BEAM POSITION MEASUREMENT FOR ELECTRON COOLER EC-300 AND EC-35

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The beam position measurement system of EC-35 and EC-300 is presented in this paper. The electrostatic pick-up is used for beam position measuring. The ion and electron currents have alternative part with the magnitude of about 1 mA. The important feature of the beam position measurement system (BPM system) is simultaneous measurements of the positions of both the ion and the electron beams. The resolution of the beam position measurement is about 1 mm, diameter vacuum chamber 300 mm.

PACS: 29.20.-c

1. INTRODUCTION

The Budker Institute of Nuclear Physics (BINP) had been manufacturing two facilities of electron cooling (electron cooler) of ion beam EC-35 and EC-300 during 1999-2003. The facilities had been prepared for the Institute of Modern Physics (IMP China, Lanzhou) for installation on a new ion accelerator complex HIRFL-CSR [1]. HIRFL-CSR is a multi-purpose system. It consists of an injector HIRFL, a main ring (CSRm) and an experimental ring (CSRe). Each of the rings is equipped with its own electron cooling devices. E-cooling will be used to increase the beam intensity and decrease the beam emittance. The principle of operation of electron cooling method is based on combining the electron and ion beams moving with the same velocity within the cooling section. So, the drag force between the electrons and ions leads to the fine equalizing of the ion and electron velocities. This method is used for the decrease of ion transverse emittances and momentum spread [2].

The cooler consists of a cooling section solenoid, two bending magnets, an electron gun, and a collector. Beam Position Monitors (BPM) are located at both sides of the solenoid. A sketch of the facility and BPM position is shown in Fig.1.

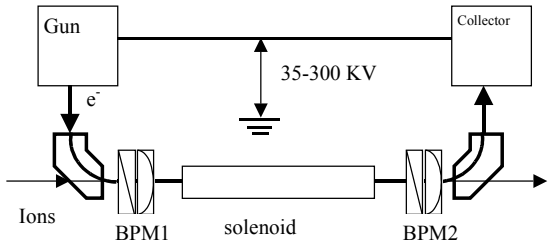

Fig.1. Electron cooler and the BPM

Some parameters of the accelerator complex and the cooler are shown in Table.

Parameters of the complex and the cooler

Parameter	Value
Ion energy	25…500 MeV/u
Ion current	0.1…1 mA
Ion revolution frequency	100…300 kHz
Electron DC current	3 A
Electron AC component	1 mA
Vacuum chamber diameter	300 mm
Cooler length	6 m

For the electron cooling process an ion and an electron beams must have the same trajectories within the cooling section. The important feature of the BPM system is simultaneous measurements of the positions of both the ion and the electron beams. For this purpose the ion and electron beams are modulated with different frequencies. Ion beam is modulated with a frequency of RF system 100…300 kHz. Electron current is modulated by means of feeding on the gun grid of voltage with a frequency 3 MHz. The diameter of the electron beam is about 10…20 mm. So the resolution of beam position measurement for adjustment of the cooler has to be of order of 1 mm.

2. POSITION MEASUREMENT

The BPM system consists of two beam position monitors (BPM), pickup stations, ADC, a synchronous detector and a reference generator (see Fig.2).

The electrostatic beam position monitors with linear transfer ratio are used at the cooler. Each BPM consists of two parts. Each part has two electrodes and measures either the vertical or the horizontal coordinate.

Pickup station (PS) is located near the BPM. It is intended for the preliminary processing of the BPM signals. PS produces sum and difference signals coming from the pick-up electrodes. The sum of all signals U_Σ is proportional to the beam current. The difference signals U_Z and U_X are proportional to the beam deviation in vertical (Z) and horizontal (X) direction correspondingly. Bandwidth of the PS is 80 kHz…5 MHz. The gain factor is regulated in the range of 40 db.

Other electronics is located in the CAMAC crate. The Reference generator produces reference signals for the synchronous detector and ADC, as well it produces signal for the modulation the electron beam. The reference signal generator receives the RF frequency from the accelerator complex (RF i+) and produces two orthogonal signals. Results of the signal analog-to-digit conversion come to the computer, where the calculation of beam position is produced. The multiplexer in the synchronous detector input chooses one of the signals (U_Σ, U_Z, U_X) processed. As the reference for the synchronous detector the signal shifted either by 0° or by 90° comes from the Reference generator. Total time of the position measurement for both ion and electron beams for two BPM is about 500 us.

