Progress of laser cooling of relativistic Li-like C^{3+} ion beams at the CSRe*

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Laser cooling is one of the most promising techniques to reach high phase-space densities for relativistic heavy ion beams. Realizing a crystalline ion beam is one of the ultimate goals of laser cooling of heavy ion beams at storage rings [1]. Preparations for laser cooling of relativistic lithium-like C^{3+} are being made at the experimental cooler storage ring (CSRe) in Lanzhou, China [2].

In September 2014 a test experiment was performed with $^{12}C^{3+}$ ion beams at an energy of 122 MeV/u on the CSRe with a pulsed laser system. A schematic view of the experimental setup is shown in figure 1. In the experiment $^{12}C^{3+}$ ions were produced by an Electron Cyclotron Resonance ion source (ECR). In the ECR, a significant fraction of $^{16}O^{4+}$ was produced alongside. Then the ions were accelerated by a Sector Focused Cyclotron (SFC), and injected into the main Cooler Storage Ring (CSRm). After accumulation and acceleration in the CSRm, the ion beams were extracted and injected into the CSRe at the energy of 122 MeV/u (at a velocity of 47% of the speed of light). Since the circumference of the CSRe is 128.8 m, this beam energy lead to the revolution frequency of 1.087 MHz. A pulsed UV laser system from HZDR was employed for this test laser cooling experiment. The closed $2s_{1/2}$—$2p_{1/2}$ optical transition at a wavelength of $\lambda_0 = 155.07$ nm of the Li-like carbon ions was Doppler-shifted to be resonant with the UV-laser at the wavelength $\lambda_{laser} = 257.3$ nm in the experiment ($\lambda_{laser} = \gamma(1+\beta)\lambda_0$).

A Schottky spectrum of an electron-cooled coasting ion beam is shown in figure 2, in which the Schottky signals of $^{12}C^{3+}$ and $^{16}O^{4+}$ ions were separated by electron-cooling. Stable operation of the CSRe was observed over several days, including rf-bunching and diagnostic systems. The injected number of C^{3+} (~5×10^8) was sufficient for testing laser cooling. The dynamics of the electron-cooled and RF-bunched ion beams were investigated systematically. However, first results did not yet indicate a strongly interaction of the laser with the ions. The fluorescence from the ions, measured using UV-CPM and UV-PMT detectors, is thereby of great interest since it reflects the interaction between laser and ion beam. Since two ion species were stored simultaneously, there is also the possibility that the laser-cooled $^{12}C^{3+}$ ions sympathetically cool the $^{16}O^{4+}$ ions. Further data analysis is currently in progress.

Laser cooling experiment at the storage ring of the CSRe and ESR are directly relevant for laser cooling and precision laser spectroscopy of highly charged and relativistic heavy ions at the future large facilities such as HIAF in China and FAIR in Germany. At these facilities, laser interaction with highly charged ions (HCIs) will open a new field of atomic physics and nuclear physics [3].

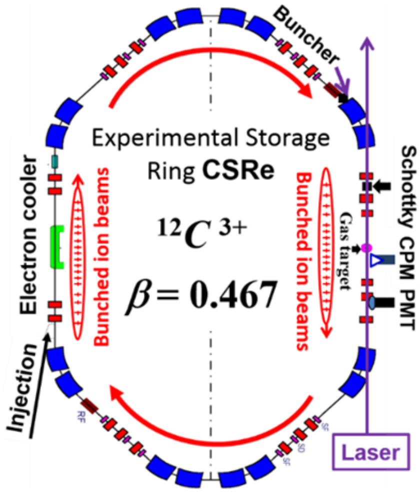

Figure 1: Schematic view of the experimental setup for laser cooling experiments at the CSRe. The locations of the resonant Schottky pick-up, RF-buncher, UV-PMT and the UV-CPM are shown.

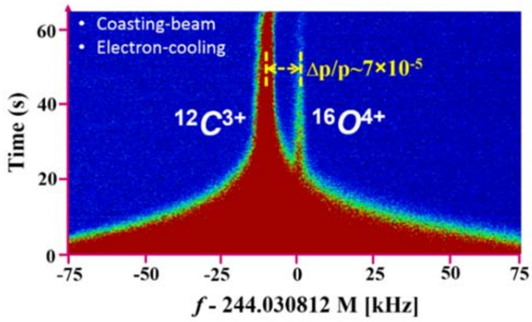

Figure 2: Schottky spectrum of the electron-cooled injected $^{12}C^{3+}$ and $^{16}O^{4+}$ at the CSRe.

References

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