Advanced Research Center for Beam Science
- Particle Beam Science -

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Visitors

Dr SMIRNOV, Alexander, V Joint Institute for Nuclear Research, Russia, 26 January–15 February 2009
Prof CHEVELKO, Viatcheslav. P P.N. Lebedev Physical Institute, Russia, 9 March–21 December 2009
Dr CHOU, Weiren Fermilab, USA, 9 July 2009

Scope of Research

The Following Subjects are being studied: Beam dynamics related to space charge force in accelerators: Beam handling during the injection and extraction processes of the accelerator ring: Ultra-low Emittance states of proton and Mg^{+} ion beams created by the electron cooling and laser cooling, respectively: Compression of the energy spread of laser-produced ion beams by an rf electric field for phase rotation: Research and development of permanent quadrupole magnets for final focusing of International Linear Collider (ILC) and for focusing of neutron beam: Development of electron-cyclotron resonance (ECR) ion source for small neutron source.

Research Activities (Year 2009)

Publications

Wakita A *et al.*: Characteristics of a Laser-produced Proton Beam Improved by a Synchronous RF Field, *Nucl. Instrum. Meth.*, **A599**, 15-19 (2009).

Suda T, Noda A *et al.*: First Demonstration of Electron-Scattering Using a Novel Target Developped for Short-Lived Nulaei, *Phys. Rev. Lett.*, **102**, 102501 (2009).

Noda A, Yogo A: Laser Ion Acceleration and Its Medical Application, *J. Vac. Soc. Jpn.*, **52**, 448-454 (2009).

Choi I.W., Iwashita Y, Noda A *et al.*: Ion Spectrometer Composed of Time-of-flight and Thomson Parabola Spectrometers for Simultaneous Characterization of Laser-driven Ions, *Rev. Sci. Instrum.*, **80**, 053302 (2009).

Ikegami M *et al.*: Radial Focusing and Energy Compresion of a Laser-produced Proton Beam by a Synchronous RF Field, *Phys. Rev. ST Accel. Beams*, **12**, 063501 (2009).

Nishiuchi M, Souda H, Noda A *et al.*: Focusing and Spectral Enhancement of a Repetition-rated Laser-driven Divergent Multi-MeV Proton Beam Using Permanent Quadrupole Magnets, *Appl. Phys. Lett.*, **94**, 061107 (2009).

Presentations

Noda A *et al.*, Recent Approach to Crystalline Beam with Laser-Cooling at Ion Storage Ring, S-LSR, The 23rd Particle Accelerator Conference, 7 May 2009, Vancouver, Canada.

Iwashita Y *et al.*, Practical Applications of Permanent Magnet Multipoles, 21st International Conference on Magnet Technology, 20 October 2009, Hefei, China.

Souda H *et al.*, Experimental Approach for 2-dimensional Laser Cooling by Resonant Coupling at S-LSR, 64th Annual Meeting of Japanese Physical Society, 28 March 2009, Tokyo, Japan.

Grants

Noda A, Creation of Innovation Centers for Advanced Interdisciplinary Research Areas: Photo-Medical Valley, Special Coordination Funds for Promoting Science and Technology, 1 June 2007–31 March 2010.

Iwashita Y, Application and Development of Super Strong Permanent Magnet Especially for Linear Collider

Transverse Laser Cooling of a Mg^+ Ion Beam Using Synchro-Betatron Resonance at S-LSR

Laser cooling of $^{24}Mg^+$ ion beams with the kinetic energy of 40 keV has been continued utilizing a transition between $3s^2S_{1/2}$-$3p^2P_{3/2}$ at an ion storage and cooler ring, S-LSR. Up to now, longitudinal laser cooling of a coasting beam has been realized [1] and heat transfer from the horizontal degree of freedom to the longitudinal direction (direction of beam propagation) has been observed experimentally. Recent research activity on S-LSR has been concentrated to experimental verification of efficient reduction of transverse temperature by laser cooling with the use of “Synchro-Betatron Resonance”.

Figure 1 shows the detection system of the transverse size of the $^{24}Mg^+$ ion beam with the use of a Cooled EB-CCD Camera (Hamamatsu Photonics C7190-11W), which detects the spontaneous emission from $^{24}Mg^+$ ion excited by a frequency-doubled dye-laser with a wavelength around 280 nm. The horizontal beam size has been observed changing the position of CCD in order to observe the coupling between the horizontal and longitudinal degrees of freedom in more straight forward way. The observed horizontal beam sizes depending on the CCD signal intensity are plotted in Figure 2. As the change of CCD signal intensity is mainly due to the ion beam intensity decrease due to beam life, it is found that reduction of the horizontal beam size is observed for synchrotron tunes between 0.068 and 0.077, estimated to be inside of the stopband of Synchro-Betatron coupling resonance although its center is a little bit shifted to a higher tune side, which is a scope for further investigation.

