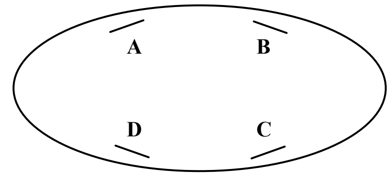


Figure 7: BPM button labelling (left side: inner ring, right side: outer ring).

Filling a bunch train with 40 nearly equal population e+ bunches (total beam current ~ 51mA) and spaced by one RF bucket, we observed clearly the frequency sidebands of the oscillation due to ECI when the chromaticities were set as $\xi_{x,y}$=1.5. The amplitude of these sidebands were recorded and analyzed for different patterns of voltage applied on the BPM buttons. Fig. 8 depicts the variation of the sidebands amplitude in different voltage patterns.

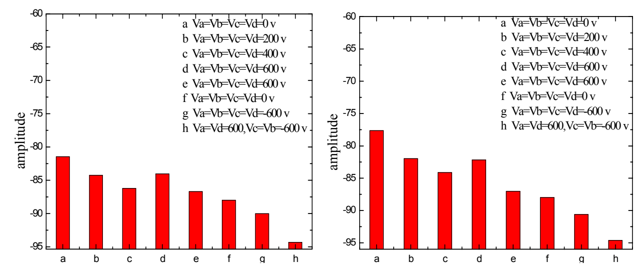


Figure 8: Left and right frequency sidebands amplitude variation in different voltage patterns.

From Fig. 8, we can see that the amplitude of frequency sidebands can be reduced when the BPM buttons are applied DC voltages. The best pattern is to apply +600V on all A and D buttons, and in the meantime, apply –600V on all B and C buttons. In this pattern, the amplitudes of sidebands are less than 20 % of the case without any DC voltages on the BPM buttons. It implies that the bunch oscillation due to the ECI is reduced after applying DC voltage on the BPM buttons. To avoid the annular slots between buttons and chamber being struck at high voltage, we didn't not try to apply voltage on BPM buttons higher than 600V.

SOLENOID EFFECTS

Solenoid coils located in straight section of rings can be used to curb the ECI. This has already been verified on both KEKB and PEPII. During the shutdown of BEPC last year, we wound solenoids in most straight sections around the BEPC storage ring. All the solenoid parts covered on different straight sections are connected in series. A DC power supply can provide a current of 0-35A to the solenoids. Some parts of the solenoids in the long straight sections can be turned off from the whole coils with switches.

EC Generation

With the solenoids on, we measure the PE current I_c with the detector of PED1V-U as the bias voltage V_b changes, shown in Fig. 9.It's clear to see that the PE generation reduced when the solenoids are powered on.

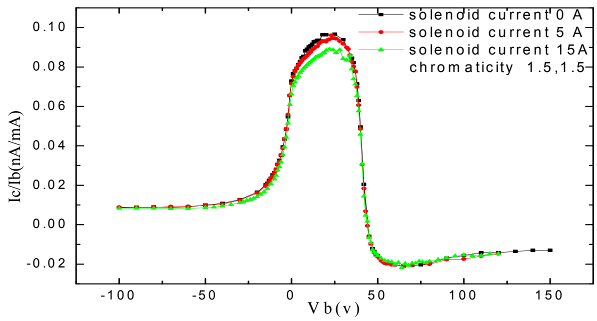


Figure 9: Solenoid effect on EC generation.

Frequency Sidebands

For multi-bunch patterns, we observed clear frequency sidebands of oscillation due to ECI when chromaticities were set to $\xi_{x,y}$=1.5. When a current of 15A is powered to the solenoid, both left and right sidebands disappeared, shown in Fig. 10.

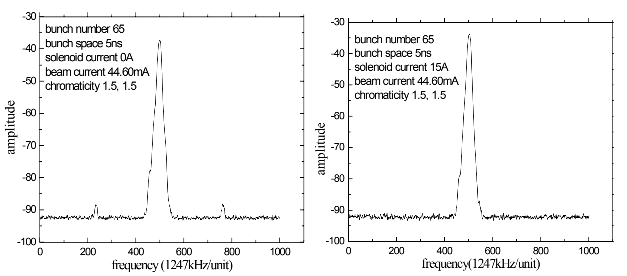


Figure 10: Solenoid effect on sidebands (left: solenoid off, right: solenoid on).

