THE STATUS OF THE DIAGNOSTIC SYSTEM AT THE CRYOGENIC STORAGE RING CSR

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Abstract
The cryogenic storage ring (CSR) at MPI für Kernphysik is an electrostatic, cryogenic storage ring for low velocity phase space cooled ion beams. Among other experiments cooling and storage of molecular ions in their rotational ground state is projected. The stored beam current are in the range of 1 nA - 1 µA. The resulting low signal strengths on the beam position pickups, current monitors and Schottky monitor put strong demands on these diagnostics tools. In the paper a summary of the CSR diagnostics tools and diagnosis of the first stored ion beam will be given.

FIRST TURN DIAGNOSTICS

For the first turn diagnostics in the CSR three destructive low intensity beam viewer to detect a low intensity injected ion beam [2] are used. The beam viewer (see Fig. 2) consists of a aluminum plate hit by the beam, producing secondary electrons. Using a grid the electrons are extracted and accelerated before they hit the 40 mm MCP/phosphorous screen combination. The image of the beam is recorded via a CCD camera and analyzed by software. Two rotary feed-troughs are used to move the aluminum plate. The inner feed-through on the experimental vacuum chamber is absolutely vacuum tight and able to operate reliable at temperatures of about 10 K. The outer rotational feed-through on the isolation vacuum chamber is connected via a terminally insulation drive with the inner one. The image of an injected 51 keV $^{40}$Ar$^+$ ion beam measured with the first beam viewer, located in the injection straight section, is shown in figure Fig. 3.

DIAGNOSES OF THE STORED ION BEAM

Directly after the first cycle of the injected $^{40}$Ar$^+$ beam the ion beam could be stored for many hundred turns at the calculated settings based on theoretical models of the storage ring. To detect the stored ion beam the continues current coming from a Penning ion source was pulsed with a chopper located in front of the storage ring. Together with the switched 6° deflector, needed for single turn injection, an injected ion pulse length of approximately half of the revolution time could be realized. With our very sensitive Schottky pick-up, a 35 cm long tube, we were able to detect the stored beam.
Every time the circulating ion pulse is passing the pick-up a voltage signal, discussed in [3], is induced in the pick-up. The measured pick-up signal for the stored $^{40}$Ar$^+$ ion beam is shown in Fig. 4. An absolute measurement of the stored ion number is possible by integration the measured pick-up signal pulses. From the measurement shown in Fig. 4 an injected pulse current of about 100 nA could be derived. In Fig. 5 the measured integral of the pick-up voltage as a function of time is shown. From that measurements a lifetime of 3.0 ms could be derived for the 51 keV $^{40}$Ar$^+$ beam at a vacuum level of about $10^{-7}$ mbar. This lifetime is mainly determined by single electron capturing in the residual gas. The measured pick-up signal as a function of time allowed an accurate determination of the beam revolution frequency by plotting the center of mass position of each individual pulse as a function of the turn number (see Fig. 6). A fit through the data, shown as a red line in Fig. 6, results in a revolution frequency of $f_0=14.112$ kHz. With $f_0$ and the CSR circumference of $C_0=35.25$ m an energy of $E=51.3$ keV for the stored $^{40}$Ar$^+$ ion beam could be determined.

**Ion Beam Bunching**

An alternative and more sensitive method to detect the stored ion beam is to bunch the beam. To bunch the stored ion beam a drift tube with a length of 35 cm can be used. During single turn injection the drift tube voltage $U_d$ is off and after injection a linear increase of $U_d$, starting at $t=0$ ms, in several ms to an value of $U_{d,max} \approx 44$ V was chosen in the experiment. In Fig. 7 the bunched beam signal taken at the 25$^{th}$ harmonic of the revolution frequency, measured with a spectrum analyzer in span zero mode.
352 kHz and for the resolution bandwidth an value of 10 kHz was chosen. The black data shown in Fig. 7 is a measurement to determine the background where no beam was injected into the CSR, whereas the red line is a fit through the data. From the fit a beam lifetime of 3.0 ms can be derived, which corresponds to the measured lifetime shown in Fig. 5. The figure shows that the bunches obtained at t=1.75 ms after injection and measured with the Schottky pick-up are shown in Fig. 8. Because the beam is bunched at 25\textsuperscript{th} harmonic number of the revolution frequency and the time displayed in Fig. 8 corresponds to the revolution time (T\textsubscript{0} = 70.85 \mu s) 25 bunches are visible. The height of the bunches are not identical since the injected ion pulse, with pulse length \(\Delta t \approx T_0\), was fluctuating with time.

**OUTLOOK**

When the whole storage ring will be operated at cryogenic temperatures the residual gas pressure must not exceed \(10^{-13}\) mbar and lifetimes for single charged ions in the 1000 s range are expected. At this condition measurements of the momentum spread of the stored ion beam using Schottky noise analysis will be possible. The large beam lifetime will further allow the determination of the horizontal and vertical tune as well beta functions of the storage ring with BTF measurements. At the anticipated pressure of \(p < 10^{-13}\) mbar at the CSR storage ring a conventional residual beam profile monitor is not usable to measure the profile of the stored ion beam. The beam profile of stored singly charged molecules can be determined by using the dissociative recombination process between the positive singly charged molecules and free electrons of the electron cooler. The neutral fragments from this process are detected with a position sensitive detector. The profile of the stored ion beam can be calculated from the distribution of the center of mass positions of the neutral fragments created in the DR process [5] [6]. The channel plate detector, which is important for the beam profile measurements was already successfully tested in the first CSR experiments.

**REFERENCES**