Measurements with the upgraded Cryogenic Current Comparator

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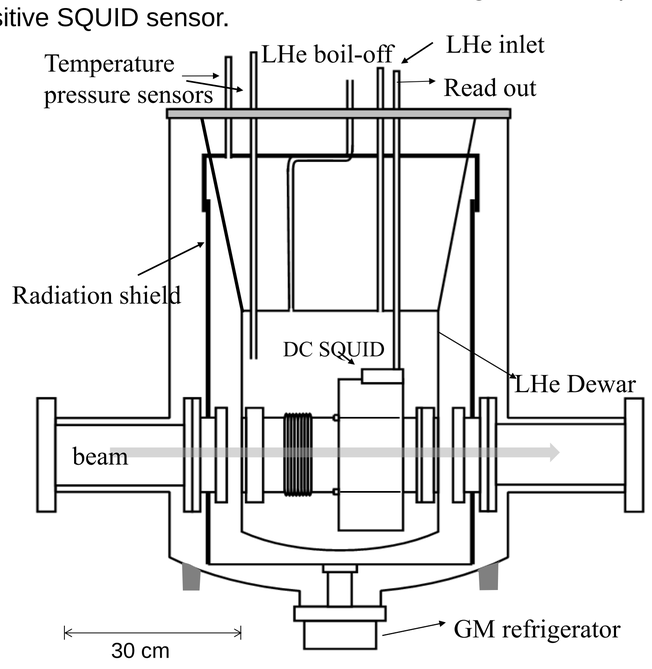
The FAIR project and Cryogenic Current Comparator

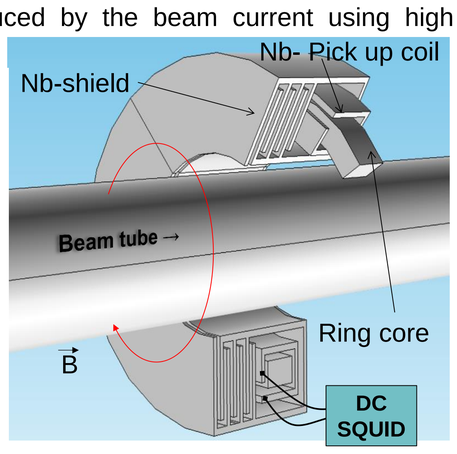
- **Foreseen beam currents down to few nA and required to measure non-destructively.**
- **Conventional non-disturbing techniques do not offer online current measurements with required current resolution**
- **Cryogenic Current Comparator (CCC) will be installed at 7 different locations in FAIR**
- **The CCC system was first developed at GSI and was operated for current measurements at the HEBT section after the GSI synchrotron SIS18.**
- **This system was refurbished as a prototype for the new CCC designs for the FAIR.**
- **The CCC system is re-commissioned and first test measurements with simulated beam current have been carried out.**
- **Optimization of the magnetic shield geometry using FEM simulation package "COMSOL multiphysics".**

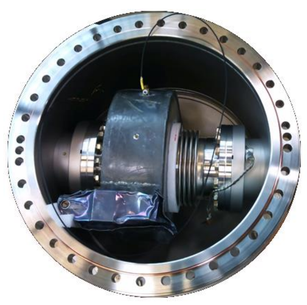
Cryogenic Current Comparator (CCC)

Precise measurement of the azimuthal magnetic field produced by the beam current using high sensitive SQUID sensor.



Schematic of the CCC prototype at GSI





Top view of the sensor part of CCC

Field Attenuation through magnetic shield

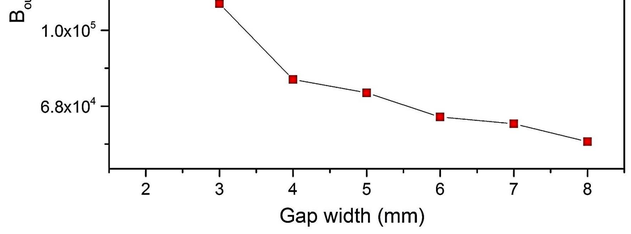
Magnetic noise components such as Earth's magnetic field (50μT), nearby magnets are attenuated by meander* shaped superconducting magnetic shield. Hence enables to measure beam current which produces extremely low magnetic field (below pT for nA beam currents)

