Sensitivity measurements of the resonant pickup in the ESR

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Qualitative measurements were carried out to determine the sensitivity of the ESR resonant pickup ([1], [2]) using short-lived uranium beams at different energies.

Conventional beam current monitors such as transformers can determine the amount of beam current. But even those devices with high sensitivity suffer from a limited bandwidth which results in reduced performance at higher frequency components of the beam current. To achieve measurements of beams with very few ions, one can make use of the high sensitivity of resonant pickups at a harmonic band of the Schottky signal.

The Schottky process can be shown to be wide sense stationary with the expected (average) value equal to the macroscopic beam current I_B as $\mathsf{E}\,[i(t)] = qf_rN = I_B$, where q is the charge, f_r is the revolution frequency and N is the number of particles [2]. Its autocorrelation corresponds to the expected instantaneous power of the signal, which in turn is related to its power spectral density (PSD) via the inverse Fourier transform. The integral under the curve of the PSD shows the total average power in a given frequency band. In this case the area is the same in every (non-overlapping) Schottky band and is equal to

$$\langle I_s^2 \rangle = 2q^2 f_r^2 N = 2qf_r I_B \tag{1}$$

Absolute power values may be difficult to obtain after several stages of signal processing. Also the noise level depends on the number of points within a given frame of sampled data, making it hard to determine at what level signals can be distinguished from noise. A solution is to use an external DC current transformers (DCCT) as a calibration reference to determine I_B and to scale the area under the curve such that it corresponds to it. The number of ions N can also be determined using Eqn. 1.

In August 2012 beams of ^{238}U were stored in the ESR at relatively low energies. Signals from both the DCCT and the resonant pickup were corrected for offset and prepared as described in detail in [2]. After scaling, the number of ions were calculated accordingly using the Schottky spectra.

The beams of $^{238}U^{88+}$ were injected at 90 MeV/u. The N_2 gas target was used to reduce the number of ions over several orders of magnitude during the measurement time. Beams of $^{238}U^{28+}$ were injected at energies of 30 MeV/u without gas target. The results can be seen in Fig. 1. The resonant pickup is several orders of magnitude more sensitive than the DCCT, but of course its sensitivity depends on the total charge and energy of the beam. The DCCT has an estimated uncertainty of $\pm 1\ \mu$A which propagates into the calculation of the number of ions, but it is not shown in the figure. Using a high precision DCCT with known uncertainties could improve measurement results in the future.

It is seen in Fig. 1 that the decrease of beam intensity is not strictly exponential. At higher beam intensities coherent Schottky signals cause amplitude suppression, while at lower signal intensities, noise background accounts for loss of precision. A detailed study of these effects may be crucial for in-ring decay studies.

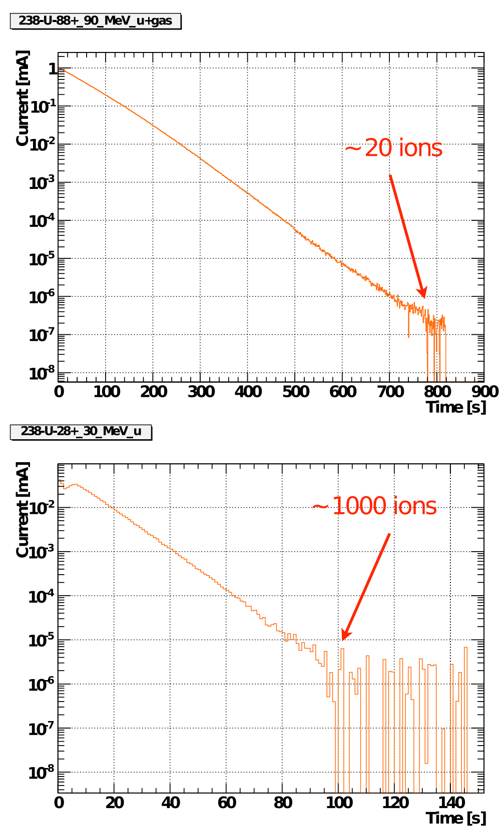

Figure 1: Number of ions after injection for $^{238}U^{88+}$ at 90 and $^{238}U^{28+}$ at 30 MeV/u.

References

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[2] M. S. Sanjari *PhD Thesis*, submitted to the Goethe University, Frankfurt am Main, Germany (2013).