Assembling NEG, Ion Pump and Bakeable BNNT Cryopump System to Reach XHV

Jefferson Lab
Thomas Jefferson National Accelerator Facility

U.S. DEPARTMENT OF ENERGY | Office of Science

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Abstract

New accelerator initiatives require spin polarized electron photoinjectors. The gallium arsenide (GaAs) photoguns must provide high average current ($\gg$1mA) and a long operating lifetime. Its performance depends on our ability to improve vacuum inside the chamber. In this project we investigated cryopump technology to maintain an extreme high vacuum (XHV) on the electron gun to achieve $P < 10^{-12}$ Torr, using a bakeable cryopump with mechanically attached Boron Nitride Nanotubes (BNNT), and the Non-Evaporable Getter (NEG)-ion pump (IP) system. We also measured the x-ray limit of the extractor and bent belt-beam (3BG) gauge that we used to measure the pressure. Additionally we used the Monte Carlo simulation software MolFlow+ to model the pressure distribution in the chamber , using the expected outgassing rates, measured temperatures, and expected pump speeds for the NEG, ion and cryopumps.

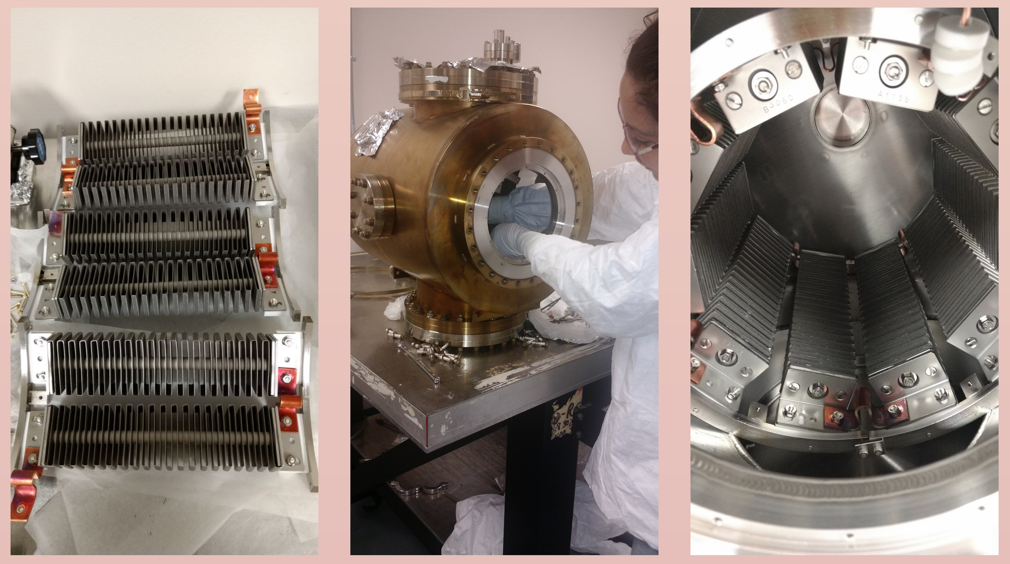
Introduction

The Center of Injectors and Sources at Thomas Jefferson National Accelerator Facility has nearly reached XHV of $P = 1 \times 10^{-12}$ Torr by combining NEG pumps and ion pumps in the Continuous Electron Beam Accelerator Facility (CEBAF) polarized source. Obtaining XHV pressure requires careful material selection and preparation, and appreciation for pump characteristics, capability and limitations. Measuring pressure at XHV is also a challenge because the limit to the lowest measurable pressure may not be caused by the pressure in the system, but by an x-ray effect in the gauges, so gauges must be used that have low x-ray limits, and the x-ray contribution to the pressure must be measured.

Assembly

Our system consists in a vessel similar in size to an electron gun chamber, with ten NEG pumps inside, an ion pump and a cryopump.