A streak camera was used to observe the change of the vertical bunch size with/without solenoids. Fig. 11 shows an example of the tail of a bunch train with an obvious coupled bunch oscillation among bunches. We take the 5th bunch from last for estimation. If the solenoids on, the vertical bunch size is reduced about 15% in average.

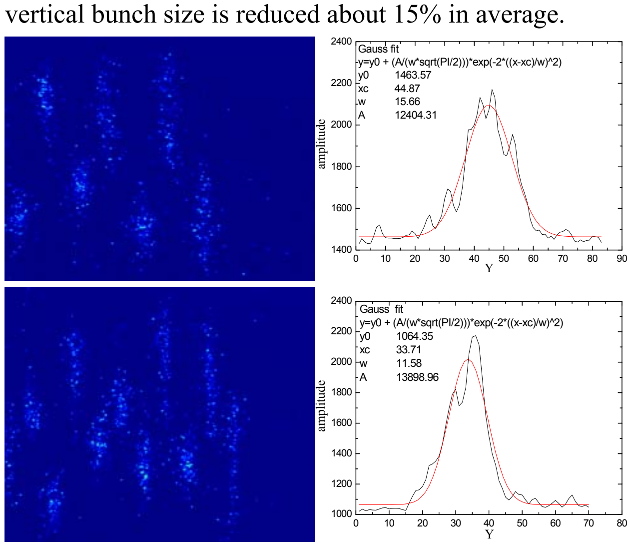


Figure 11: Solenoid effect on bunch size in a bunch train (upper: solenoid off, lower: solenoid on).

Combination with Chromaticity Effect

An effective way to curb the ECI is to enhance the chromaticity, which had already been verified in BEPC. Higher chromaticity can not only lower the amplitude of sidebands, but reduce the bunch size. On average, the bunch size is reduced about 30% when chromaticity is enhanced from 1.5 to 4 without any solenoid field.

Fig. 12 shows the chromaticity effect on left sideband amplitudes combined with solenoids at different energies..

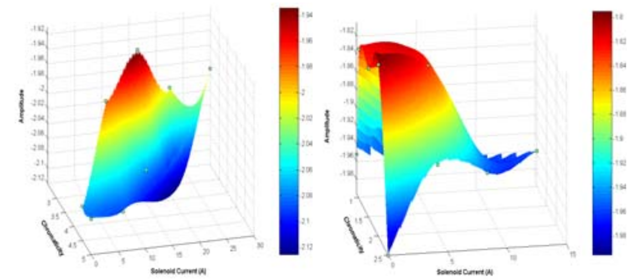


Figure 12: Left sideband variation when chromaticity and solenoid field change (left: E=1.3GeV, right: E=1.89GeV).

DISCUSSIONS

Besides the new PE detectors were installed in BEPC, clearing electrodes including BPM buttons were used as trials, and solenoid coils were tested to curb the ECI in recent experiments.

The newly installed detectors can get the similar results with the previous one on measuring PE. One of the new detectors was modified as a clearing electrode. PE's were reduced when the electrode-plate was applied DC voltage. The behaviour of PE variation from another electrode-plate in the same detector is contrary to the one shown in Fig. 6. This is not yet understood till now. With the BPM buttons, on which up to ±600V DC voltages were applied, a reduction of sideband amplitudes was clearly observed. But since there are not as many BPM buttons as possible, and the buttons are too short in longitudinal, the result on restraining PE looks not so effective compared with other methods. Covering most of the straight sections around the ring, the powered solenoids can effectively lower the generation of PE, reduce the amplitudes of frequency sidebands of oscillation, and squeeze the vertical bunch size. In comparison with the effect of chromaticity, the solenoids look a bit weaker, even they are powered as high current as 30A, which corresponds to about 30Gauss field.

Some new experimental results observed on beam size and sidebands are described in this proceedings [5]. The experimental results comparable with the result of simulation, see [6] in this proceedings.

REFERENCES

[1] Z.Y. Guo, et al, PAC'97, Vancouver, 1997, p. 1566.
[2] J. Xing, ECLOUD'2 proceedings, CERN, 2002.
[3] Z.Y. Guo, et al, PRST-AB, Vol. 5, Issue 12, 124403, 2003.
[4] Z.Y. Guo, et al, PAC'2001, Chicago, 2001, p. 676.
[5] Z.Y. Guo, et al, this proceedings, 2004.
[6] Y.D. Liu, et al, this proceedings, 2004.