* Strongly attenuates all magnetic field components except Azimuthal components within the cylindrical geometry (produced by beam current)

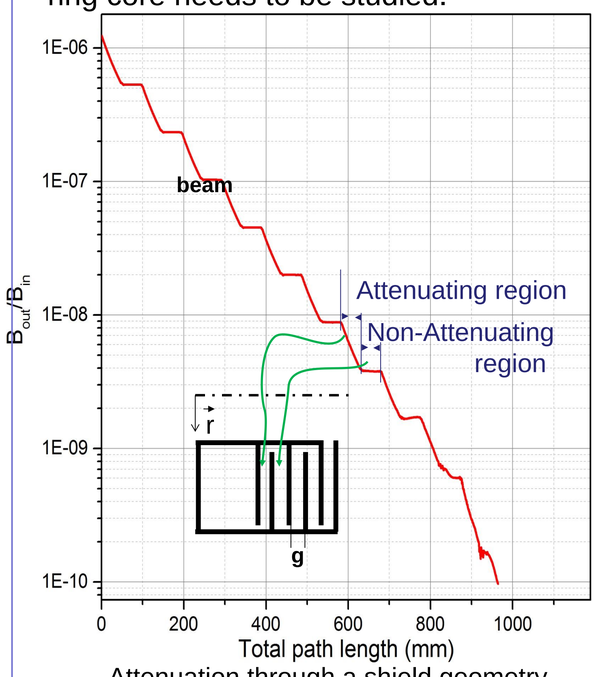
The field attenuation is found to be exponentially decreasing with the gap width.

For the shielding with 10 meanders, simulation gives an attenuation factor of **115dB**.

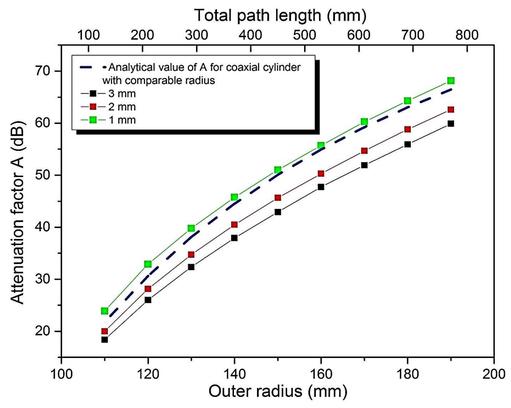
To complete the simulation, coupling of the field with the pick up coil and ring core needs to be studied.



Attenuation as a function of gap width (g)



Attenuation through a shield geometry of 10 meanders having 2 mm gap width



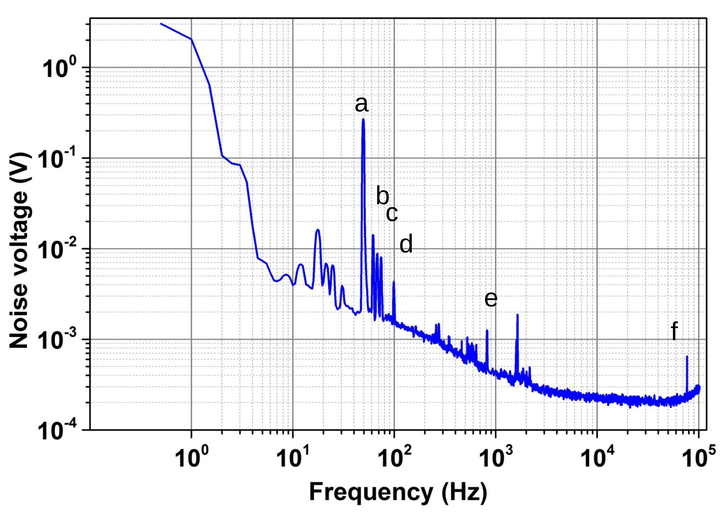
Variation of Field attenuation as a function of total path length through which the field to pass for different gap width (g)

Noise spectrum of the SQUID sensor

SQUID: UJ111 + SQUID-5 Controller (Developed at FSU, Jena)

Current sensitivity of the SQUID sensor : 175 nA/√Hz corresponding to a signal voltage of 10V

Noise limited current resolution : 30-60 pA /√Hz at low frequency range (<100 Hz)



Important Characteristic lines,

a) 49.5 Hz : The strongest noise contribution caused by the electric interference from the roughing pump

b) 62 Hz
c) 68 Hz
d) 74 Hz
} Caused by the mechanical resonances of the LHe cryostat.

