COMMISSIONING OF BEPCII

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Abstract

The commissioning of BEPCII is planned in 3 phases. The phase 1 of beam commissioning was carried out from Nov. 2006 to Aug. 2007 with the so called backup scheme, which adopted conventional magnets in the IR instead of the superconducting insertion magnets (SIM). The second phase commissioning was carried out from Oct. 2007 to Mar. 2008 with the SIM in the IR. The third phase will be started in June after the detector is installed into the IR. This paper describes the procedure of beam commissioning and focuses on the results achieved in the second phase.

INTRODUCTION

The BEPCII is the upgrade project of BEPC, serving continuously the dual purpose of high energy physics experiments and synchrotron radiation applications. The design goals and its construction is described in Ref. [1,2]. As an e^+-e^- collider, it consists of an electron ring (BER) and positron ring (BPR), respectively. For the dedicated synchrotron radiation mode, electron beam circulates in the ring made up of two outer half rings.

In accordance to the progress of construction, as well as to meet the demand from the SR user community, the commissioning of BEPCII is carried out in 3 phases: Phase 1, with the conventional magnets in the IR instead of SIM; Phase 2, with SIM in the IR; Phase 3, joint commissioning with detector.

The phase 1 commissioning was from Nov. 13, 2006 to Aug. 3, 2007. The beam performance and commissioning results were reported on the APAC07[3] and PAC07[4].

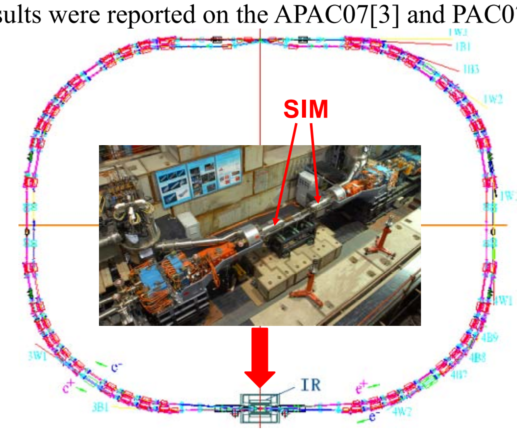

Figure 1: The layout and the SIM installed in IR.

The phase 2 commissioning was carried out from Oct. 24, 2007 to Mar. 28, 2008, after the SIM and new vacuum chambers were installed into the IR in summer of 2007, as shown in Fig. 1,

The main milestones of collision mode commissioning in phase 2 are listed in the following:

Oct. 25, the electron beam was stored

Oct. 31, the positron beam was stored

Nov. 18, the first e^+ e^- collision realized at β_y^*=1.5cm

Jan. 29, 2×500mA e^+ e^- collision realized with luminosity higher than 1×10^{32}cm^{-2}s^{-1}, 10 times of BEPC.

The dedicated SR mode was commissioned from Feb. 1, and user operation was started on Feb. 25 for about 1 month. The typical beam current is 250mA to 140mA, with beam lifetime about 10hrs at 200mA while the gap of the in-vacuum wiggler 4W2 was set to 18mm.

The following sections will mainly introduce commissioning of the collision mode in phase 2, emphasis on the beam performance and luminosity tuning.

BEAM PERFORMANCE

The growths of the beam current in the BER and BPR are shown in Fig. 2. When the beam current in BER exceeded 100mA, the SC cavity (SCC) tripped often due to its arc interlock of window and following vacuum pressure raised quickly. Similar condition happened in BPR when the current is over 200mA. To overcome the problem, a DC bias voltage was applied on the power coupler of the SC cavities to suppress the multipacting effect. This worked very effectively and the vacuum condition significantly improved. Then the beam current of both rings could be improved steadily. Transverse feedback system was employed for smooth injection and stable operation at high beam current.

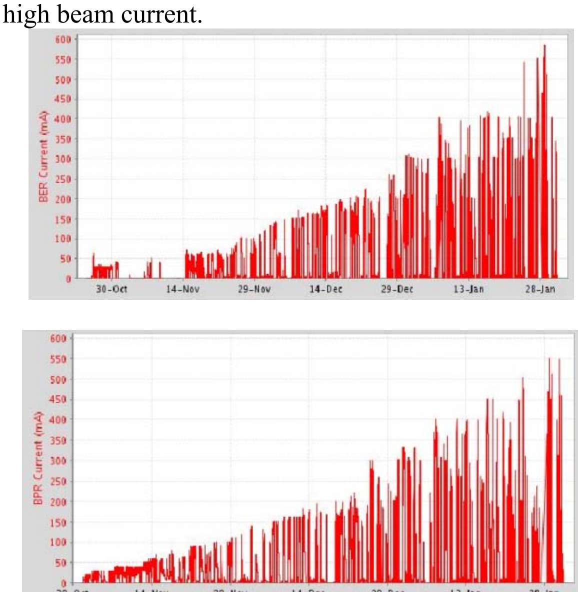

Figure 2: Current growth during the period of commissioning, BER (upper) and BPR (down)

Table 1 summarizes the main parameters achieved for BER and BPR during this commissioning period in comparison with designed values.