NEG. The SAES SORB-AC Non-Evaporable Getter Wafer Modules WP 950. These pumps have been designed to maximize hydrogen and active gases pumping speed.



(a) WP950 modules (b) Mounting the NEG array (c) 10 NEG array

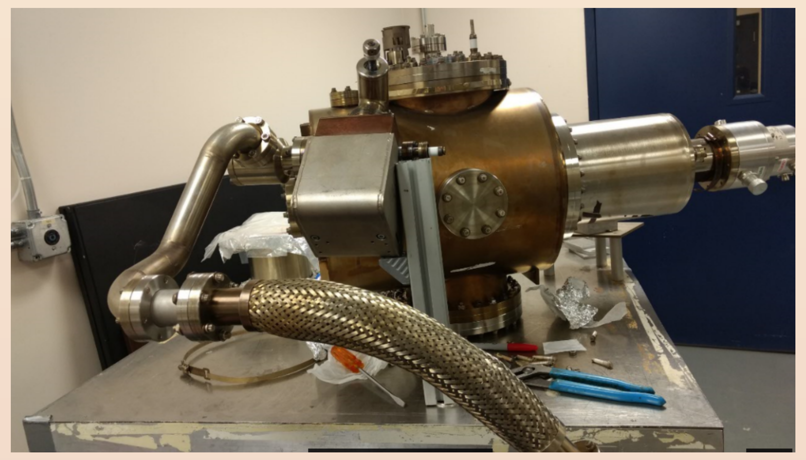
Figure 1: Images of the WP950 modules before and after being mounted into the chamber.

Cryopump. BNNT has a molecular-sieve structure giving the material a high surface area $300\ m^2/g$. It also has a high thermal conductivity of $3000\ W/mK$, remains strong in air up to 800°C, and is resistant to thermal oxidation up to 920°C. This is the first test of this material as a cryosorber.

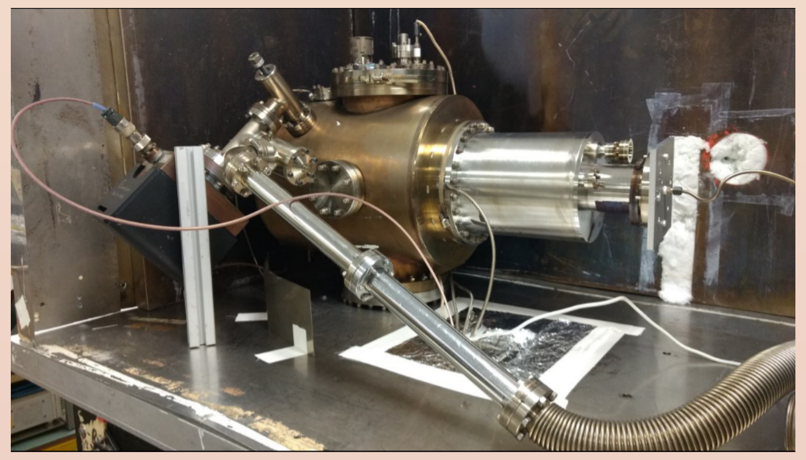
Figure 2: BNNT on the fin array.

Troubleshooting

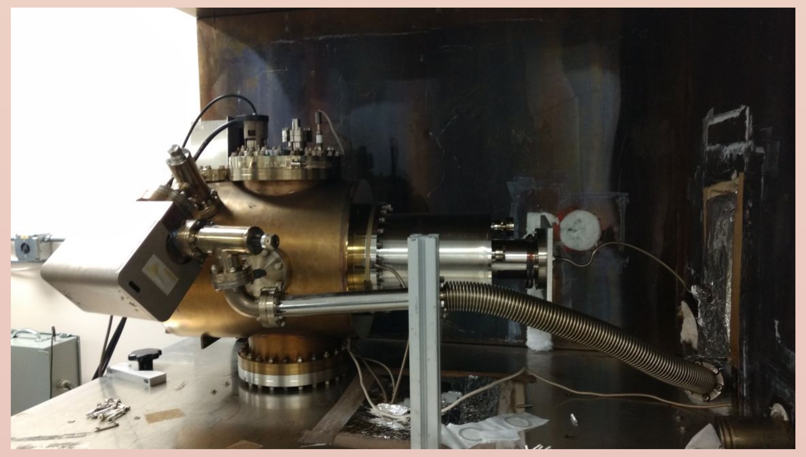
Through the process we found that two ion pumps had trouble, and we had to replaced them. Also, we needed to reconfigure the system in order to install the oven panels for the baking.



