Beam test with the Cryogenic Current Comparator*

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Cryogenic Current Comparator (CCC) units are foreseen to be installed at various locations of the FAIR facility, for the online measurement of ion beam current down to nA range. In this contribution, successful test measurements of ion beam current using the upgraded CCC at GSI are reported. The CCC data show excellent match of the measured spill structure with the SEM measurements.

For the development of the improved version, the existing CCC system at GSI was refurbished as a prototype for FAIR, to test new sensor components [1]. Based on the studies done on different sensor combinations by R. Geithner *et al*. [2], a new dc-SQUID and new control electronics were selected and installed in the refurbished system. After successful test measurements in lab environment, the CCC was installed in the beam diagnostic test bench HTP at the extraction line of the GSI synchrotron. The signals measured by the CCC were amplified and read out at the equipment room located about 70 m from the beam line.

A built-in single-turn wire loop was used to calibrate the CCC output voltage to equivalent current. Response to known dc currents from a precision source (Keithley 261) in the range of 2 nA to 5 μA was measured. From this, a current sensitivity of 71.5 nA/ϕ_0 was calculated, which is equivalent to 74.2 nA/V output to the oscilloscope.

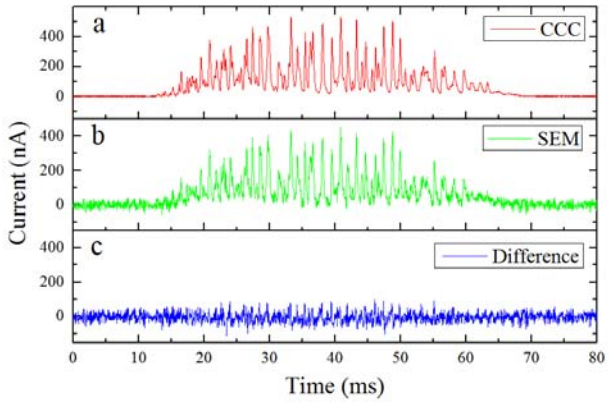

Figure 1: Comparison of the beam current signal measured by (a) CCC, (b) SEM, and the difference between the two signals (c). See text for details.

Slowly extracted Ni^{26+} ion beams at 600MeV/u in the intensity range from 2.8×10^8 particles per spill to 5×10^9 particles per spill were used to test the CCC response to the beam signal. A set of beam signals with the extraction time in the range of 64 ms to 5 seconds at different beam intensities was measured by the CCC. With an anti-aliasing filter (10 kHz cut-off frequency) at the output, the CCC measured the beam current down to 2 nA with a resolution of 1.2 nA rms. To compare the current measured by the CCC with a conventional technique, a Secondary Electron Monitor (SEM) - installed about 1 m downstream the CCC's installation point - was used in parallel. The secondary electron current produced by the SEM was amplified by a trans-impedance amplifier (Femto DHPCA-100).

Figure 1 shows a typical spill structure of an ion beam (about 4×10^9 particles) extracted over 64 ms measured by CCC (a) and SEM (b). The SEM signal was normalized to the CCC signal (normalized to total charge) for comparison. The difference between the spill structures measured by CCC and SEM as plotted in Figure 1 (c) shows excellent agreement. The spikes in the extracted beam, originating from the power converters of the magnets for the resonant extraction, are visible in the CCC measurement as shown in Figure 1. These ripples correspond to 50 Hz and its harmonics in the frequency spectra as expected [3].

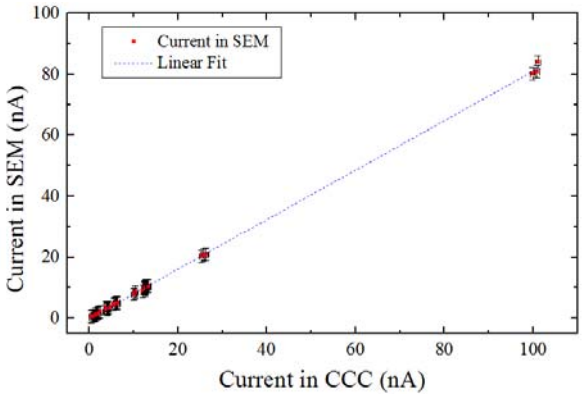

Figure 2: Comparison of the current measurement using CCC and SEM within a bandwidth of 200 Hz.

In Figure 2 the current signals as measured with the CCC are plotted vs. SEM data in the range of 2 nA-105 nA. Whereas the relation is precisely linear (standard error: 0.7%) as expected, the 19% deviation of the measured average current is subject of ongoing examinations.

References

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[3] M. Kirk *et al.* "SIS-18 rf knock-out optimisation studies", IPAC2013, Shanghai, China.

* Work supported by Helmholtz Institute, Jena.
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