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First Tests of LEIR – Cooler at BINP

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Abstract. New electron cooling device was constructed for LEIR accumulator ring according to ILHC project at CERN. The cooler was designed, manufactured and completely tested with electron beam at BINP (Novosibirsk, Russia). Special features of the device and the results obtained are presented in the paper.

Keywords: Electron cooling, electron gun, electron collector, magnetic measurements.

INTRODUCTION

New electron cooling device was designed and constructed at BINP in collaboration with CERN. It is intended to be a significant part of newly upgraded low energy ion ring (LEIR) under ILHC project. The cooler is equipped with electron gun with variable beam profile, high perveance collector and electrostatic bending. Other important features are precise cooling section solenoid made of adjustable pancake coils and ultra high vacuum system. All systems were completely tested at BINP before shipping to CERN.

MAGNETIC MEASUREMENTS

One of the main parts of the cooling device is magnet system. It consists of drift solenoid as a cooling section, toroidal magnet bends and solenoids for electron beam expansion at a gun and compression at a collector region. Also it includes various correction coils for both electron and ion beams adjustments. Special dipole correctors are built in the toroid magnets for ion beam deflection compensation. Results of Hall probe measurements are sown in Fig.1.

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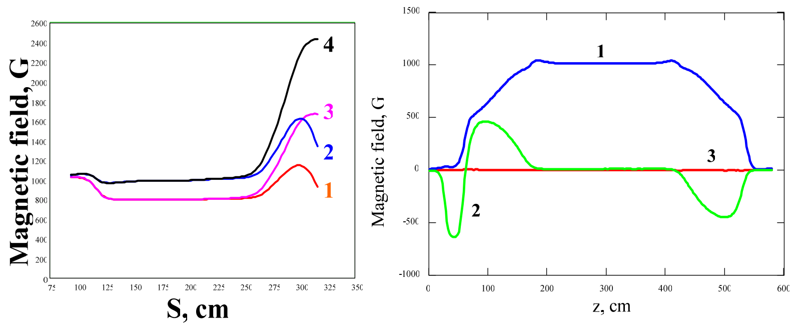

FIGURE 1. Curvilinear Hall probe measurements along electron orbit (in the left) and 3D straight measurements along ion trajectory. Magnetic field distribution along straight section (ion orbit) of the cooler. Right picture: 1-longitudinal, 2-vertical, 3- horizontal components of magnetic fiels. Left picture: magnetic field distribution along electron orbit of the cooler for different combinations of currents applied to the power supplies

Vertical component of magnetic field in drift solenoid is dependent on its longitudinal value because of toroidal field penetration from bending magnets. This fact is rather important for those cases when cooler is intended for use at different field values. Linear and cubic correction wound on drift solenoid were foreseen to eliminate vertical field slope dependent on longitudinal value. Measurements of those correction replies (Fig.2 right) are very important further operation of the magnet system and drift solenoid in particular.

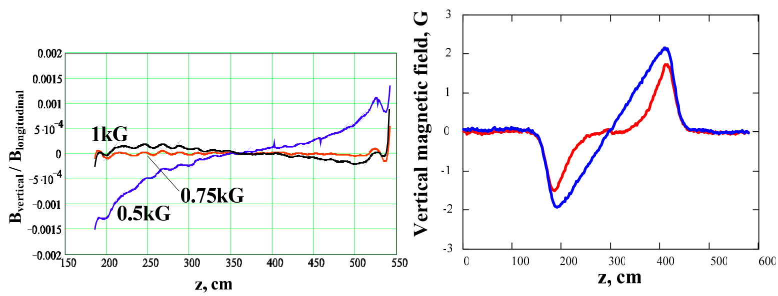

FIGURE 2. Vertical field slope in the cooling section dependence on longitudinal field value (on the left). Vertical magnetic field produced by linear (blue curve) and cubic (red curve) 2.5m long correctors installed on cooling section (on the right).

Magnetic field in the drift solenoid was measured and tuned to meet designed requirements. For more complete description of the methods applied for measurements and adjustments refer to [1].

ELECTRON GUN AND COLLECTOR OPERATIONAL CHARACTERISTICS

One of the main tests were done was putting into operation the electron gun and collector. While backing out of the vacuum system was being carried out cathode activation was performed step by step with applying required voltages to the gun electrodes. Electron current of 1.5A emitted by the gun was obtained (Fig. 3 on the left).

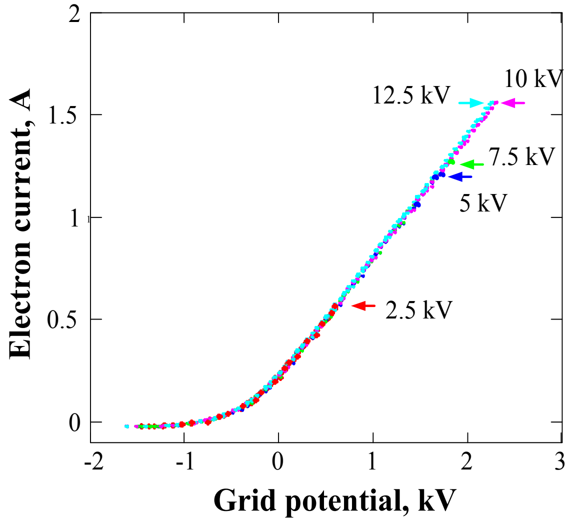

FIGURE 3. Electron gun current. Different curves show measurements for different potentials applied to the collector when arrows point them.

