Influence of Injection Beam Emittance on Beam Transmission Efficiency in a Cyclotron

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Abstract
The JAERI AVF cyclotron accelerates various kinds of high-energy ion beams. Beam intensities of an ion species on the order of $10^{-8}$ to $10^{-6}$ amperes are often required for various experiments performed sequentially over a day. To provide ion beams with sufficient intensity and stability, an operator has to retune an ion source in a short time. However, the beam intensity downstream of the cyclotron rarely increases in proportion to that at the ion source. To understand the cause of this beam behavior, transmission efficiencies of a $^{12}$C$^5^+$ beam from an ECR ion source through the cyclotron were measured for various conditions of the ion source. Moreover, a feasible region for acceleration in the emittance of the injection beam was clarified using a transverse-acceptance measuring system. We confirmed that the beam emittance and profile were changed depending on the condition of the ion source and that matching between emittance and acceptance of the cyclotron was degraded. However, after fine-tuning to improve the matching, beam intensity downstream of the cyclotron increased.

INTRODUCTION

Characteristic use of our cyclotron
1. Mainly for biotechnology and materials science
2. A wide range of ion species and energies
3. Short time irradiation for many users

Frequent beam change of the cyclotron (3 hours), irradiation port (1 hour), and careful retuning of the ion source for each user.

The beam intensity outside the cyclotron rarely increases in proportion to that at the ion source. Transmission efficiency of the ion beam degrades depending on the condition of the ion source.

EXPERIMENT

Ion beam: 220 MeV $^{12}$C$^5^+$

What is the cause? Change of the beam emittance or something else?

Conceptual diagram of the relation between injection beam emittance and acceptance of the accelerator. Ions in the overlap region are accelerated.

(a) Ideal matching and (b) realistic matching in which the ion beam is off-axis and meandering (bad matching).

We measured the beam transmission efficiency, beam emittance and clarified the region for acceleration for 3 conditions of the ion source.

RESULT

We confirmed that better matching of the emittance and acceptance resulted in higher transmission efficiency of the ion beam.

Beam emittance of $^{12}$C$^m$ for the conditions shown in the above table and the region for acceleration represented by beam transmission from I-2 to Def. The region enclosed by the red solid lines was obtained by adding three regions for acceleration; this region represents a part (NOT the whole) of the acceptance of the cyclotron.

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