The Electron Beam Probe for HIAF

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Introduction

HIAF(High Intensity heavy ion Accelerator Facility), the next generation facility to the existing Heavy Ion Research Facility in Lanzhou (HIRFL) , will be built in Huizhou, China, which consists of a Super-conducting Electron-Cyclotron-Resonance ion source (SECR), a heavy ion Linac (iLinac), a synchrotron Booster Ring (BRing), HIAF FRagment Separator (HFRS), a Spectrometer Ring (SRing) and several experiment terminals. The layout of the HIAF complex is illustrated in Fig. 1.

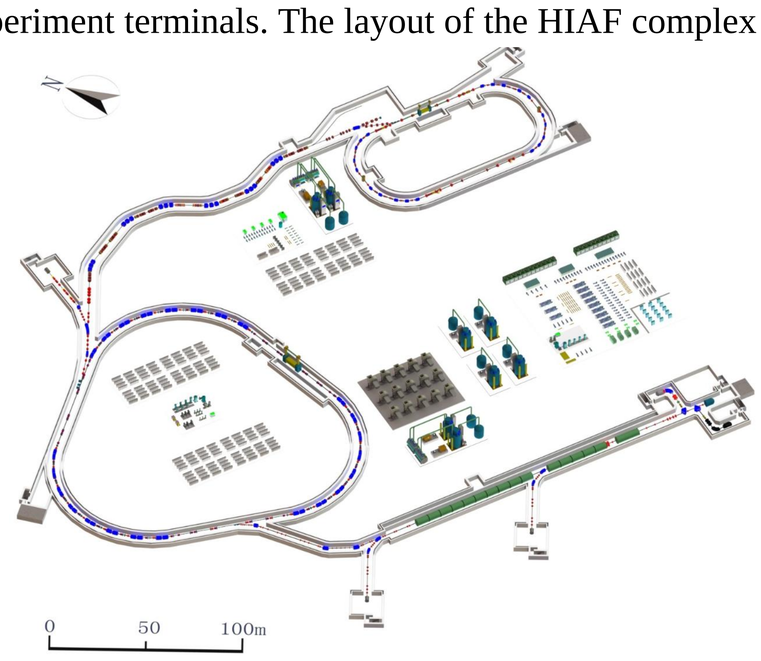
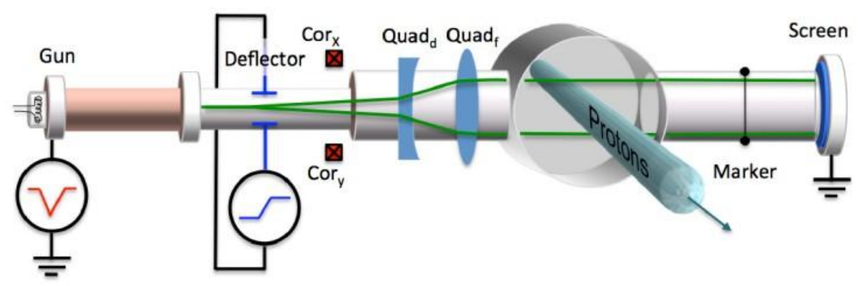


Fig. 1. HIAF layout (phase 1)

Since the high power up to 400 kW, invasive detectors are avoided. For beam profile measurement, a electron beam probe is employed and now under heavy commissioning. An electron beam probe is a non-interceptive diagnostics detector to measure beam transverse profile and bunch length with single-shot capacity, which makes use of the deflection of a low-intensity and low-energy electron beam by target beam collective field when it is injected across the target beam.



