Advanced Research Center for Beam Science
- Particle Beam Science -

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Visitors

Dr GRIESER, Manfred	Max-Planck-Institut für Kernphysik, Germany, 11–24 February 2007
Prof MESHKOV, Igor N	Joint Institute for Nuclear Research, Russia, 12–22 February 2007
Dr SMIRNOV, Alexander V	Joint Institute for Nuclear Research, Russia, 12 February–10 March 2007
Prof SYRESIN, Evgeny	Joint Institute for Nuclear Research, Russia, 11–29 March 2007
Dr WÜSTEFELD, Godehard	Berliner Elektronenspeicherring-Gesellschaft für Synchrotronstrahlung m.b.H. (BESSY), Germany, 2 October 2007
Prof SHEVELKO, Viatcheslav P	P. N. Lebedev Physical Institute, Russia, 19 October 2007

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: Electron cooling of a hot proton beam; Ultra-low emittance state of a proton beam created by the electron cooling; Laser cooling of Mg^+ ion beam; Compression of the energy spread of laser-produced ion beams by an rf cavity for phase rotation; Research and development of permanent quadrupole magnets for final focusing of International Linear Collider (ILC); Mitigation of power loss due to skin effect.

Research Activities (Year 2007)

Publications

Shirai T *et al.*, *Phys. Rev. Lett,* **98**, 204801 (2007).
Nakamura S *et al.*, *Jpn. J. Appl. Phys*, **46**, L717 (2007).
Iwashita Y *et al.*, *Int. J. Mod. Phys. B*, **21**, 600 (2007).

Presentations

Present Status and Recent Activity on Laser Cooling at S-LSR, Noda A, Invited Talk at The Workshop on Beam Cooling and Related Topics, COOL'07, 14 September 2007, Bad Kreuznach, Germany.

Experimental Approach to Ultra-Cold Ion Beam at S-LSR, Noda A, Particle Accelerator Conference 07 (PAC07), 27 June 2007, New Mexico, USA.

Rapid Cycling Variable Permanent Magnet Sextupole Lens for Pulsed Cold Neutrons, Iwashita Y, Invited Talk at ICANS-XVIII, 25–29 April 2007, Dongguan, Guangdong, China, P.R.

Electron Cooling Experiments at S-LSR, Shirai T, Invited Talk at the Workshop on Beam Cooling and Related Topics, COOL'07, 13 September 2007, Bad Kreuznach, Germany.

Grants

Noda A, Special Coordination Funds for Promoting Science and Technology, Creation of Innovation Centers for Advanced Interdisciplinary Research Areas: Photo-

Laser Cooling of a Mg^+ Ion Beam at S-LSR

Ion beams circulating in a storage ring usually have a high temperature. It has theoretically been predicted that ion beams are transferred to a crystalline state with a regular arrangement if a strong enough cooling force is applied. In 2006, we have succeeded to create a one-dimensional ordered state of 7 MeV protons by an electron cooling in the ion storage ring S-LSR at Institute for Chemical Research. For the purpose of realization of a crystalline beam, a stronger cooling force than the electron cooling such as a laser cooling, is required.

We have carried out a laser cooling experiment for a 40 keV $^{24}Mg^+$ ion beam. A transition; $3s^2S_{1/2}$-$3p^2P_{3/2}$, corresponding to a laser frequency at laboratory frame of 280 nm is utilized for the cooling. In addition to a co-propagating laser with the beam, an induction accelerator has been introduced to create a stable point of the cooling forces. A ring dye laser system pumped by a frequency stabilized Nd:YVO_4 laser, followed by a frequency doubling unit is used to produce the laser light of 280 nm (Figure 1).

Figure 2 shows the momentum spread before and after laser cooling. It was found that the momentum spread has been reduced from 1.7×10^{-3} to 2.9×10^{-4} by laser cooling when it is applied for the Mg ions with the intensity of 10^8. Up to now, temperature cooling down in the longitudinal direction is achieved. We will extend the laser cooling to a three-dimensional one by a resonant coupling method, to obtain an ultra-low temperature beam.

Radial Focusing/defocusing of a Laser Produced Protons by an rf Electric Field

Laser-plasma ion acceleration has possibility to downsize usual electromagnetic accelerators. However, such laser-produced ion beams had not been suitable for actual use, because they had almost 100 % energy spread. In order to compress the momentum spread of the laser-produced beam, we have proposed to combine laser-plasma acceleration and phase-rotation by a synchronous rf electric field. If the phase of the rf electric field is adjusted so that the faster ions are decelerated and the slower ions are accelerated, the ions can be collected into a certain energy region. We have succeeded to compress the energy spread less than 7% with this method [1]. In our experiment, it was also found that the radial component of the rf electric field gives focus or defocus effects on the motion of the protons in the transverse direction as shown in Figure 3. From the analysis, it was found that the ions included in the energy peak were defocused in a radial direction, and the focused ions in radial direction had an almost continuous energy spectrum.

[1] S. Nakamura *et al.*: Jpn. J. Appl. Phys. **46** (2007) L717.

Figure 1. A ring dye laser system (upper picture) and a frequency doubling unit (lower picture).

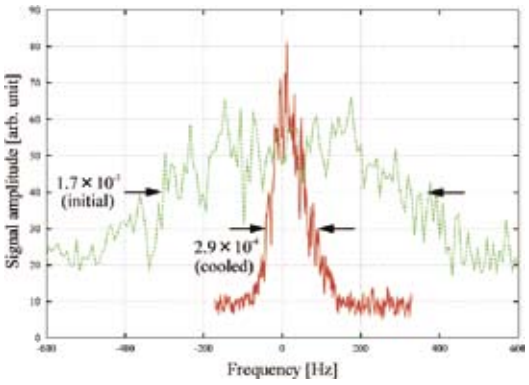

Figure 2. Momentum spread before and after the laser cooling.

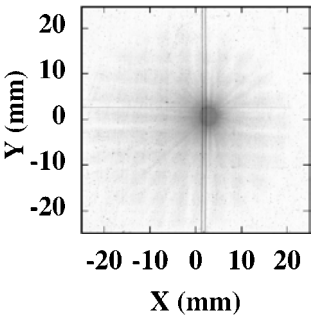

Figure 3. Radial distribution of the laser-produced proton beam after phase-rotation.

Medical Valley, 1 June 2007–31 March 2010.

Iwashita Y, Application and Development of Super Strong Permanent Magnet Especially for Linear Collider and Neutron Optics, Grant-in-Aid for Scientific Research, (A) (1), 1 April 2006–31 March 2009.

Shirai T, Realization of Ultra Low Emittance Ion Beam Using Phase Transition by Electron Cooling, Grant-in-Aid for Scientific Research (C), 1 April 2007–31 March 2009.

Iwashita Y, Development of Satellite Compact Pulse Neutron Source, Joint Development Research at High Energy Accelerator Research Organization (KEK), 1 April 2007–31 March 2008.