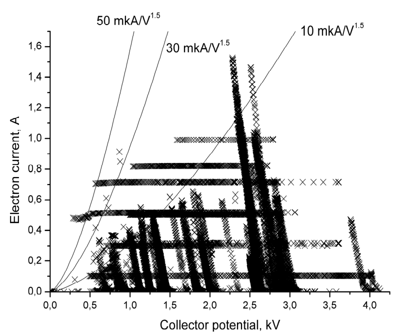

FIGURE 4. Electron collector current versus collector potential. Rows – series of measurements when collector potential was decreased at constant suppressor voltage and electron current. Solid curve is asymptote of the collector perveance for each series.

Much attention was paid for collector properties study. Rows on right part of Figure 3 show how varying collector potential al constant suppressor voltage extremely high value of collector perveance (solid curves) was achieved. Recuperation efficiency in those measurements was very high that meet all requirements. This was obtained thanks to using electrostatic bending. Recuperation efficiency arise up to 10^{-6} or even better in comparison with magnet bending (left picture in Figure 5). This fact opens results in opening new possibilities in cooling device techniques [2], [3].

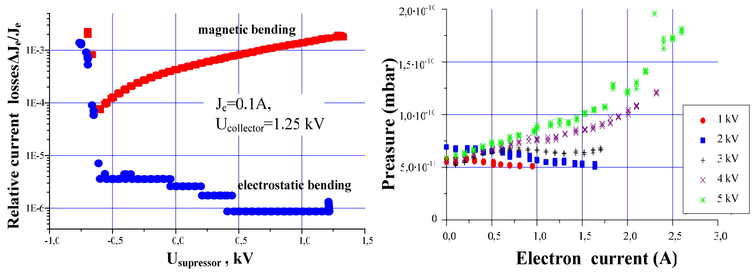

FIGURE 5. Left picture: relative current losses versus suppressor potential at constant electron current and collector potential. Left picture: vacuum pressure versus electron current.

Lower curve in left part of Fig.5 shows that current loss is almost independent on suppressor potential if electrostatic bending is used, and it even gets worse at some regimes of operation. It means that collector should be opened as much as possible for better capturing secondary electrons [4].

One of the advantages of electrostatic bending use is low desorption because of low current loss. Pressure in vacuum system was observed to get even better under the electron beam action (lower curves in right part of Fig.5). Intensive electron current ionizes residual gas atoms and then they are captured by ion pumps belonged to the vacuum system. Using of electrostatic bending seemed to be the only way out to meet very strict requirement to the vacuum condition in LEIR machine (10^{-12} mbar).

Space Charge Effects in the Collector

Collector potential was being decreased while collector current was kept constant by value of 0.5A and suppressor potential by 0.47kV. When collector potential went down below suppressor potential, current losses increased significantly, because of potential barrier disappearance. Collector current changed a little with losses increased, the much beam losses the less collector current. It may be explained as an additional space charge of secondary electrons in the gun influenced on electron current.

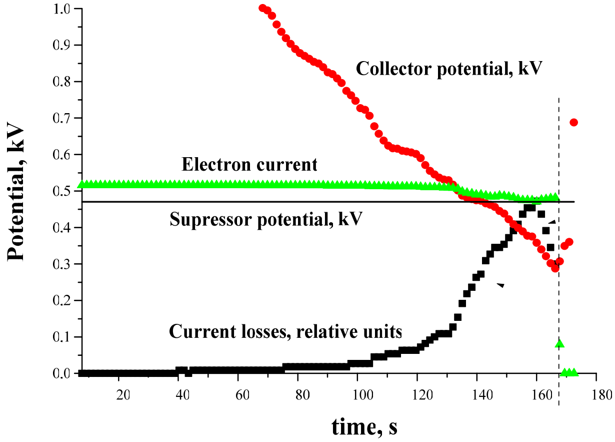

FIGURE 6. Beam current losses, collector potential, collector current and suppressor potential depending on time.

Break-down occurred when collector potential was below suppressor potential so that virtual cathode supposed to arise inside the collector cavity rather than suppressor. Beam current losses decreased just before break-down, because secondary electrons were suppressed by space charge inside the collector cavity. Collector perveance was observed to be about 100μA/$V^{3/2}$ in this experiment. This interesting result gives us an opportunity to use space charge inside collector as additional suppressor.

CONCLUSION

All results obtained during tests will serve for operation conditions setting and are important for cooling process tooling. Measurements of the space charge in the gun and collector look very interesting and after complete study may result in further technique improvement. High recuperation efficiency gives a possibility to use high voltage power supplies with low power consumption. On the other hand it allows achieving ultra high vacuum condition in the cooler.

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