COMMISSIONING OF BEPCII SUPERCONDUCTING RF SYSTEM

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Abstract

BEPC single-ring machine had been upgraded to BEPCII double-ring machine in the past four years, four 199.6MHz RT cavities were replaced by two 499.8MHz superconducting cavities.

Two SRF stations of BEPCII had passed the first beam commissioning, physical problems such as changing frequency from 200MHz to 500MHz and compressing the bunch length in colliding mode, have been solved step by step. The engineering problems such as feeding 100KW beam power had also been solved. The SRF system of BEPCII project had finished on schedule. This paper gives a brief introduction to the commissioning of the SRF system of BEPCII.

INTRODUCTION

Two SCC had been fabricated by MELCO since 2003.They had passed the vertical test at KEK at the beginning of 2005, and the horizontal test at IHEP in the summer of 2006, respectively. Since Nov.2006, two SCC had been employed in the first beam commissioning of the synchrotron radiation (SR) mode, also in the e+/e- colliding mode. During the SR operation, the beam reached 250mA/2.5GeV with 100KW RF power under 1.3MV RF voltage, the maximum inject beam current at 1.89GeV had reached 500mA. For the e+/e- colliding mode, the beam current of either e+ or e- ring had exceed 100mA, the bunch length can be reduced to 21mm in e-ring.

The East and West cavity are installed at electron(e-) and positron ring(e+) respectively, near the beam crossing point in symmetry, and both in outer ring. There are two operation modes: physics collision mode, 1.89GeV top-off injection and beam colliding; and the Synchrotron Radiation (SR)mode, electron beam run along the outer ring and ramp energy from 1.89GeV to 2.5GeV with the RF power from SCC (individual or together), as shown in Fig 1.

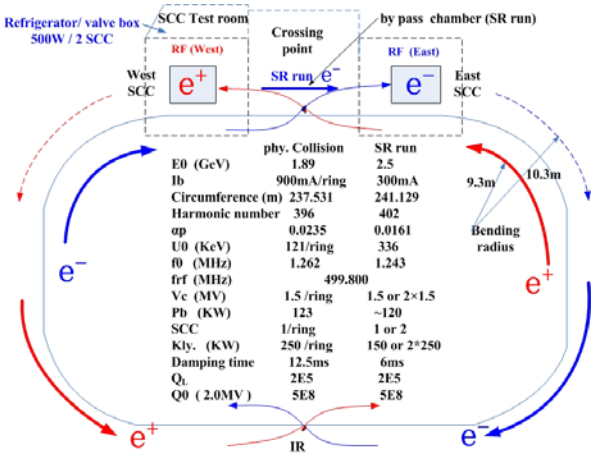

Fig.1 two SRF stations in BEPCII

Fig.2 East cavity in BEPCII tunnel

Fig.3 250KW (CW) klystron in East RF hall

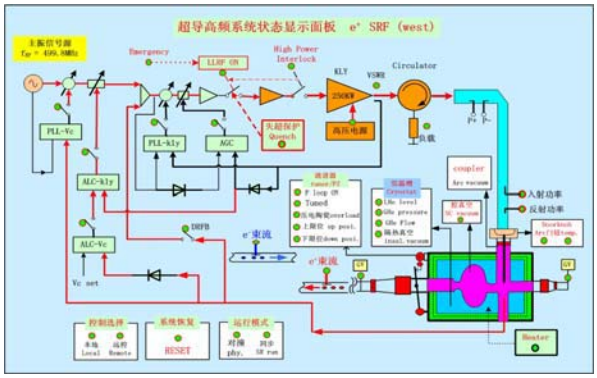

Fig.4 One SRF station with LLRF

FIRST BEAM COMMISSIONING

During Nov.2006 to Aug.2007, the new SRF system had been put into the initial commissioning and operation. The beam and SRF parameters had been

measured, such as beam power, bunch length, longitudinal oscillation frequency, beam loading, etc. The results are matched with the design values.

- *SRF beam commissioning outline*

The first beam commissioning of SR-ring started at Nov.2006. Within one month, the first beam accumulated and then reached 2.5GeV/100mA. Finally the beam had been dedicated to the SR users at Dec. 2006. During the SR operation, the East cavity was working and the West cavity was detuned. The e- ring /e+ ring commissioning started at Feb./Mar. of 2007, with East and West SCC respectively. The first e+ and e- beam collission reached 110/114mA at May 2007. Step by step, The beam current reached 1.89GeV/500mA and 2.5GeV/250mA in the second phase operation for SR from May to Aug of 2007.