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Table 1: The main parameters of the BER and BPR

Parameters	Design	Achieved	
		BER	BPR
Energy (GeV)	1.89	1.89	1.89
Beam curr. (mA)	910	550	550
Bunch curr. (mA)	9.8	>10	>10
Bunch number	93	93	93
RF voltage	1.5	1.6	1.6
Tunes (ν_x/ν_y)	6.54 /5.59	6.544 /5.599	6.540 /5.596
$*\nu_s$ @ V_{RF}= 1.5MV	0.033	0.032	0.032
β_x^*/β_y^* (m)	1.0 /0.015	~1.0 /0.016	~1.0 0.016
Inject. Rate (mA/min)	200 e^- 50 e^+	>200	>50

$*\nu_s$ is extrapolated from the measurement at RF voltage of 1.69MV for BER and 1.61MV for BPR, respectively.

Orbit and Optics

The closed orbit and optics correction was done based on the response matrix and its analysis using LOCO (Linear Optics from Closed Orbits) method [5]. As the result, the measured beam optics functions are in good agreement with theoretical prediction with discrepancy within ±10% at most quadrupoles [6].

LOCO analysis indicated that the quadrupole strengths are mostly lower than the design set within 1~2%. One contribution to this systemic component was from the short distance between the quadrupole and its adjacent sextupole. Another may from the fringe filed effect. Other origin of these errors is still pursued.

Injection

Efforts were mainly made to improve the injection rate of positron beam. After the optimization of energy set and the orbit in the transport line, the injection rate was improved to higher than 50mA/min, which meets the designed goal.

The two-kicker system is adopted for injection, thus the betatron phase advance between the two kickers is designed as 180 degree to form a local bump during injection. However, to reduce the residual orbit oscillation of the stored beam during injection, it's tricky to set the right timing and amplitude of the two kickers. This was done using the Libra BPM system [7]. Thanks to the sameness between the waveforms of the two kickers, after the time delay and amplitude of the two kickers was optimized for the injecting bunch, the residual orbit oscillation of all the other bunches during injection can be reduced to around 0.1mm, corresponding to about 0.1σ_x. This made it possible to inject beam during collision.

Instabilities & Feedback

The single bunch beam dynamics as well as collective effects are described in detail in ref. [8]. An analog bunch-by-bunch transverse feedback (TFB) system has been adopted to cure the instabilities [9].

In longitudinal, since SC cavity is adopted, the beam behaves fairly stable. However, synchrotron oscillation sideband was sometime observed along with beam current increase, while it seemed not caused by the beam instability, but by some noise in the LLRF loop. After the LLRF properly tuned, the beam is much stable in longitudinal direction up to 550mA with 99 bunches in both rings.

In transverse, coupled bunch instability was observed in both BER and BPR. In the BER, vertical sidebands near the rf frequency was observed on the spectrum analyser. These may be due to resistive wall impedance. In the BPR, a broadband distribution of vertical sideband spectrum has been observed, which can be attributed to the electron cloud effect, as shown in Fig 3. With the TFB carefully tuned, the sidebands of couple bunch instabilities in both BER and BPR can be well suppressed.

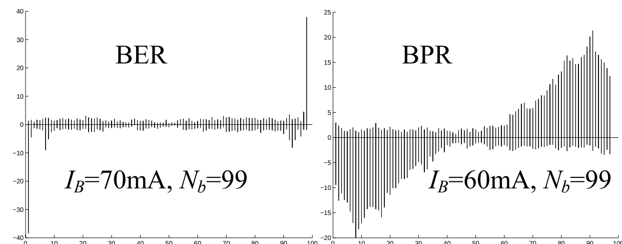

Figure 3: Mode distribution between BER and BPR

Besides, streak camera was used to measure the bunch length, as well as the vertical beam size blow up due to ECI, and there was not obvious grow up of the bunch size at the tail of the bunch train. As prevention to further ECI, solenoid was winded on the vacuum chamber and can be put into use when needed.