(a) First configuration



(b) Configuration with new rough line for baking



(c) Final configuration of our system.

Bake-out and pumping

The system was pumped down with the turbo and the ion pumps and the vacuum was in the low 10^{-6} Torr range before starting the bake-out. The heating must be even for all surfaces so we used a hot air blower oven in order to heat uniformly. The system was baked to 250°C for 155 hours as we show in figure 3.

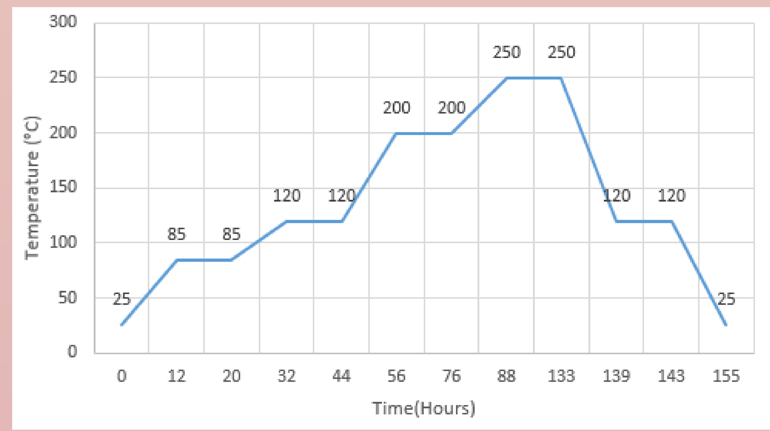
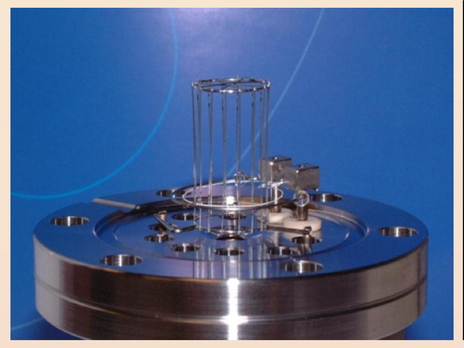


Figure 3: Temperature ramp of the bake-out process.

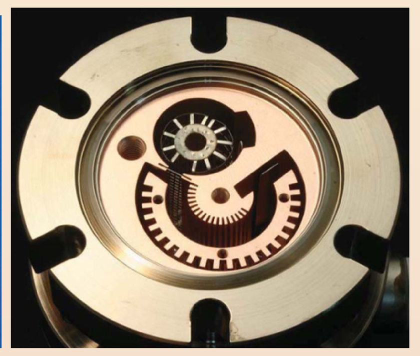
Measuring

Above the ultrahigh vacuum (UHV) regime it is not possible to measure pressure as a force on a certain area as the definition of pressure indicates. Instead, the indicator for pressure is the ionization rate produced by electrons hitting the neutral gas atoms in a UHV chamber [1].

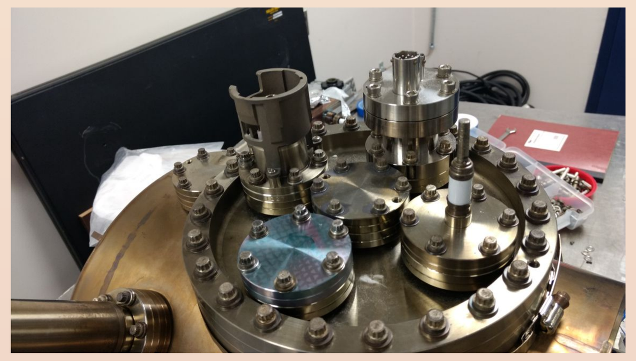
We used a Leybold extractor gauge IE 514 and a Watanabe 3BG gauge for measuring the pressure, both of which have very low x-ray limits.