The outline of the SRF commissioning is listed at the Table.1

	Time	Reached record	Design
SR-ring (East SCC was used)	2006.11-12 commissioning	1.89GeV@180mA 22KW	2.5GeV@300mA 120KW
	2006.12-2007.2 operation-1	2.5GeV@160mA 64KW	
	2007.6-8 operation-2 100~300 bunches 2.5GeV	2.5GeV@250mA 100KW 1.89GeV@500mA 300bunches	
e^--ring 1.89GeV	2007.2-5 commissioning	140mA ~100bunches	900mA
e^+-ring 1.89GeV	2007.3-5 commissioning	200mA ~100bunches	900mA
e^+/ e^--ring 1.89GeV collision	2007.5 first colliding	110×114mA 20bunches	900×900mA

Table. 1 outline of the SRF commissioning

- *Beam current and RF power*

100KW max beam power reached by using the East SCC under the beam of 2.5GeV/250mA.

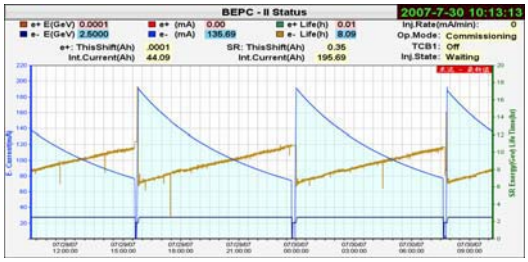

Fig.5 SR mode operation in 24hrs

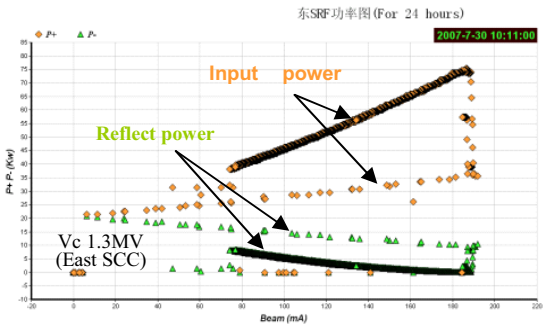

Fig.6 RF and beam power in SR operation

Without the beam, both input RF power(P+) and reflection power(P-) are 21KW for 1.3MV RF field, With 190mA injection beam, the P+ increased to 36KW and P- reduced to 10KW. After ramping the beam energy from 1.89GeV to 2.5GeV, P+ and P- changed to 76KW and 0KW, and the klystron matched with the SCC and beam load. The energy loss per turn (U_0) increase from 336KeV to 386KeV with 5 wigglers, beam lifetime was ~7hrs with ~300 bunches. Fig.5 and Fig.6 show the typical SR mode operation in 24hrs.

- *Bunch length and RF voltage*

In order to increase the luminosity, higher RF voltage is employeed to compress the bunch length. During the e- ring commissioning without detector, the relationship between RF voltage and bunch length was measured by a stripe camera. The measured bunch length, as shown in Fig.7, is longer than theoretic values with a factor of 25%, and the design target is 15mm with RF voltage 1.5MV. the more experiments are need in the future.

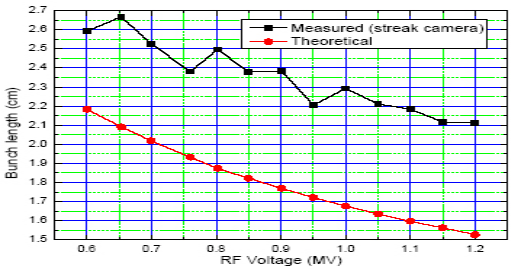

Fig.7 RF voltage vs bunch length

- *Longitudinal oscillation frequency fs*

fs had been measured by using HP8568B and TEK 3303A spectrum analyzer. For e- ring, fs=35.8KHz at Vc=1.2MV, as shown in fig.8. For SR-ring, at 1.27MV, while ramping E_0 from 1.89GeV to 2.5GeV, fs decreased from 34.5KHz to 29.3KHz, φ_s moved about ~13^0 .

