Measurement of the emittance of an ECR ion source using a Glaser magnet

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Introduction

The emittance of the ion beam from an ECR ion source is an important ion-optical parameter. The design of the beam line, especially the e/m-resolution of the beam is largely dependent on the beam emittance. Various methods are employed for estimating the emittance. Movable slit and wire scanner method is the basic technique employed in earlier measurements [1,2].

Pepper-pot method, in which the beam passing through a number of holes is recorded, is a fast method of emittance measurement [3]. An indirect method is to use a quadrupole magnet in front of a beam profile monitor [4]. The beam size measured by the profile monitor depends on the beam emittance, the initial beam ellipse and the transfer matrix of the quadrupole and the intervening beam line. Quadrupole current is varied to vary the transfer matrix and consequently, the beam size. By measuring the variation of the beam size at a number of quadrupole currents, the transverse emiitance of the beam can be determined. Allison type emittance measurement setups are also used.

In this work, we have employed the method of varying the transfer matrix in the beam line for measuring the beam emiitance, but instead of using the usual quadrupole magnet, we have employed a Glaser magnet which is there in the upstream in front of a target. A Glaser magnet focuses or defocuses the beam in both the planes simultaneously. So the measurement in both the planes can be performed at one go. This is the advantage of employing a Glaser magnet in the emittance measurement. The disadvantage, of course, is that a large spherical aberration exists in Glaser magnets.

We have measured the beam emittance of the analyzed beam from a 6.4GHz Electron Cyclotron Resonance (ECR) ion source developed at Variable Energy Cyclotron Centre [5]. It was developed for injecting heavy ion beams into the cyclotron, and is nowadays used for experiments in material science.

Emittance measurement setup

The scheme of measurement is as follows. The beam from the ECR source is analyzed with a 90^0 dipole magnet and focused to a point. There are a quadrupole triplet and a Glaser magnet for transporting and refocusing the beam on to a target in the experimental chamber.

The target holder can hold twelve targets simultaneously and can be rotated from outside to change the target position. A home-made fluorescence beam viewer is placed below each target where the beam can be viewed and optimized during experiments. The fluorescent material is KBr which is first dissolved in acetone. A drop of the solution is put on a thin substrate and it is spinned at a high speed. The drop spreads evenly on the substrate and dries up. This works as the beam viewer. The thickness of KBr film is about 0.05mm. A similar beam viewer but larger in size (~3cm dia) was used for the emittance measurement. The beam glow is viewed with a CCD camera and a TV monitor. The beam size is measured directly with a scale, and measurement error of the size is estimated to be about 0.5 mm.

Estimation of beam remittance

In the preliminary analysis we have assumed the Glaser magnet to be composed of three solenoid magnets of different strengths. This is possible because the actions of a Glaser magnet and a solenoid are basically the same. The transfer matrix of a solenoid of length L is

$$S(K,L)=\begin{bmatrix} C^2 & \frac{SC}{K} & SC & \frac{1}{K}S^2 \\ -KSC & C^2 & -KS^2 & SC \\ -SC & -\frac{1}{k}S^2 & C^2 & \frac{1}{K}SC \\ KS^2 & -SC & -KSC & C^2 \end{bmatrix}$$

where $K=B/p$, $S=\sin(KL)$, $C=\cos(KL)$, B is the field and p is the particle momentum. We write the composite matrix of the Glaser magnet as

$$G(K,L)=S(.5K,.25L)S(K,.5L)S(.5K,.25L)$$

The overall matrix from the object slit to the target is obtained by multiplying the above matrix with the drift matrices upstream and downstream. The beam matrix $\sigma(K,\varepsilon_x,\varepsilon_y)$ in terms of the initial beam matrix $\underline{\sigma(\varepsilon_x,\varepsilon_y)}$ and the transfer matrix $R(K)$ is given by

$$\sigma(K,\varepsilon_x,\varepsilon_y)=R(K)\sigma(\varepsilon_x,\varepsilon_y)R(K)^T$$

and the beam sizes $x(K)$ and $y(K)$ are related to the beam matrix as

$$x(K,\varepsilon_x,\varepsilon_y)=\sqrt{\sigma_{1,1}} \qquad y(K,\varepsilon_x,\varepsilon_y)=\sqrt{\sigma_{3,3}}$$

The parameters K, ε_x and ε_y are then optimized manually to minimize the χ^2 values for the fit between the calculated sizes and measured beam sizes in both the x- and y-planes.

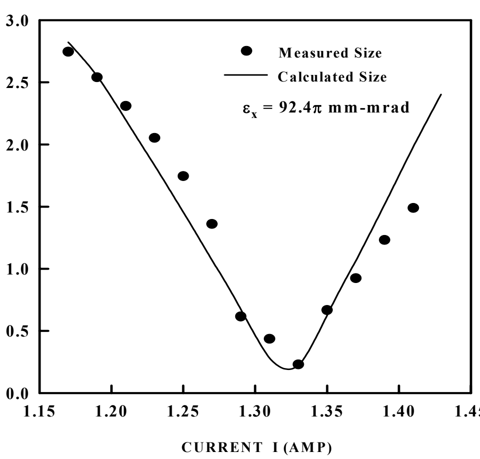

Fig. 1. Beam size in the horizontal plane of the

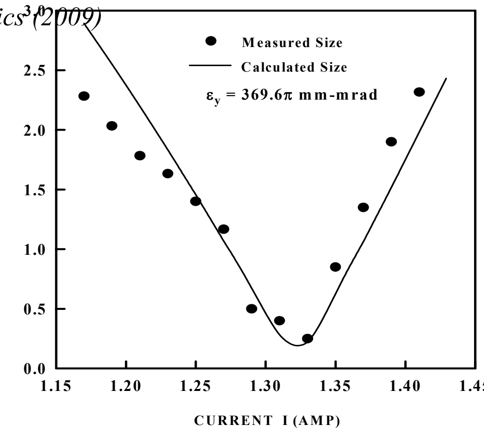

Fig. 2. Beam size in the vertical plane

Results and discussions

Figs.1 and 2 show the experimentally measured sizes. The solid lines are the fitted lines. The emittances which minimize the χ^2 value are 92.4π mm-mrad in the x-plane (i.e., the horizontal plane) and 369.6π mm-mrad in the vertical y-plane. The emittance in the vertical plane is four times that in the horizontal plane. This may be because the analyzing slit trims the beam in the dispersive plane.

Generally one uses this technique of measuring the beam emittance by using a pair of quadrupole singlets. We have demonstrated that a Glaser magnet (often used in low energy beam lines) also can be utilized for this purpose.

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