Cryogenic Current Comparator for Storage Rings and Accelerators

MOPB013

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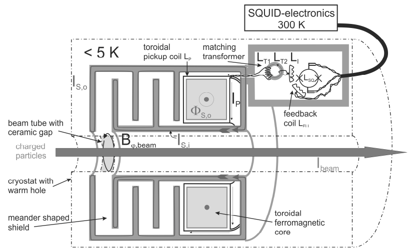
Abstract

A Cryogenic Current Comparator (CCC) was developed for a non-destructive, highly sensitive monitoring of nA beams at the planned FAIR accelerator facility at GSI. Measurements were carried out with a refurbished prototype at GSI. The sensor part of the CCC was optimized for lowest possible noise-limited current resolution in combination with a high system bandwidth of about 200 kHz. It is foreseen to install a improved CCC inside the CRYRING, which will act as a well-suited test bench for further optimization of the CCC performance and the cryostat. In the meantime - until the completion of CRYRING - a CCC has been installed and will be tested in the antiproton storage ring AD at CERN. The pulse shape in the AD requires dedicated optimization of the sensor time response. The beam current will increase rapidly during injection from 0 to 12 µA. Since the slew rate of the overall system is limited by the CCC pickup coil, the input signal has to be low-pass filtered, to not exceed the slew rate of the CCC system and to ensure a stable operation. For this purpose different low-pass configurations had been tested. In this contribution we present results of the CCC sensor for AD, CRYRING and FAIR, respectively.



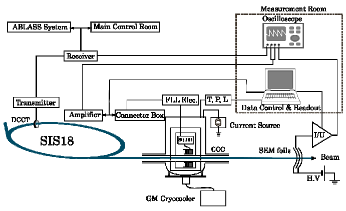
Schematic of the CCC.

Lead-shielded CCC @ GSI

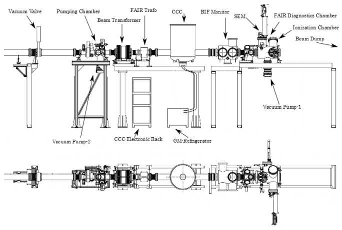
- Re-commissioning of existing CCC: lead shielding, niobium pick-up coil with amorphous Vitrovac 6025 core material
- Commercial state-of-the-art SQUID components: Supracon SQUID, Magnicon XXF-1 SQUID electronics
- Measurement of 600 MeV/u beam of slowly extracted Ni^{26+} from SIS18
- Secondary Emission Monitor (SEM) for comparison of current measurements downstream in the beam line

Improved CCC for FAIR and CERN/AD

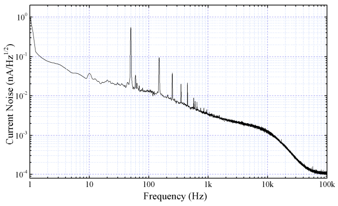
- Improved CCC for FAIR and CRYRING: niobium shielding, niobium pick-up coil with nanocrystalline Nanoperm core material, Commercial state-of-the-art SQUID components: Magnicon SQUID, Magnicon XXF-1 SQUID electronics
- Loan to CERN until completion of CRYRING
- Signal slew rate during AD injection exceeds slew rate of CCC-system
- Low pass filter in input circuit, 1 kHz bandwidth in final configuration
- Beam simulating wire along beam axis and additional wire loop around pick-up coil for calibration



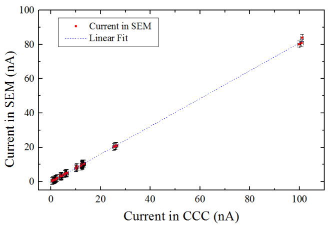
Schematic of measurement setup at GSI.



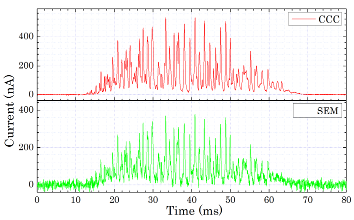
Schematic of beam line at HTP including the CCC and the SEM.