Theory

The principle behind EBPs is that a low energy, low current electron beam is injected across the target beam perpendicularly and then deflected by the target beam collective field (mainly electric field). A screen and CCD located downstream capture the deflected electron beam trace, and then, by some mathematical treatment, i.e. derivative, the beam profile can be reconstructed accurately.

$$\frac{d\theta_y}{dy} = \frac{e}{\varepsilon_0 m v^2}\int \sigma(x,y)\,dx$$

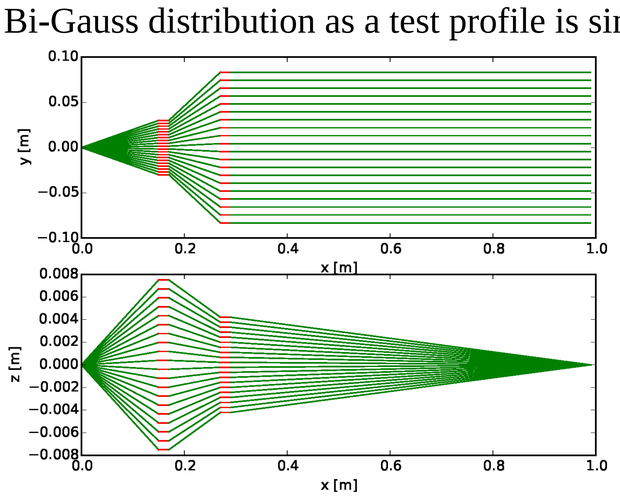
A trick to achieve good accuracy of reconstruction is to scan electron beam with a tilted angle, i.e. 45 deg, which separates the deflected and undeflected traces significantly. Hence, the analysis will focus on the traces instead of intensity which gives poor quality result.

Producing parallel electron beam

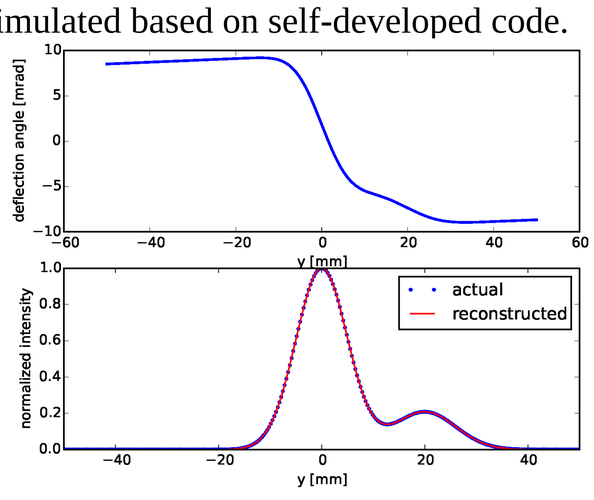
To reconstruct profile as accurate as possible, the electron beam have to scan target beam perpendicularly like a CT. A fast deflector and two quadrupole are implemented to launch a parallel electron beam. A simplified optical model is introduced to describe beam transport, which makes use of the beam forming condition, i.e. point to parallel transformation in the scanning direction and point to point transformation in the other direction, to obtain the optimized optical parameters.

Profile reconstruction simulation

Bi-Gauss distribution as a test profile is simulated based on self-developed code.



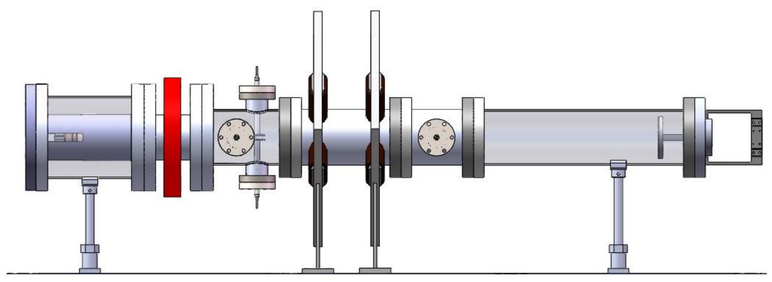
Simulation results for parallel electron beam scan. x-y plane represents the scanning.



