Optical beam diagnostics at ESR and beyond*

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Laser cooling, applied as a stand-alone cooling technique, or in combination with electron cooling, has high potential to generate relativistic ion beams with high phase-space densities. Even the generation of crystalline ion beams might be accessible. A neccessary prerequisite to reach this goal is the implementation of powerful diagnostics for the characterization of the resulting ion beam parameters. Schottky pick-up techniques [1] will lead a long way in this direction, but might be running short for the highest phase-space densities targeted. Optical diagnostics, making use of the collection of scattered optical photons during resonant excitation of relativistic ions, will open a second window for characterizing the ion beam with improved momentum resolution.

Therefore, we have developed two different detector systems for the UV-range (λ ~150 nm): one system uses a photomultiplier tube (PMT) and is mounted in air (on a CaF_2 viewport), the other system is based on a photochanneltron electron multiplier (PEM) and is mounted *in vacuo* (10^{-11} mbar). Figure 1 shows two PEM systems with shielding (cage + mesh), mounted on linear translators with bellows.

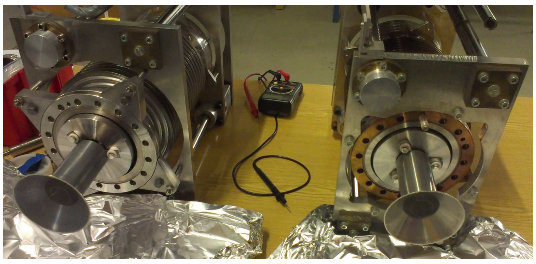

Figure 1: Two moveable PEM detector systems, used for optical diagnostics at the ESR (GSI, Darmstadt). [Now further tested at the CSRe (IMP-CAS, Lanzhou, China).]

During the laser cooling beamtime at the ESR (GSI) in August 2012, these detector systems have been used to detect the fluorescence from laser-cooled carbon ions [2]. At a kinetic energy of 122 MeV/u, or a Lorentz factor $\gamma = 0.47$, the $2s \rightarrow 2p$ cooling transition in $^{12}C^{3+}$ ($\lambda_0 = 155$ nm) is reached by using anti-collinear laser light at a wavelength $\lambda_L = 257$ nm [3]. Figure 2 shows the detected fluorescence signal as a function of time, while the cw-laser system was repetitively scanned over the cooling transition. Therefore, the cw-laser was detuned from the 'red side' (*i.e.* below the transition frequency) to just over the resonance, and back again. During each scan, which took about 30 s, a strong increase in the detected number of fluorescence photons could be recorded at the resonance condition. Strong fluorescence peaks could only be observed when electron cooling was applied in parallel. The overall exponential intensity drop of the signal is due to the limited lifetime of the stored ion beam, caused by charge-changing collisions with the residual gas.

In summer 2013, the detector systems have been shipped to the Institute of Modern Physics (IMP) in Lanzhou, China, for further development and tests at the CSRe. During the experimental run in September 2014, laser cooling of stored, relativistic $^{12}C^{3+}$ ions (@122 MeV/u) was attempted for the first time at the CSRe [4, 5]. Further development of fluorescence diagnostics, especially in the XUV-regime, is required for future laser cooling studies at the HESR ($\gamma \sim 6$) and the SIS100 ($\gamma \sim 12$).

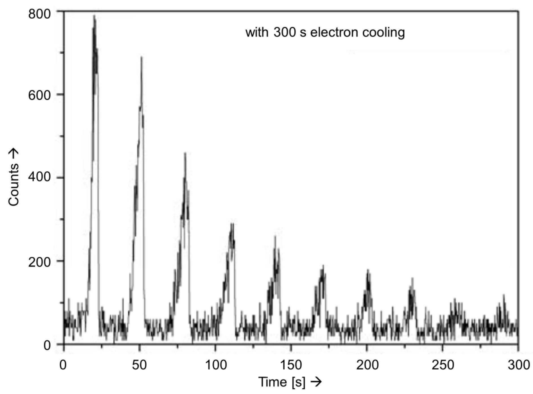

Figure 2: Fluorescence signal ($2p \rightarrow 2s$ transition) from relativistic $^{12}C^{3+}$ ions at the ESR. When the scanning cw-laser is in resonance with the Doppler-shifted cooling transition of the ions, a strong increase in the signal is observed.

References

[1] F. Nolden *et al.*, Nucl. Instr. Meth. Phys. Res. A **659**, 69 (2011).

[2] D. Winters *et al.*, JACOW, COOL 2013 conf. proc., THAM1HA04 166 (2013).

[3] T. Beck *et al.*, GSI Scientific Report (2012).

[4] W.Q. Wen *et al.*, GSI Scientific Report (2014).

[5] M. Löser *et al.*, GSI Scientific Report (2014).

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