

The Global COE Program

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Bilateral International Exchange Program (BIEP, invite) report

Send report to: Your responsible Professor in Kyoto University

gcoe-biep@scphys.kyoto-u.ac.jp , gcoe-office@scphys.kyoto-u.ac.jp

(Year/Month/Day) 2011-12-19

Invited Student

Name	He Zhengqi
University and Country	Tsinghua University, China
Grade	Grade 2
Phone and FAX	0086-10-62795280
e-mail address	hezq06@mails.tsinghua.edu.cn
URL	http://www.ep.tsinghua.edu.cn/
Name and Position of Ph.D. advisor	Tang Chuanxiang, Professor
e-mail address of Ph.D. advisor	tang.xuh@tsinghua.edu.cn

Responsible Researcher in Kyoto University

Name	Akira Noda
Group and Faculty	Laboratory of Particle Beam Science
Position	Professor
e-mail address	noda@kyticr.kuicr.kyoto-u.ac.jp
Phone and FAX	0081-774-38-3281

Research Project

Title	Laser Cooling Simulation at S-LSR
Duration	2011-9-28 ~ 2011-12-23

Please summarize your activities and results during your stay in Kyoto University.

Also please describe how your stay has been beneficial to the graduate students in the host institute. You can add a sheet, if you need more space.

You can also write any comments and requests to the GCOE program.

My work mainly based on S-LSR, which is a compact ion cooler ring built in ICR, Kyoto University. It is a storage ring constructed to study beam cooling and ultra-cold beam physics. The final target is to achieve a crystalline beam, where ultra low temperature around m-Kelvin is needed. Up to now, this temperature is expected only by laser cooling theoretically for a finite velocity beam.

In order to achieve this goal, we should push forward and eventually approach the low temperature limit available at S-LSR. So, a systematic study of laser cooling at S-LSR should be made. A laser set co-propagating with the 40keV Mg⁺ beam and slightly tuned below the transmission frequency of the Mg⁺ beam is scanned. With the synchrotron motion of bunched beam, particles would automatically circles around in the longitudinal phase space and falls into the cooling region of the laser, thus making bunched beam cooling possible. The aim of the experiment is to make the lowest beam temperature we've ever achieved in the storage ring of S-LSR.

In order to get well prepared for the experiment, simulations based on the real situation of S-LSR should be done beforehand. My work mainly concerns about simulations designed for the experiment with single scanning laser beam cooling, which is going to be carried on at S-LSR. The parameters are all chosen according to the data of past experiment.

The work can be mainly divided into two parts, the numerical simulation work and experimental

work. For the numerical, first part is about bunched beam single laser cooling with scanning laser frequency. Different coupling conditions, 1-D, 2-D and 3-D cooling, are used and simulated. All kinds of variables, for example, laser detuning, laser scanning speed, laser properties, would be varied and the cooling effect is evaluated and compared. When analyzing the simulation result, it is found out that using a not so strong laser would result in a hot corona and cold beam core in longitudinal phase space. So a variable, capture rate, is defined to describe the capture efficiency of laser. When we progress to 2D cooling and 3D cooling, it is found out that particles get captured in longitudinal phase space would also be cooled down in horizontal phase space in 2-D cooling and both horizontal and vertical phase space in 3-D cooling. As a result, we developed the idea of more effective beam cooling using scrapers to cut out hot beam corona in multi-dimensional beam cooling. Simulation work of laser cooling with scrapers has also be studied. Then comes to the laser cooling strategy study part. In this part, different kinds of laser cooling strategies have been tried to find out the most effective laser cooling strategy. It has been found out that one continuous laser scanning method would be effective to obtain better cooling effect than other kind of laser scanning method. Different laser properties are also tried and we found out that larger saturation parameter and laser radius would always result in better cooling effect, and for the fixed laser power case, a larger laser radius (no larger than the beam radius), would be preferred. Different initial emittance in longitudinal direction has been tried and it shows that a lower initial emittance would always result in better result of laser cooling, indicating that it is always a good idea to decrease beam emittance before laser cooling. Laser cooling of coasting beam is also simulated and the comparison between past experiments have been made and discussed.

These simulations would not only give us a glimpse of the nature of laser cooling, but also help us a lot to choose parameters when we actually run the experiment. I hope this work would become a meaningful guidance in our effort towards the goal of our near future beam cooling experiment.

The second part is about experimental work in S-LSR. During my stay here, several bunched beam laser cooling experiment has be done and I've participate nearly all of them. During the experiment period, close cooperation between experiment and simulation has been made and we exchanged many information and ideas. Together, we conducted the experiment of bunched beam laser cooling of fixed detuning and also scanning detuning. Both cold part and hot part of the beam are observed in experiment, which has been clarified in simulation. Cooled beam has been observed by CCD camera and beam profiled has been checked and studied. Bunched beam Schottky signal has also been observed and the observed effect of laser cooling on the bunched beam Schottky signal has also aroused our interest. Besides that, I also had chance to do some experiment on accelerator beam physics, which will bring me further understand to S-LSR lattice parameter. Comparison between experimental result and simulation result is still under processing and I think the result would be helpful to our future experiment.

During my stay here in Kyoto university, I had lots of communication with the graduate student here in Laboratory of Particle Beam Science. We exchanged our ideas and opinions and discussed lots of problems, pushing our experiment forward together. During this process, we practiced both our English and critical thinking, which will of course benefit us all. During the resting period, we also discussed about interesting Japanese culture and Chinese culture, and we think we'll have a better knowledge of each other through communication, thus arriving in precious friendship.

I should first of all thank GCOE program, who offered me such a valuable chance to visit S-LSR for 3 months. And I fully support GCOE program offered more chances to scholars all over the world to visit and research in Kyoto University, sharing the splendid work going on here, while indicating that Kyoto University is not only a first-class university in Japan, but also a first-class university in the world.