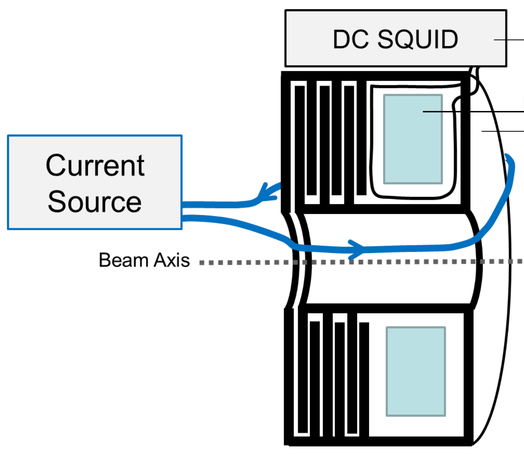
e) 820 Hz and it's harmonics: Turbo molecular pump

f) 76.8 kHz : Noises from the readout unit

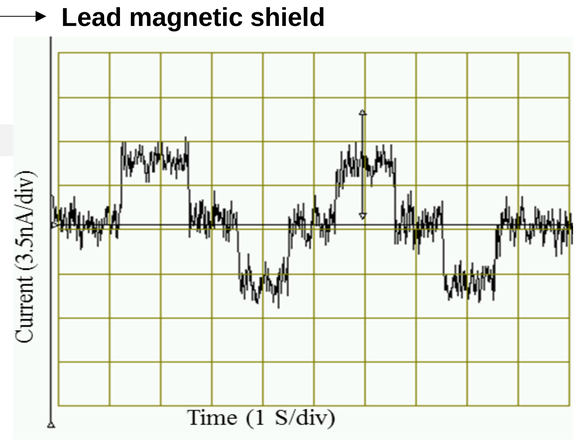
Noise spectrum taken with HP35670A Dynamic signal analyzer

Test Current Measurement with CCC

A known current from a precise pA current source (Keithley 261 pA source) Applied through a wire loop around the sensor unit was used to simulate the beam current



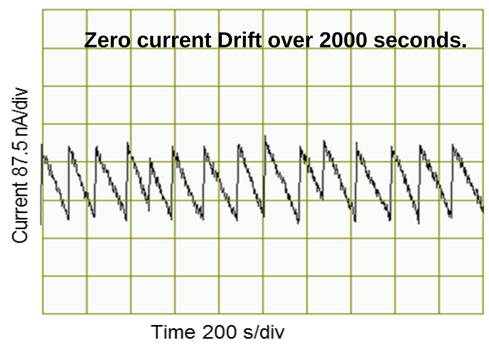
Schematic of the test measurement arrangement. The sensor parts are operated at liquid helium temperature.



5nA peak to peak current signal measured in full bandwidth mode

Zero Current Drift:

- Any temperature/pressure fluctuations inside the cryostat produce zero current drift.
- Slowly vanishes as the system becomes stabilized.
- As the noise current exceeds the current equivalent to unit flux quantum (here 175 nA), the working point of the SQUID will be reset.



Further Studies

- Introduction of new SQUID sensor (Supracon) and SQUID controller (Magnicon**)** to the CCC prototype (see poster TUPF32 for details)
- Beam current measurement with the upgraded CCC prototype at the GSI beam line
- Finalizing new CCC designs for FAIR installations.

References

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[5] R.Geithner et al. Rev.Sci. Instr, 82(1):01302-01302-5, Jan. 2011.
[6] R. Geithner, R. Neubert, W. Vodel, P. Seidel, Cryogenics 54(2013), pp. 16-19

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