Numerical simulations of a field emitter-based extractor gauge for pressure measurements in cryogenic vacuum systems

M. Lotz[1,2], St. Wilfert[1], A. Krämer[1], and O. Kester[1,2]
[1]GSI, Darmstadt, Germany, [2]Goethe University of Frankfurt, Germany

Pressure measurement in the UHV and XHV range in cryogenic vacuum environments has always been considered a metrological problem. However, especially for the cryogenic beam vacuum sections of the SIS100 a pressure measurement would be useful since local pressure rises caused by dynamic vacuum can lead to self-amplifying beam loss effects.

In general, conventional hot-filament ionization gauges can be used in cryogenic vacuum systems. However, during operation they generate a huge heat load causing numerous disadvantages in low temperature systems. Therefore, an ionization gauge was developed where the heat-generating filament was replaced by a non-thermal cathode. The electron release mechanism of this cathode type is based on field emission. It has been shown in a previous study [1] that it is possible to read pressures under cryogenic vacuum conditions using this type of gauge. Unfortunately, the lower pressure measuring limit of the used gauge is too high to measure the low pressures expected in the future SIS100. This was caused inter alia by the low electron current relative to the current used in a commercial extractor gauge with thermionic filament. To increase the current, the carbon nanotube-type (CNT) field emitter will be replaced by a field emitter array (FEA), which is developed at the Paul Scherer Institute (PSI) in Switzerland.

The FEA consists of an array of micro-structured molybdenum tips and has an integrated micro grid for electron extraction at a very short distance. Therefore, even small extraction voltages between 100-150 V are sufficient to generate an emission current in the range of mA. These emitters were repeatedly tested at PSI and showed promising emission properties [2].

Numerical simulations on the previously studied CNT-based gauge have been carried out using the program suite *AMaze*. The results showed that in this gauge configuration many electrons directly hit the anode grid end closure without the typical oscillation within the ionization volume, i.e. the volume inside the anode grid (Figure 1).

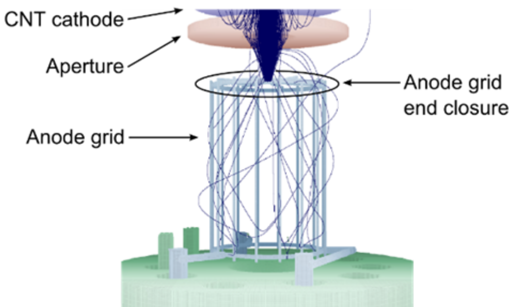

Figure 1: Electron trajectories in the CNT-based extractor gauge.

Since ions generated outside the ionization volume do not reach the ion collector electrode, the detectable pressure dependent ion current is very low. In order to increase the ion current signal the electrons must run on elongated paths through the ionization volume. This can be facilitated by a change of the cathode position. Therefore, an improved gauge design is developed in which three individual field emitter spots are arranged as a ring around the anode grid. This geometry is similar to that of conventional extractor gauges with ring-shaped thermionic cathodes. Numerical simulations on this improved gauge design have confirmed the considerations on the electron trajectories within the gauge (Figure 2). As a result, the gauge sensitivity should be substantially increased relative to the CNT-based extractor gauge previously investigated.

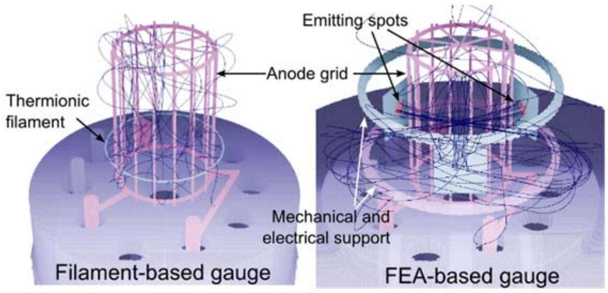

Figure 2: Comparison of electron trajectories in a FEA-based and a filament-based extractor gauge.

The improved gauge design, as shown in Figure 3, will be realized and studied extensively in terms of its operating performance in both room temperature and cryogenic vacuum environments. The experimental investigations will provide information on whether the lower pressure measuring limit is shifted to significantly lower pressures by the modifications made.

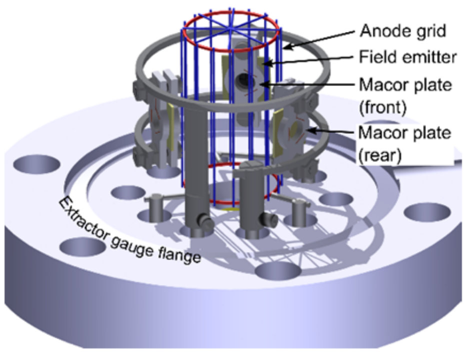

Figure 3: The improved FEA-based extractor gauge.

References

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