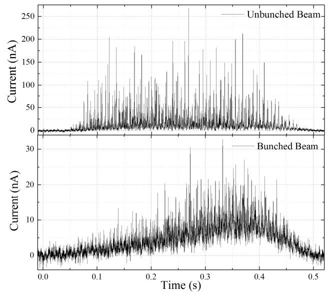
Current spectral density of the CCC installed at HTP.



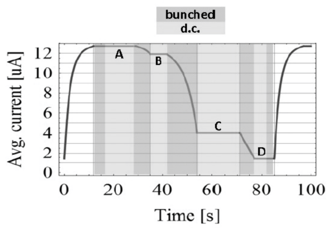
Linear correlation between SEM and CCC signal with a slope of ~ 0.8.



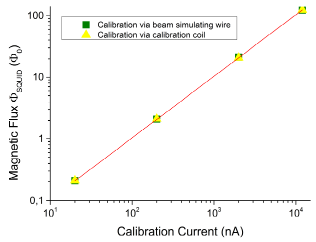
Comparison between SEM and CCC measurement of a 600 MeV/u beam of slowly extracted Ni^{26+} ions, extracted over 64 ms.



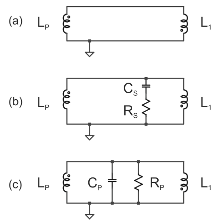
Comparison between the CCC measurements of a 600 MeV/u beam of slowly extracted Ni^{26+} ions in the unbunched case (top) and with bunching in the SIS18 (bottom).



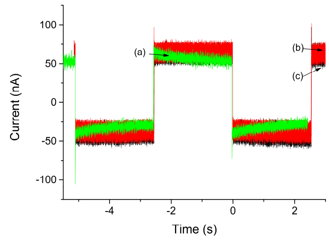
Expected average beam current in AD during injection and deceleration of antiprotons.



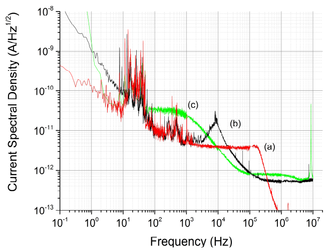
Comparison between current sensitivity of the CCC. Test signal applied to beam simulating wire or to calibration coil.



Connection scheme of the tested filter setup in the input circuit between the pick-up coil L_P = 104 µH and the primary coil L_1 = 104 µH of the matching transformer while the upper scheme is the original one. C_S = 10 µF, R_S = 1 Ω, and C_P = 10 µF, R_P = 0.225 Ω at 4.2K.



Step function response to a test current of 90 nA for the original configuration without filtering (a) as well as with filtering in parallel connection ((b) test current applied to beam simulating wire, (c) to calibration coil).



Current noise of the CCC in the original configuration without filtering in the input circuit (a), with serial connection of R_S and C_S (b), and with parallel connection of R_P and C_P.

Conclusion and Outlook

The CCC has demonstrated its outstanding performance in the beam line at GSI. Spill structures of extracted beams could be measured with very high temporal and current resolution. The CCC could also be used for calibration of different devices like SEM, due to its own linear working function which is independent of particle energies. Using improved core materials the current noise could be reduced while the bandwidth of the overall system could be increased. If the bandwidth is not crucial, the detector could be applied to the demands of the signal. For AD the slew rate of the signal would exceed the slew rate of the CCC. Using low pass filters in the input circuit could solve these problems. The CCC is delivered to CERN and installed in AD in a customized cryostat with a stand-alone helium re-liquefier system and connected to the control system. Details of the AD installation and first results of beam measurements are presented by M. Fernandes during this conference [MOPB043]. In the meantime the installation of the CCC at CRYRING will be prepared using the results from AD regarding cryostat design and control.

References

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