

5-17 Observation of the Beam Injected into the Acceleration Region of the Cyclotron — Development of an Emittance and Acceptance Measurement System —

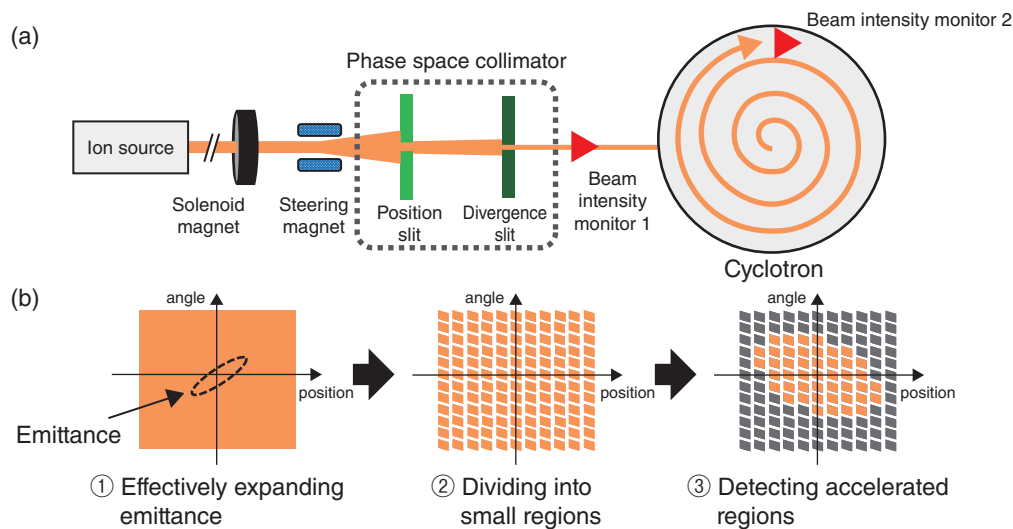


Fig.5-44 (a) Emittance and acceptance measurement system and (b) acceptance measurement procedure

The system is composed of electromagnets that effectively expand beam emittance, a phase space collimator that limits the position and angle range of the beam, and two beam intensity monitors.

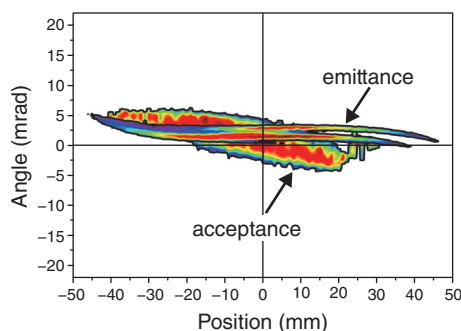


Fig.5-45 Results of emittance and acceptance measurements

(modified from Kashiwagi, H. et al., Rev. Sci. Instrum., vol.85, no.2, 2014, p.02A735-1-02A735-5.)

The relationship between the acceleration region and injected beam region is visualized by displaying the measured emittance and acceptance in one graph.

The TIARA cyclotron facility produces various types of ion beams for different researches (such as bioscience and material sciences) by changing the ion species in each experiment. Beam injection tuning that maximizes the ratio of the accelerated beam current to the beam current injected into the cyclotron is required to ensure sufficient current for each experiment. The tuning corresponds to the overlapping of emittance (a region occupied by the injected beam) and acceptance (an acceleration region) in phase space. Because any emittance regions outside the acceptance are not accelerated, the emittance must be matched to the acceptance. Although various methods are available for measuring the emittance, no method has been developed for measuring the acceptance of a cyclotron. To fill this gap, we devised a method for measuring the acceptance, and developed a transverse emittance and acceptance measurement system for visualizing the emittance–acceptance relationship.

Figs.5-44(a) and (b) are schematics of the measurement system and procedure, respectively. The acceptance is determined by the following three steps: (1) The beam

emittance from the ion source is effectively expanded by solenoid magnets and a steering magnet to ensure sufficient measurement range (Fig.5-44(b)①). (2) The expanded emittance is divided into many small regions by two slits called phase space collimator (Fig.5-44(b)②), and the beamlets with the regions are sequentially injected into the cyclotron. (3) The acceptance is obtained by aggregating the accelerated beamlets detected by beam intensity monitor 2 (Fig.5-44(b)③). The emittance is obtained by measuring the beam intensity of each region divided by the phase space collimator using beam intensity monitor 1.

Fig.5-45 shows the measured emittance and acceptance on a single plot. We succeeded to visualize the relationship between the injected beam emittance and the acceptance of the cyclotron using the system.

On the basis of the results of the emittance and acceptance measurements, we will develop a beam injection tuning system that overlaps the emittance and acceptance to maximize the ratio of the accelerated beam.

Reference

Kashiwagi, H. et al., A Transverse Emittance and Acceptance Measurement System in a Low-Energy Beam Transport Line, Review of Scientific Instruments, vol.85, no.2, 2014, p.02A735-1-02A735-5.