COMMISSIONING OF THE 60 KEV ELECTRON COOLER FOR THE NICA BOOSTER

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Abstract

The 60 keV electron cooler for the NICA booster was designed and constructed at BINP SB RAS. The article describes results of various measurements obtained during its commissioning. Also 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, *ΔE/E*	$\leq 1\cdot 10^{-5}$
electron current stability, *ΔI/I*	$\leq 1\cdot 10^{-4}$
electron current losses, *δI/I*	less than $3\cdot 10^{-5}$
longitudinal magnetic field	0,1 ÷ 0,2 T
inhomogeneity of the field, *ΔB/B*	$\leq 3\cdot 10^{-5}$
transverse electron temperature	≤ 0,3 eV
ion orbit correction:	
displacement	≤ 1,0 mm
angular deviation	≤ 1,0 mrad

The requirement for vacuum condition is usual for heavy ion accelerators $\leq 1\times 10^{-11}$ mbar [1].

MEASUREMENTS OF THE ELECTRON GUN PERVEANCE

After long term training of the electron gun cathode, efficiency of the cathode increased and behavior of the perveance became similar to that of the electron gun being used in the electron cooler for COSY (Fig.1).

The main source of the current losses in the electron cooler is the secondary emission of electrons from the collector. In order to reduce losses, the suppressor placed before the collector creates a potential barrier that constrains the secondary emission. However, the magnitude of this barrier depends on the distance from the vacuum pipe axis and reaches its minimum at the center of the beam electron. The space charge of the electron beam produces the potential, which behaves the opposite way – the farther from the beam's axis, the lower the potential created by beam's space. With growth of the electron beam current the resulted potential barrier can lock the secondary emission and decrease the current losses (Fig.2). However, further increase of the beam current is limited as the beam's space charge can form an electrostatic mirror and lead to the breakdown.

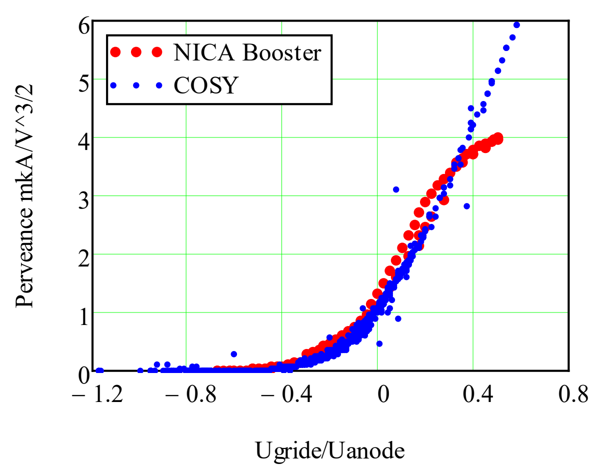

Figure 1: Electron gun perveance.

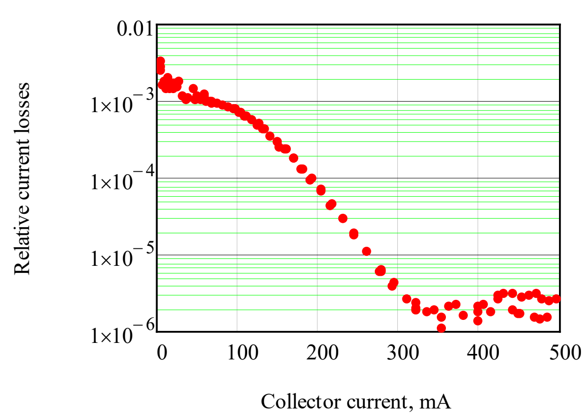

Figure 2: Electron current losses at collector.

VACUUM GENERATION

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

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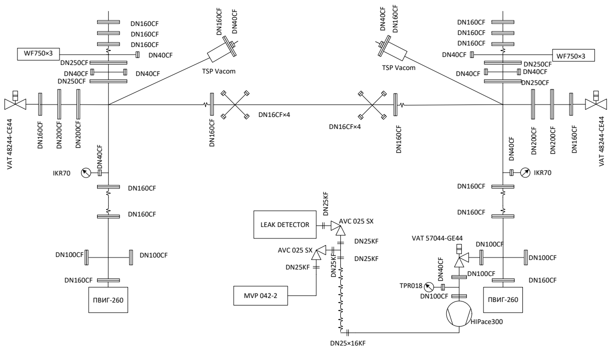

Figure 3: Scheme of the vacuum system.

