Development of Beam Diagnostic System for HIRFL

Zheng Jianhua and Beam Diagnostic Group
Institute of Modern Physics, Chinese Academy of Sciences
P.O.Box 31, Lanzhou 730000,China

Abstract

Beam diagnostic is an essential part of any accelerator. The beam diagnostic system for HIRFL had been developed and used for years, and the system is being improved continuously to satisfy the requirements of the operation and beam tuning of HIRFL. This paper describes the present status and development of the beam diagnostic system at HIRFL.

1 Introduction

The beam diagnostic system for HIRFL is a distributed microcomputer system, which can be divided into three layers. In the top layer, the microcomputer control station manages the diagnostic system of HIRFL and offers man-machine interfaces and operation functions used by operators. In the middle layer, the CAMAC system with serial highway and function modules receive commands from the computer and return status and measurements information. In the bottom layer, a variety of beam diagnostic devices along the beam lines and inside SFC and SSC are installed, such as profile monitors, Faraday cups, slit devices, radial probes, the capacitive phase probes and so on for the measurement of beam intensity, beam profile, energy and energy dispersion, beam phase, beam emittance and other parameters of beams.

2 Improvement of the beam diagnostic system

2.1 Beam profile measurements

About 40 sets of secondary emission multi-wire profile monitors are installed on beam transportation lines of HIRFL to measure the horizontal and vertical profile of beam. The measurement can be done with several monitors simultaneously at different position along the beam line, the beam loss is only 3%. They can display the beam profile on the oscilloscopes of the main console and process the profiles with computer. The measurement sensitivity is about 10nA.

In the beginning of operation, the main problems were that the wires sometimes were broken off, and the accuracy of the profile measurement was low. Then the mechanical driver parts of probes and the electronic unit used to measure the beam profile were improved, the measurements of profile are reliable and the position accuracy of the profile measurement is about ±1mm.

2.2 Beam intensity measurements

Beam intensity is a main parameter for accelerators. About 30 sets of Faraday Cups have been installed in the beam lines to measure the beam intensity, beam energy and analyze the charge states and also use as the beam stop. 19 sets of movable and static probes inside SFC and 29 sets of one are set to measure the internal beam intensity.

Any beam current from each probe can be measured by a current-to-voltage converter which should have good insulation and shielding property, low offset voltage, and wide frequency responsibility. The careful calibration for every converters is also important to assure the measurement accuracy. But fabrication technology and the calibration error of converters made in factory may cause errors in measurement of system. New improvement of the beam intensity measurements has been considered, as shown in Fig.1, which will decrease the error of measurements system.

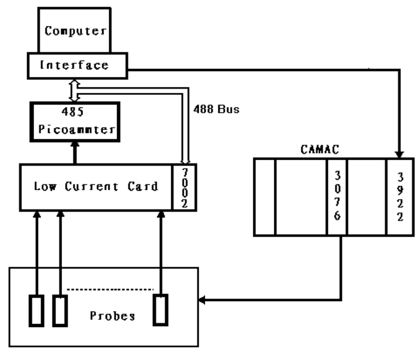

Fig.1 The system of beam intensity measurements

2.3 Beam slit and energy measurement

There are two kinds of slits, about 19 sets installed on beam lines of HIRFL. One is a changeable width slit, which is used to limit the beam emittance. The another is a fastened width slit, which is used to measure the ion energy and the energy dispersion. The main functions of them are: the adjustment for slit width and position, accurate measurement for slit width and position, beam intensity measurement on the slit plates, remote control of the driver power and the safe protection of slit limit position. The precision of position adjustment is about ±0.5mm. The energy measurement device with the slit control device has been developed. It is convenient to measure and analyze the beam energy during the beam tuning.

2.4 Beam phase measurement

The phase detection system of HIRFL is based on the heterodyne principle using RF_signal mixing and filtering techniques to monitor continuously phase inside SFC, SSC and on the beam line. The new HIRFL phase measurement system is shown in Fig.2.

Some problems were found in operation in the old system. In order to improve its performance, a selftest system

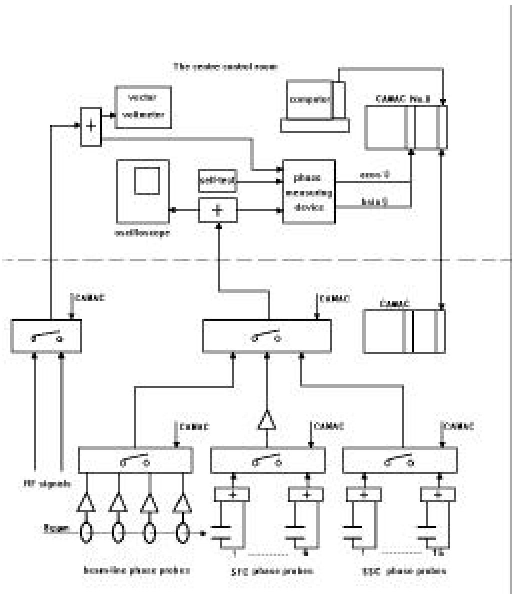

Fig.2 Diagram of phase measurement system for HIRFL

Shown in Fig.3 has been designed and developed. By means of the selftest system, the accuracy of the old system

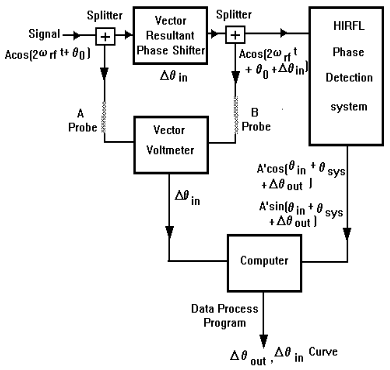

Fig.3 Principle of the selftest system for HIRFL phase measurement system

was detected and the system is improved from ±6° to ±1.5°. A new method to match the cable electrical length has been developed according to our present condition. It can not only match the cable made of the same medium but also match the cable in difference medium. Using the method, the phase difference between the cables connected with the probes had been decreased to 0.3°. Double shield signal preselectors have been developed to improve the crosstalk of signal channels to -70dB. The new control software shown in Fig.4 has been developed to improve the system reliability, The error probability of measurement is 10^{-3}.

