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LOW ENERGY ELECTRON COOLER FOR THE NICA BOOSTER

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Abstract

The low energy electron cooler for the NICA booster has recently been installed at the booster ring of the NICA facility. The article describes results of various measurements obtained during its commissioning. In addition, some details of design and construction of the cooler are discussed.

INTRODUCTION

NICA collider contains a big number of complicated systems and subsystems. One of them is gold ion booster which is located at the existing hall of former synchrophasotron, and new superconductive magnets sit inside old giant iron yokes [1]. Low energy cooler is one of the elements of the booster those provides sufficient improvement of the ion beam quality.

Main specifications of the cooler are listed below:

ions type	p+ up to $^{197}Au^{31+}$
electron energy, E	1,5 ÷ 50 keV
electron beam current, I	0,2 ÷ 1,0 Amp.
energy stability, $\Delta E/E$	$\leq 1\cdot 10^{-5}$
electron current stability, $\Delta I/I$	$\leq 1\cdot 10^{-4}$
electron current losses, $\delta I/I$	less than $3\cdot 10^{-5}$
longitudinal magnetic field	0,1 ÷ 0,2 T
inhomogeneity of the field, $\Delta B/B$	$\leq 3\cdot 10^{-5}$
transverse electron temperature	≤ 0,3 eV
ion orbit correction:	
displacement	≤ 1,0 mm
angular deviation	≤ 1,0 mrad
residual gas reassuretion	$\leq 1\times 10^{-11}$ mbar.

MAGNETIC MEASUREMENT RESULTS

Magnetic system of the cooler consists of central solenoid, bending toroids, gun-collector solenoids and correctors [2]. Requirement for the magnetic field straightness is $\Delta B/B \leq 3\cdot 10^{-5}$ for the central (cooling) solenoid.

Measurements were performed with compass based measurement system [3].

The results of those measurements are shown on Fig. 1. Vertical and horizontal components of the magnetic field were measured several times during solenoid adjustment. Starting data (just after shipping of the cooler) are drawn as black curves. Red curves present final results of solenoid adjustment thus the requirement was fulfilled.

The solenoid was tuned at 1 kG of the longitudinal field as long as it is a middle of required field range. If we apply other values of magnetic field the vertical component

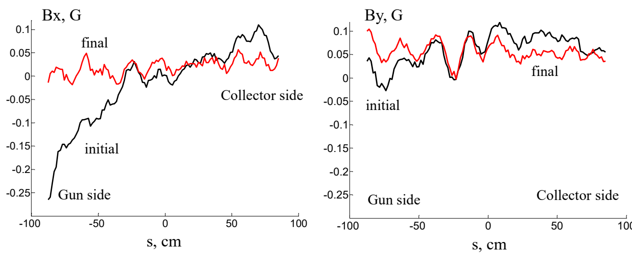

Figure 1: Horizontal (left) and vertical (right) magnetic field components before (black) and after (red) coils adjustment.

will change (Figs. 2 and 3). To improve the situation the cooler is equipped with linear correction coils attached along the solenoid so as each value of longitudinal field corresponds to amplitude of current applied to the linear corrector.

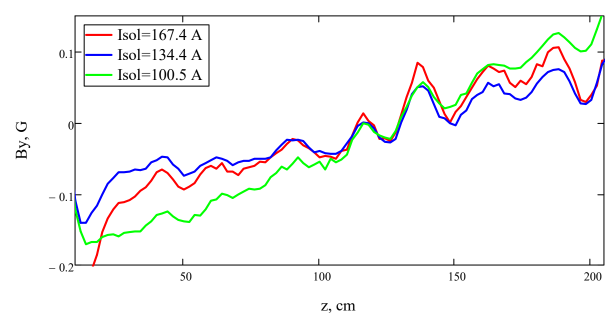

Figure 2: Vertical field component measured at different value of the longitudinal field. Red – 1 kG, blue – 800 G, green – 700 G.

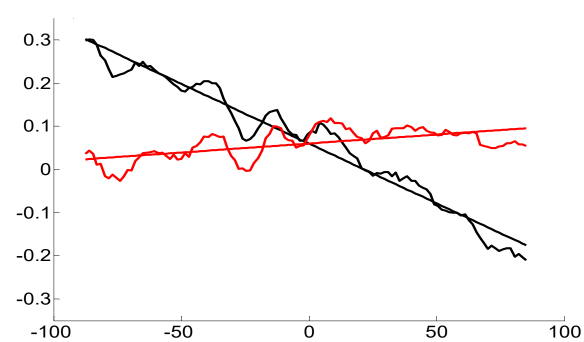

Figure 3: Linear (vertical) corrector calibration.

For the solenoid tuning its coils are slightly rotated or inclined depending on direction of the transverse field to be corrected. The movement of the coils on 0.1 mm corresponds to $3\cdot 10^{-4}$ in angle of the field that by order of magnitude higher than required accuracy.