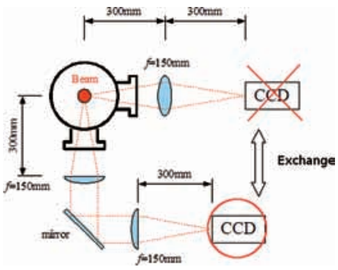

Figure 1. Observing system of the horizontal size of $^{24}Mg^+$ ion beam detecting spontaneous emissions from the ion excited by a laser with the use of a Cooled EB-CCD Camera.

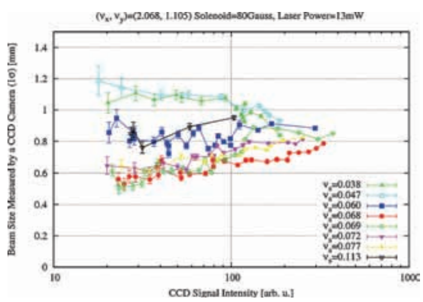

Figure 2. Dependence of the horizontal beam size on the CCD signal intensity, which is considered to reduce according to passage of time due to the life time of the ion beam. Horizontal beam size reduction is observed selectively for synchrotron tunes between 0.068 and 0.077.

Qualification of Laser-produced Ion Beam both in Radial and Longitudinal Directions

For the purpose of real application of a laser-produced ion beam, qualification of its characteristics, diverging both in radial and longitudinal directions as it is created from a laser-induced plasma, is a key issue. For such a purpose, we have applied radial focusing by quadrupole magnetic fields created with permanent magnets set just downstream of the production target parallel to energy focusing by an RF electric field with use of a phase rotation cavity. In Figure 3 (a), the experimental set up of the radial focusing system with the use of doublets of permanent quadrupole magets, is shown [2]. This system can be operated with the 1Hz repletion rate using Ti:sapphire drive laser, J-KAREN, at the Kansai Photon Science Institute of the Japan Atomic Energy Agency and can focus a proton beam to a spot less than ~3×8 mm^2 at the focus spot 650 mm downstream from the production target. Using chromatic aberration of the quadrupole magnets, creation of quasi-monochromatic beam with the energy of 2.4±0.1 MeV is expected from a simulation, which is supported by experimental observation with use of TOF measurement. This scheme might be one possibility to create a quasi-monoenergetic peak with attaining radial focusing, although the present method is limited in ion beam intensity and adjustability of the peak energy different from the phase rotation scheme [3]. Careful comparison between the present method and phase rotation is to be applied in quantitative manner including the capability of extension to higher ion beam energy.

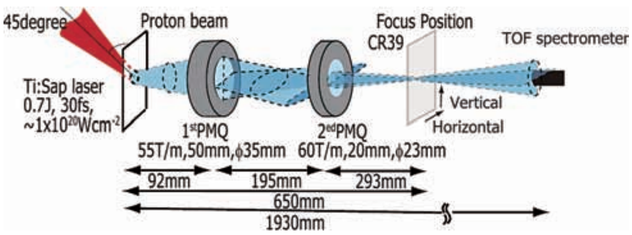

Figure 3. Experimental set up of radially focusing scheme for laser-produced protons with the use of a doublet of quadrupole magnets set just downstream of the production target.

[1] Tanabe M *et al*.: *Appl. Phys. Express*, **1**, 028001 (2008).
[2] Nishiuchi M *et.al*.: *Appl. Phys. Lett*., **94**, 061107 (2009).
[3] Nakamura S *et al*.: *Jpn. J Appl. Phys*., **46**, L717-L720 (2007).

and Neutron Optics, Grant-in-Aid for Scientific Research, (A) (1), 1 April 2006–31 March 2010.

Souda H, Three-dimensional Crystalline Beam by Laser Cooling and Beam Orbit Control, Grant-in-Aid for Scientific Research for JSPS Fellow, 1 April 2007–31 March 2009.

Award

Iwashita Y, Nishikawa Prize, “Development of an Optical Inspection System for Superconducting RF Cavities and Surface Observation”, Foundation for High Energy Accelerator Science, 23 March 2009.