LASER COOLING OF RELATIVISTIC HIGHLY CHARGED IONS AT FAIR*

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The Facility for Antiproton and Ion Research (FAIR) is currently being built in Darmstadt, Germany, and will deliver high-quality beams with high energies and high intensities for a broad range of new physics experiments [1]. The heavy-ion synchrotron SIS100 is a key element of FAIR and will accelerate intense beams of highly charged ions up to relativistic velocities [2]. However, for such extreme ion beams ($\gamma \approx 12$), established beam cooling techniques, such as electron and/or stochastic cooling, become rather expensive and difficult to implement. Laser cooling of bunched ion beams was then considered to be a valid, interesting, and affordable alternative for the SIS100 [3, 4]. Therefore, a special project group was formed to specifiy, design, order, construct, set up, and test the *SIS100 laser cooling facility* for FAIR, see Fig. 1. The project group consists of scientists from GSI and the collaborating partner universities and research centers in Dresden-Rossendorf, Darmstadt, Jena, Münster, and Lanzhou (China).

Laser cooling is based on the principle of fast photon absorption (energy and momentum) by ions and the successive fast emission of fluorescence. Since the emission occurs randomly, the recoil momenta average out to zero, leaving a net reduction of the ion momentum in the direction of the laser, thus slowing down the ions. To achieve cooling at a fixed velocity, and not deceleration, a counter-balancing force is required, which is provided by a moderate bunching of the stored ion beam. The ions will then produce synchrotron oscillations inside the rf-bucket, and the laser is tuned to cool this motion and thus strongly reduce the momentum spread (and bunch length) of the ion beam. The GSI Helmholtzzentrum in Darmstadt will provide the infrastructure required for the facility: laser lab (clean room), detector cave, (vacuum) laser beam lines, vacuum chambers, scrapers, control systems, cables, etc. The laser systems will be developed by the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) / Technical University of Dresden, and by the Technical University of Darmstadt. These laser systems can be operated at 257 nm or 514 nm, and produce about 100 mW of coherent radiation. By combining cw and pulsed laser systems, strong cooling power over a broad spectral range can be obtained. Also, the spectral shape of the combined laser light can be tailored for optimal cooling rate or range. The group in Münster will conduct a study for xuv/x-ray detectors for the SIS100. Due to the high velocities of the stored ions, relativistic effects strongly influence the fluorescence and dedicated *in vacuo* detection, surrounding the ion beam, is required [5].

In 2016, two test beamtimes for laser cooling at heavy-ion storage rings are scheduled: one at the CSRe of the IMP in Lanzhou, China, and one at the ESR in Darmstadt. At the CSRe, the pulsed laser system from HZDR/TU-Dresden will be used. At the ESR, this system will also be used but in combination with the cw-laser system from the TU-Darmstadt. In addition, the new xuv-detector system from Münster University will be employed for the first time.

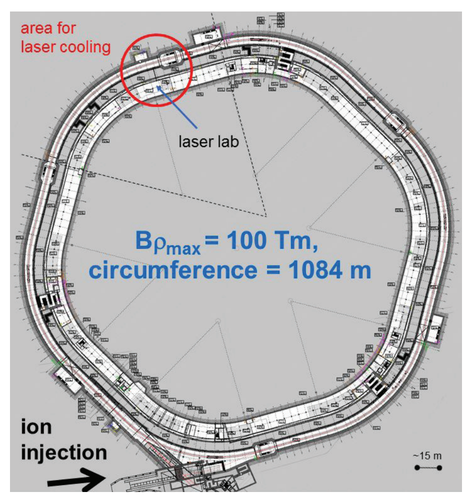

Figure 1: The laser cooling facility at the SIS100.

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