ESR Operation and Development

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The ESR storage ring was operated for physics experiments as well as for FAIR-related machine development.

Internal target experiments included tests of the FOCAL detector and the electron spectrometer. The series of laser cooling experiments was continued successfully, and beams were decelerated for HITRAP.

An experiment on dielectronic recombination (DR) aimed at comparing DR spectra in both ground and isomeric states of $^{235}U^{89+}$. An almost pure isomeric state was populated through the β^- decay of $^{235}Pa^{88+}$. The latter was identified among other fragmentation products by Schottky spectroscopy, and a pure $^{235}Pa^{88+}$ beam was produced by appropriate scraping.

A completely new type of experiments was launched in autumn 2012 with the advent of the first nuclear reaction experiments at the internal gas jet target. In particular, a sufficiently intense secondary $^{56}Ni^{28+}$ from the fragment separator was accumulated before being used by the experiment. This experiment is covered in a separate contribution to this report [1].

Another nuclear reaction experiment aimed at the measurement of the $^{20}Ne^{10+}$ (p,d) reaction. This experiment was successfully performed in autumn 2012.

The ESR internal target was run with different types of gases. Hydrogen operation was remarkably reliable, for the first time a helium cluster jet was successfully used for experiments with a density of almost $6 \cdot 10^{12}$ cm^{-2}.

An obstacle impeding beam transport into the inner parts of the ESR aperture without dedicated vertical bumps [2] has been identified by now. All stochastic cooling pickup and kicker stations are equipped with resistively coated ceramic cylinders in order to supress undesired higher microwave modes in the beam chamber. Due to mechanical problems which are not yet understood completely, one such cylinder had fallen down into the beam aperture, leading to severe practical problems in beam handling. This obstacle will be removed before the autumn 2013 beam period.

The machine experiments focused on comparative studies of the different longitudinal stochastic cooling systems. These experiment made use of the newly developed optical notch filter [3]. Here the ESR is an important test bench for components of the FAIR project, as a similar device will be installed at the CR of FAIR.

Three different longitudinal stochastic cooling methods are available at the ESR: Palmer cooling, time of flight (TOF) cooling, and notch filter cooling (see [4]). All of these are also planned to be applied at the CR. The components of the optical notch filter worked reliably. The prescise setting of the notch frequencies by changing the position of an optical mirror was a necessary prerequisite for the low momentum width equilibria achieved. The same is true for the optical attenuator settings. First preliminary tests in April confirmed quantitatively the expectation that the momentum acceptance of notch filter cooling is smaller than for TOF or Palmer cooling [5]. Another series of measurements were performed in October with a 400 MeV $^{58}Ni^{28+}$ beam in order to determine optimum cooling times. The measurements were made with a beam of $6 \cdot 10^6$ particles. The second moment of the momentum distribution $\sigma(t)$ was evaluated and fitted with an exponential decay towards an equilibrium as a model:

$$\sigma(t) = (\sigma_0 - \sigma_\infty) \exp(-t/\tau) + \sigma_\infty$$

A preliminary evaluation of the data confirms the expectation that the equilibrium value for notch filter cooling ($\sigma_\infty = 2.47 \cdot 10^{-5}$) is much lower than for TOF cooling ($\sigma_\infty = 4.33 \cdot 10^{-5}$). Also the cooling time for notch filter cooling ($\tau = 0.18$ s) is much shorter than for TOF cooling ($\tau = 4.33$ s). The latter is mainly due to the much larger amplification (22 dB higher!) which is affordable in the case of notch filter cooling. This is due to the well-known fact that notch filtering reduces largely the random noise in the vicinity of the revolution frequency. It is planned to provide a fast switching from TOF cooling (with its large momentum acceptance in the beginning of the cooling process) to final notch filter cooling in order to profit from both schemes in an optimized fashion..

During the shutdown period in 2013 the high voltage power supply of the electron cooler will be repaired, as the high voltage was less stable than usual from time to time.

It is planned to establish a new model for the supply of data to the quadrupole magnet power supplies during deceleration, because it has turned out that there are deviations between the set values and the measured values of both tunes, particularly during deceleration. A more flexible programming of the rf voltage and frequency ramps during deceleration is under work, as well.

References

[1] F. Nolden et al., this report

[2] C. Dimopoulou et al., GSI scientific report 2011, 470

[3] C. Peschke et al., GSI scientific report 2011, 328

[4] D. Möhl, Stochastic Cooling of Particle Beams, Lecture Notes in Physics 866

[5] F. Nolden et al.; *Nucl. Inst. Meth A* 564 (2006) 87-93