PROBLEMS OF ATOMIC SCIENCE AND TECHNOLOGY. 2006. № 2.
Series: Nuclear Physics Investigations (46), p.108-109.

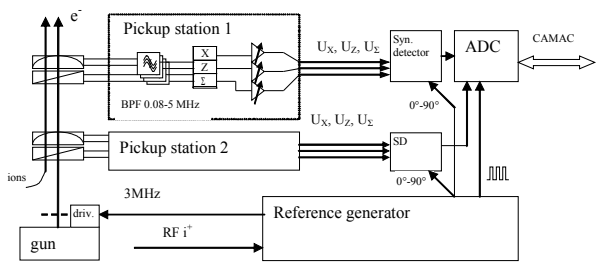

Fig. 2. System of beam position measurement

The beam coordinates are calculated with a formula:

$$X = A_X \cdot \frac{\overline{U}_X \cdot \overline{U}_\Sigma}{\overline{U}_\Sigma \cdot \overline{U}_\Sigma},$$

where: X – coordinate; A_X – geometric factor; $\overline{U}_X$ – complex voltage proportional to the deviation of the beam (it is formed with two orthogonal component); $\overline{U}_\Sigma$ – complex voltage proportional to the beam current.

3. ELECTRON BEAM MODULATION

The focusing grid at the gun is used for modulation of electron beam [1]. The voltage with frequency 3 MHz from the 3W amplifier is supplied to the grid. The light guide is used for the electrostatic isolation, since the gun and amplifier are under the potential of 35 kV for the cooler EC-35 and 300 kV for EC-300, respectively.

4. CONCLUSION

The testing of the coolers EC-35 and EC-300 has been performed at BINP and IMP. Since these tests were performed without the installation in the ring no tests with ions were carried out. During these tests all cooler systems including the beam position measurement system were checked. The parameters of the electron beam were measured. The parameters of beam position measurement system were measured also. Resolution of beam position measurement was 0.4 mm with the current modulation of 1 mA. The DC current of the electron beam was changed within the range of 0…3 A. When DC current is changed the alternating component of the beam current is changed proportionally to DC current if the modulation voltage on the grid is constant. The possibility of the regulating of the modulation voltage on the grid allows keeping of the desired value of the AC component of electron beam. Resolution of beam position measurement in the DC current range 0.5…3 A not worse than 1 mm, resolution becomes worse at a smaller beam current.

The author expresses thanks to V. Parkhomchuk, V. Reva and V. Berezkin for help in this work and useful advices.

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СИСТЕМА ИЗМЕРЕНИЯ ПОЛОЖЕНИЯ ПУЧКА ДЛЯ УСТАНОВКИ ЭЛЕКТРОННОГО ОХЛАЖДЕНИЯ ЭПОХА-300 И ЭПОХА-35

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Описана система измерения положения пучков электронов и ионов в установках электронного охлаждения ЕХ-300 и ЕХ-35. Для определения положения пучков применяются электростатические пикапы. Важной особенностью системы измерения положения пучков является её способность одновременно измерять положения как ионов, так и электронов. Разрешение измерения положения пучков около 1 мм при диаметре вакуумной камеры 300 мм.

СИСТЕМА ВИМІРУ ПОЛОЖЕННЯ ПУЧКА ДЛЯ УСТАНОВКИ ЕЛЕКТРОННОГО ОХОЛОДЖЕННЯ ЕПОХА-300 І ЕПОХА-35

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Описано систему виміру положення пучків електронів і іонів в установках електронного охолодження ЕХ-300 і ЕХ-35. Для визначення положення пучків застосовуються електростатичні пікапи. Важливою особливістю системи виміру положення пучків є її здатність одночасно вимірювати положення як іонів, так і електронів. Розділення виміру положення пучків близько 1 мм при діаметрі вакуумної камери 300 мм.