For the obtaining the required vacuum condition as $\leq 1\times10^{-11}$ mbar following pumping equipment was includes 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 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 ohm, 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 feedthroughs 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 (see Fig.4).

Figure 4: Vacuum in the cooler vacuum chamber.

OXIDE CATHODE ACTIVATION

The oxide cathode, as required, was activated during the vacuum system bake-out with back pumping (see Fig. 5). 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.

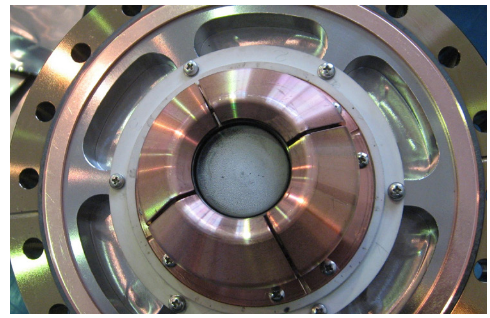

Figure 5: Oxide cathode (at the centre).

Gray and dark grey areas on the cathode surface show 'cathode poisoning'.

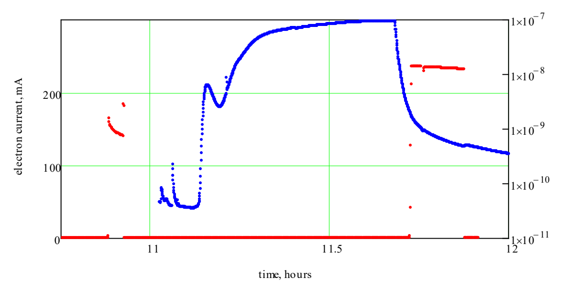

Figure 6: Electron current (red) and residual gas pressure (blue).

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 (Fig. 6). Cathode filament was on during the experiment. Pressure measurement plotted 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.

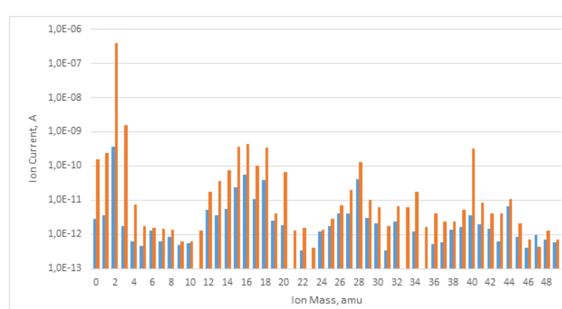

Figure 7: Residual gas mass spectrogram.

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Mass spectrogram of the residual gas composition is shown on the figure 7. Blue bars correspond to the ions current at the cooler vacuum chamber; those are 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.

HIGH VOLTAGE TEST

Figure above shows electron current leakage dependence on voltage for the HV terminal when its vessel was filled with air (red) and SF6 gas (blue). Sharp increase of the losses near 20 kV was observed due to the corona discharge (see photo on the Fig.8 upper left corner). SF_6 gas filling at atmosphere pressure suppress the corona discharge. This experiment shows that no extra pressure of the SF_6 is needed so the HV vessel design may be simplified.

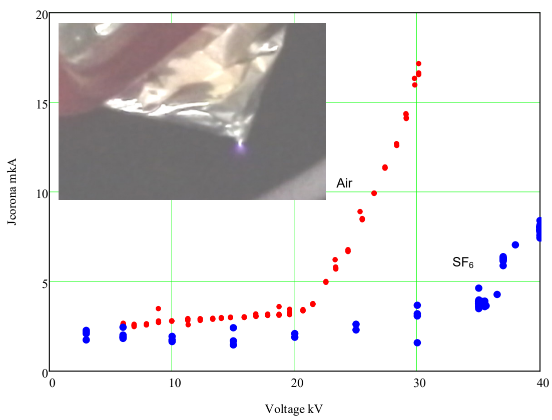

Figure 8: Electron current leakage.

SUMMARY

The 60 keV Electron Cooler for the NICA Booster [2 – 5] was successfully commissioned at BINP. At the moment of writing this article it is disassembled and prepared for the shipping to JINR.

ACKNOWLEDGMENT

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