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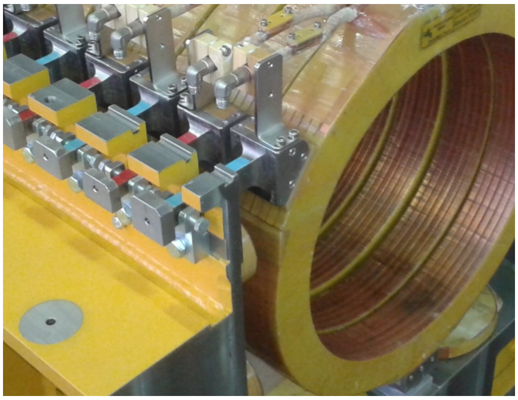

Figure 4: So-called pancake coils in cooling solenoid.

All coils in the solenoid have the supports on both sides those can be turned with two screws as shown in Fig. 4.

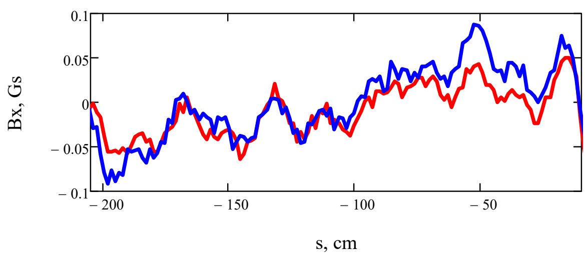

Figure 5: Horizontal field component before (red) and after (blue) all screws were tightened.

The position of the coils is very sensitive to those screws tension. Figure 5 showed the difference between two measurements of the field preformed just before and after screws tightening.

One more important thing in reaching high straightness is residual field. Its value is rather high in comparison with acceptable transverse field distortion.

ELECTRON GUN AND COLLECTOR

The electron gun design is similar (Fig. 6) to one taken from the 2 MeV cooler for COSY synchrotron [4]. Few changes were made to improve pumping of the inner volume and insulator was modified to meet HV requirement.

The collector consists of two parts. First is massive copper body with water cooling for primary electron beam accepting. Second one is metal-ceramics assembly providing 60 kV insulation and support for suppressor and pre-collector electrode. Both electrodes are intended to reduse the number of secondary electrons, reflected from collector.

The electron gun has four sectors control electrode what give an opportunity of the electron beam position measurement (with BPMs). Also it is possible to estimate the beam shape [4].

The volt-ampere characteristic of the gun is shown in Fig. 7. Control electrode voltage U_{grid} is devided on U_{anode}, and beam current I_{coll} on anode voltage $U_{anode}{}^{1.5}$. This scaling allow to compare data obtained at different anode voltage so curves are similar.

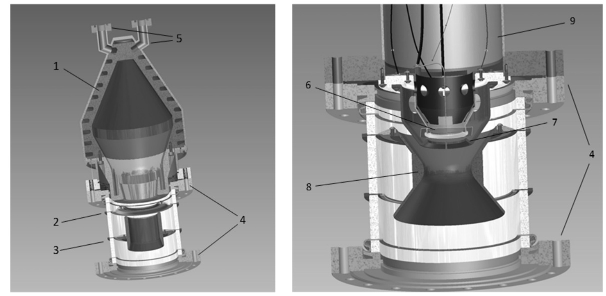

Figure 6: collector (left) and the gun (right). 1 – electron input, 2 – suppressor, 3 – pre-collector 4 – vacuum flanges, 5 – oil cooling tubes, 6 – cathode assembly, 7 – control electrode, 8 – anode, 9 – feedthoughts.

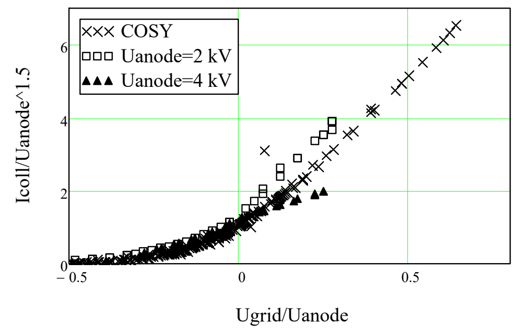

Figure 7: Volt-ampere characteristic of the gun at different setups of the cooler parameters.

VACUUM GENERATION

The vacuum system of the cooler has a volume approximately 0.2 m^3. On the other hand, the internal surface of the vacuum chamber is very advanced as it contains bending plates and other various electrodes [5]. That leads to rather high outgassing rate. The scheme of the vacuum system is shown in Fig. 8.