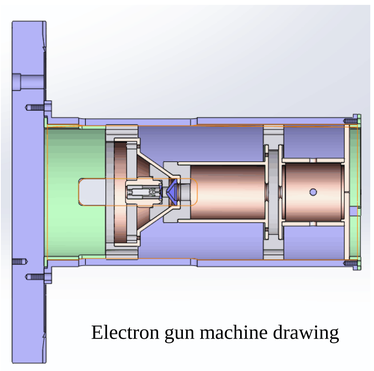
Simulation results for bi-Gauss distribution in y direction.

Prototype construction & preliminary test

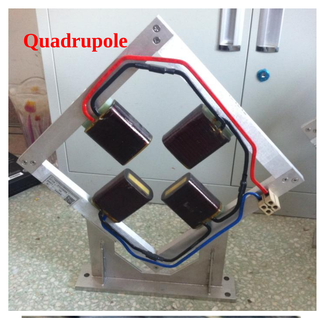
To fulfill the requirement of electron beam with low current and long work distance, a thermionic emission based electron gun has been constructed and a beam spot with one sigma size of 1.2mm is achieved behind the gun exit 1.3m under the energy of 5KeV. Considering the low energy of electron beam, magnetic shielding is essential. Permalloy is employed to reduce the geomagnetic field(~0.6 Gauss) to a ultra low level(~0.05 Gauss) significantly. A fast deflector with rapid rise of 25 ns and repetition rate of 1MHz is designed and a preliminary test is launched under a low repetition rate of 10 KHz. A solenoid and two quadrupoles have been completed based on the simulated optical parameters. A YAG:Ce screen and a high resolution CCD camera are now integrated into this system for electron trace acquirement.

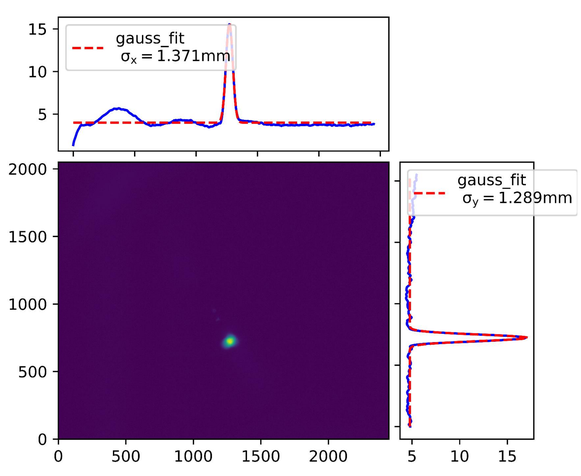


Layout of electron beam probe

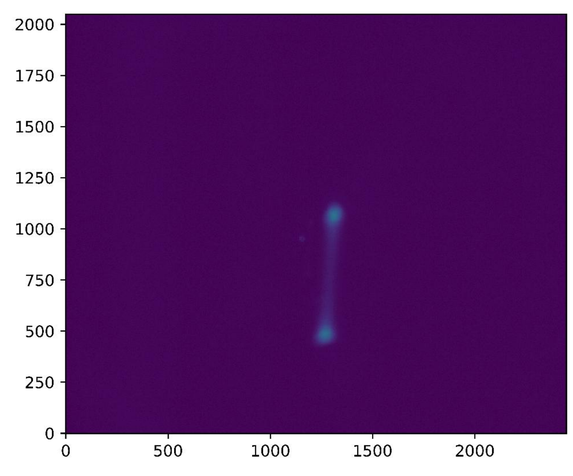


Electron gun machine drawing





Electron beam spot on the YAG screen behind gun exit 1.3 m (python pseudo-color image)



Scanned electron trace at deflector voltage 50V @ 10KHz repetition rate

References

1、W. Blokland, A Non-Destructive Profile Monitor for High Intensity Beams, PAC2011, p.1438
2、Yong-Chun Feng, Beam distribution reconstruction simulation for electron beam probe. Chinese Physics C Vol. 41, No. 7 (2017) 077001.

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