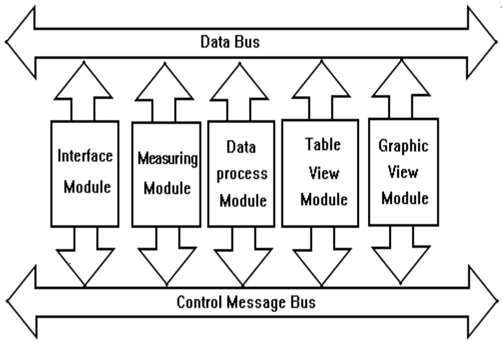

Fig.4 Constructure of control software for phase measurement

The data of beam phase measurement in the accelerator operation shown in Fig.5. has been analyzed. All results show that the repeatability, and reliability are satisfactory and the accuracy of measurement is about ±0.5°.

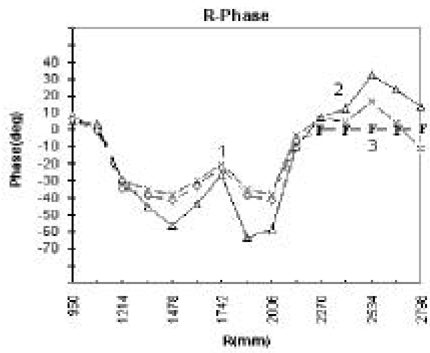

Fig.5 SSC $^{12}C^{6+}$ Phase measurement curve

2.5 Emittance Measurements

In order to monitor the transverse beam emittance in beam tuning, the three-profile-method have been used to measure the beam emittance. Three profiles of a beam in a field-free drift space of beam line can be obtained to calculate the three parameters of the emittance ellipse. The measurement results are processed by a least square fitting and Gaussian distribution fitting. The measurement result is shown in Fig.6.

The observation of beam profiles on fluoresent screens has been changed from a qualitative approach to a quantitative method due to the availability of high quantity video imaging systems and the progress in suitable software. The pepper-pot method based on the measurement techniques will be used in the ECR beam line and pre-beam line of HIRFL to measure beam emittance. This method shown in Fig.7 uses an array of identical holes in a plate oriented in beam transverse X-Y plane, after drift distance L the fluorescent screen is placed.

The transmitted beam strikes the fluorescent screen and produces an image that is proportional to 4-dimensional emittance $\varepsilon(x,x',y,y')$ of the beam.

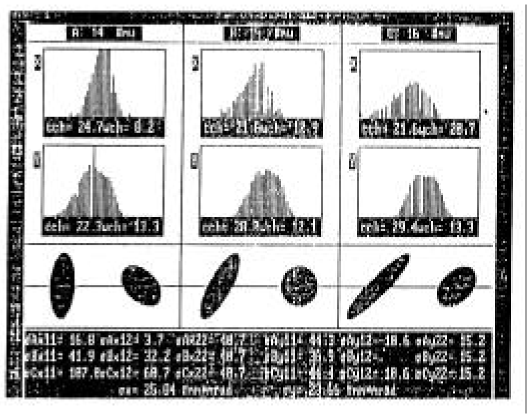

Fig. 6 The result of transverse beam emittance measurements in Pre-beam line

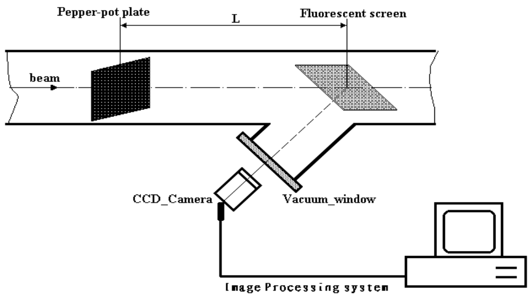

Fig. 7 Schematic of measurement facility for emittamce

When the pepper_pot plate is moved from the beam line, the images produced on the scintillating plate viewed by a CCD- Camera can display the beam shape and position and operators can see the effects of parameter adjustments directly.

3 Beam diagnostic control system

The beam diagnostic system for HIRFL is a branch of HIRFL control system and is also an independent control subsystem. According to the location of the probes distributed at HIRFL, the system is divided into three microcomputer control stations: SFC diagnostic control station, beam line diagnostic control station and SSC diagnostic control station. The system has been improved and the microcomputers have been updated. The computers for diagnostic system are being linked with the network of HIRFL control. The software based on the windows programming technique, is being developed, instead of former FORTRAN program. The accelerator parameters will be calculated and their graphics will be displayed on the computer screen that will make the beam tuning easier and more directly visible.

4 Conclusion

All the beam diagnostics use in HIRFL use interceptive probes except the phase detection system. In order to optimize the efficiency of beam tuning, some non-interceptive beam diagnostic devices will be developed which is also necessary for the development of HIRFL in future.

It is a pleasure to acknowledge Dr. Liu Wei, who participated in the design of the emittance measurements, and I would like to thank Dr. F. loyer for valuable information and help.

References

[1] Z.Q.Shen et al, The Beam intensity and Emittance measurements,IMP Annual Report 1989.

[2] J.G.Wang et al,Beam Emittance Measurement by the Pepper-pot Method, Nuel.Instr. and Meth.,A307,1991.