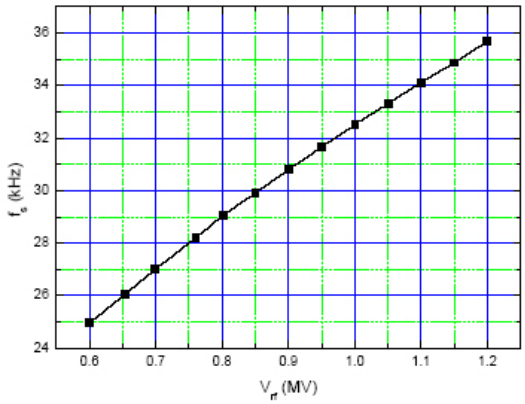

Fig.8 RF voltage vs fs in electron ring

- *Beam loading detune*

At SR-ring injection, when East cavity voltage is 1.31MV, the measured beam loading is -3.4KHz under the beam current 200mA, which is close to the theory value 3.6KHz.

- *Problems*

For East SCC, 300mA beam can injected along the SR-ring, but at the same time, many arc, vacuum alarms happened in e- ring commissioning even at 20mA. The e- beam current increased to 140mA after weeks' beam aging. Similar phenomena did not happen on the West SCC during e+ ring commissioning, the positron beam exceeded 200mA in days.

For West SCC, arc and vacuum protection happened frequently when it was used in SR ring, the outgasing around SBP taper might be caused by Synchrotron light.

HOMs power will be measured at different bunch length and numbers for the physical colliding mode in the future.

FIRST HIGH POWER TEST OF SCC

In the summer of 2006, two cavities had passed the first high power horizontal test in IHEP. That is the first experience of commissioning SRF system together with Cryogenic system. Both cavities reached the design target, Q_0 >5×10^8 at 2MV RF voltage. The test results are showing as Tab.2 and Fig.9

	East SCC	West SCC
Static loss	30W	27W
Q_0 (2MV)	5.4×10^8	1.02×10^9
Q_0 (1.8MV)	9.8×10^8	1.28×10^9
Q_0	1.7×10^9(1.5MV)	1.44×10^9(1.6MV)
Q_L	2.1×10^5	1.92×10^5

Table 2 First horizontal test results in IHEP

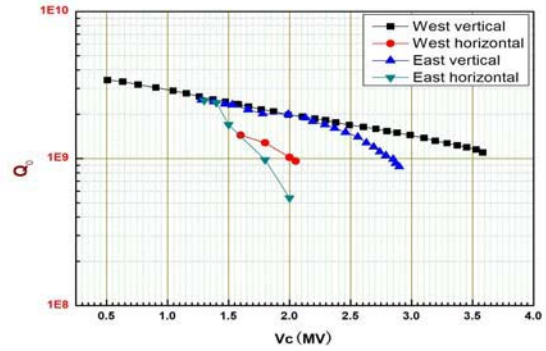

Fig.9 Q_0 measurement results

Because of the heat influence from the coaxial coupler, the measured Q_0 below 1.3MV may be not precise enough. RF voltage(V_C) calibration also exist about 3% error by measure power from cavity pickup and input of waveguide. The power loss of circulator and WG is 6%.

After CW and pulse RF aging to a new cavity, the radiation intensity of the cavity decreased while the breakdown voltage increased. Fig.10 shows the test result of East SCC, the first quench happened at 1.6MV.

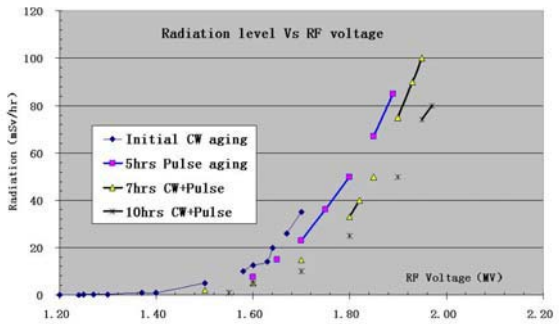

Fig.10 Radiation vs RF voltage

CONCLUSIONS

Two BEPCII SRF stations had passed the initial beam commissioning for electron ring, positron ring and also SR ring. RF voltages of the two SCC both had exceeded 1.3MV with beam. Bunch length had reduced in

colliding mode and beam power reached 100KW in SR mode operation, most of the parameters of BEPCII SRF system were reached the design target already.

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