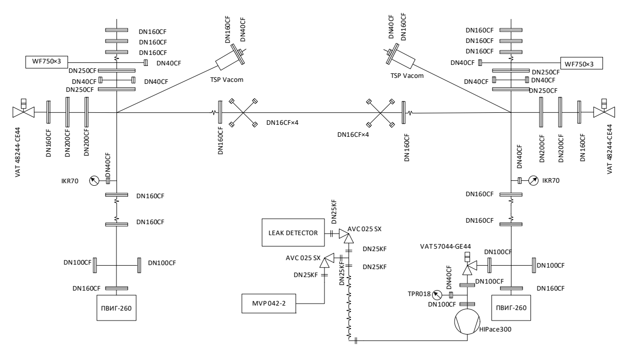

Figure 8: Scheme of the vacuum system.

For obtaining the required vacuum condition as $\leq 1\times10^{-11}$ mbar following pumping equipment was included into the system.

1. Ion pump combined with TPS "PVIG – 260" is most efficient in the range 1×10^{-6} to $1{,}5\times10^{-8}$ Pa, total highest pumping speed 630 l/s.
2. Titanium sublimation pump TSP-IPG ("Vacom") is used with special ambient screen with surface

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area 1320 m^2, which corresponds to approximately 2000 l/s of pumping speed.

3. Every getter pump contains three modules of WP750-ST707. Data for one module: stripe surface 870 cm^2 , stripe thickness 0.2 mm, resistance 0.16 Ω, size 207×50×30 mm, pumping speed (H_2 - 330 l/s, CO - 130 l/s), sorption capacity (H_2-660 $torr^{-1}$, CO - 75 $torr^{-1}$, activation current (450ºC) is 27 amps.

All components of the vacuum system were baked out up to 300ºC for about two days with back pumping (300 l/s turbopump). The heating as well as cooling speed was about 0.5 ºC/min to protect numerous electric feed-throughs and other components contained ceramics. During cooling of the vacuum system the oxide cathode activation was performed and the NEG pump activation was done. After all those procedures were completed the system was closed from back pumping and ion pumps were turned on. Finally, the required vacuum condition was obtained.

OXIDE CATHODE ACTIVATION

The oxide cathode, as required, was activated during the vacuum system bake-out with back pumping. The activation process is very sensitive to the vacuum condition when the cathode surface is overheated to provide necessary temperature. If the pressure is over required threshold so called, ‘cathode poisoning’ may occur. This leads to dramatic decrease of the emission ability of the cathode.

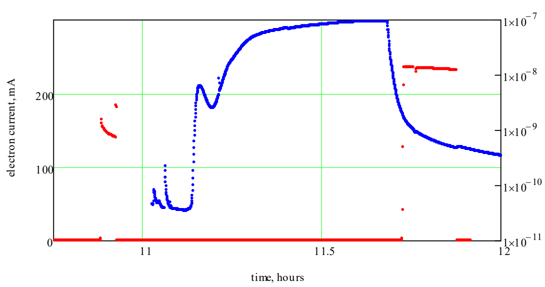

Figure 9: Electron current (red) and residual gas pressure (blue).

This experiment aimed at study the influence of the residual gases released during NEGs regeneration on oxide cathode properties. The electron current vas measured before and after regeneration process. Cathode filament was on during the experiment. Pressure measurement plotted on Fig.9 as a blue curve while electron current is red. Surprisingly the current significantly increased, that means the cathode surface was ‘cured’ with the hydrogen released from the NEGs.

The mass spectrogram of the residual gas composition is shown in Fig. 10. Blue bars in the figure correspond to the ions current at the cooler vacuum chamber; those are

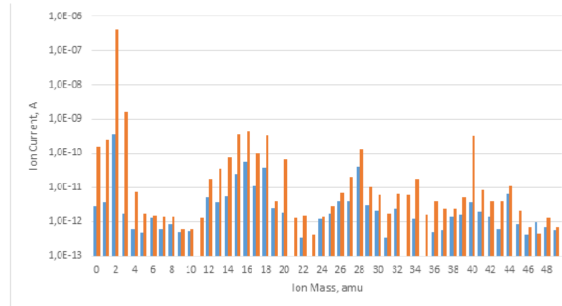

Figure 10: Residual gas mass spectrogram.

proportional to the partial pressure of the correspondent gas components. Red bars show the condition during NEGs regeneration. One may conclude that the hydrogen has pressure higher by 1000 times in comparison with other components.

SUMMARY

The low energy electron cooler was successfully tested at BINP, shipped and partially commissioned at NICA booster.

During various measurements some techniques were improved. Nevertheless there are some points where the limits are reached and more efforts are needed to go further. One of them is magnetic lines straightness in the cooling solenoid. To get this parameter better than $3 \cdot 10^{-5}$ for future projects following steps have to be made:

- improve design for coils support
- increase accuracy for mechanical movement
- residual field has to be compensated
- in-vacuum measurements are required.

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