LUMINOSITY TUNING

Single Bunch Collision

Electron and positron beams in two rings were brought to collision at the IP by Beam-Beam Scan (BBS). A luminosity monitor (LUM) based on the detection of zero degree γ from radiative bhabha process was installed. It can distinguish the luminosity bunch by bunch with a response fast enough to be used in the tuning procedures. Thus the beam parameters such as tune, coupling and local optics at IP were optimized to maximize the specific luminosity given by the LUM.

According to the beam-beam simulation the factional part of the transverse tunes were chosen near (6.54/5.59) for both rings. To get the best luminosity, tunes of each ring were scanned around the region. Then the tunes for BER and BPR were set near (6.54, 5.64) with two rings differed by about 0.005.

Optimization is also on the x-y coupling or beam size. This was done by adjusting the local vertical orbit in one sextupole in the arc. It is found that 1% coupling gives the best specific luminosity.

The vertical dispersion at IP was measured to be less than 10mm, and the contribution to the beam size at IP can be neglected. The local optical functions at the IP such as coupling and β_y^* waist were also adjusted to optimize the luminosity.

With the above beam parameters optimized iteratively, the maximum bunch current achieved in stable collision with high luminosity is 11mA×11mA, which is higher than the design of 9.8mA. However, there is still room to improve the specific luminosity at high bunch current.

Multi-bunch Collision

For multi-bunch collision, it is important to have uniformly filled bunches. This has been configured in the injection control programme based on the event timing and bunch current monitor systems. An algorithm has been developed to select the bucket and refill it with the rule of the smallest the first, thus, to get a uniform filling.

Multi-bunch collision was practiced in two ways, one with relative high bunch current but small number of bunch, say above 7mA/bunch, the other is with moderate bunch current, but 93 bunches as designed. At the same total beam current, the former case has the higher luminosity. However, the injection and collision process is not so stable when the bunch current is high. Thus, the best luminosity achieved was with 93 bunches at total beam current of 500mA. To investigate better ways for smooth injection and stable collision with high bunch current is still under way.

The spec. lum. was scanned versus vertical beam offset at IP both in single bunch and multi-bunch cases, as shown in Fig.4. It indicates the beam size in multi-bunch case is large, while the spec. lum. is lower at zero offset. One possible reason is the coupled bunch oscillation at high current. An indication is that when sometime the transverse feedback was better tuned, particularly at Y-direction, the luminosity could be improved significantly.

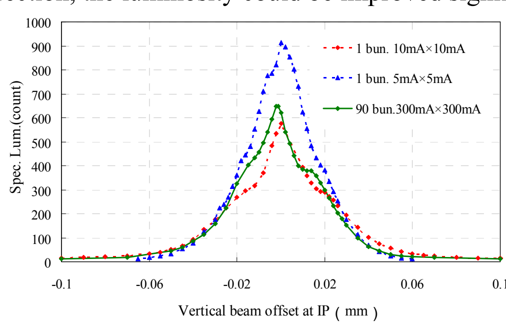

Figure 4: Scan of spec. lum. for single(dashed) and multi-bunch (solid) vs. the vertical offset at IP.

Background

Experimental studies have been carried out to investigate the radiation dose around IP as well as the way to reduce the background. The main conclusion is that with the injection optimized, the dose rate in the IR gets acceptable for the BESIII detector which is to be pulled into the IR. The backgrounds due to steady runs and ways to reduce them should be studied thoroughly in the near BEPCII/BESIII joint experiment [11].

OTHER HIGH CURRENT ISSUES

Along with beam intensity growth, the heating effect due to SR and HOM appears. In most case, it was due to the SR power increase and after the flux of cooling water adjusted the heating was mitigated. However, some HOM heating effects appeared in the DCCT and the in-vacuum permanent wiggler 4W2, with the temperature rise shows the feature of sensitive to the bunch current. These somewhat limited the beam current increase. For the 4W2, to prevent the magnet poles being over heated, a movable beam pipe designed to shield the HOM, was put into use and functioned as expected. For the DCCT, improvement on the water cooling is under way.

Besides HOM heating, nonlinear increase of vacuum pressure versus beam current was observed in BPR. This may due to the beam induced multipacting effect. Solenoid winding may be helpful to ease the problem.

PLAN AND SCHEDULE

The detector was moved into the IR in early May as shown in Fig. 5. The third phase commissioning is scheduled in mid of June. It is expected that the luminosity would be high enough for the BESIII detector to start experiment by the end of this year.

Figure 5: The IR with detector.

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