(a) Extractor gauge.



(b) Watanabe Bent Belt Beam gauge.



(c) Gauge Flange. In the bottom, extractor gauge (left) and 3BG gauge (right).

Molflow+ Simulation

Molflow+ is a test particle Monte Carlo code developed at CERN by R. Kersevan and M. Ady [2], has been modified to calculate pressure in a direct way from the mass and velocity of the molecules. The geometry of each pump was simulated in AutoCAD and Blender to approximate real surface areas [3].

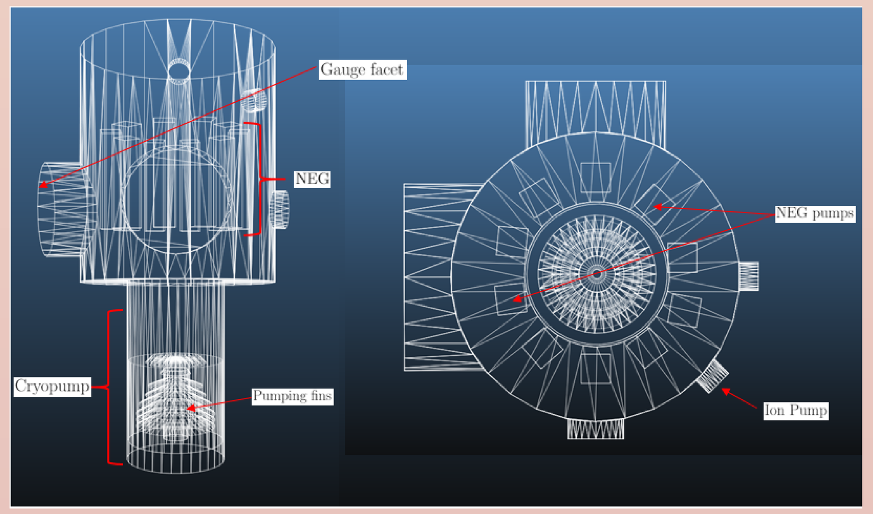
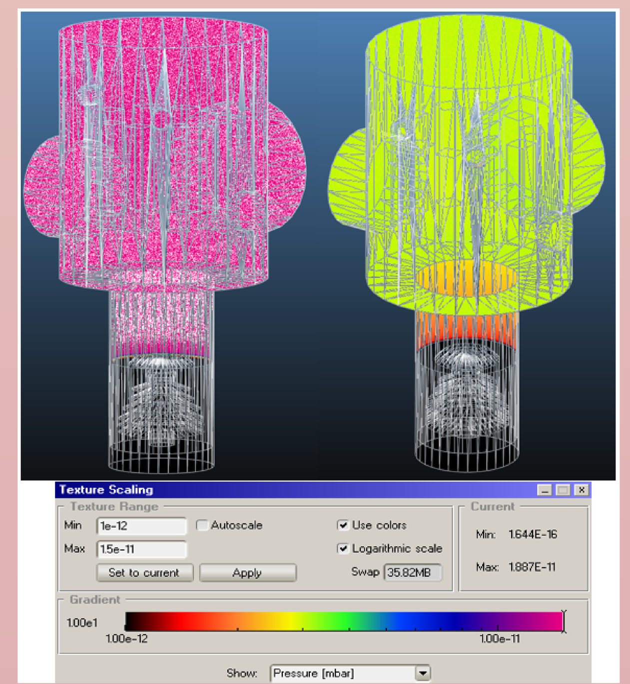
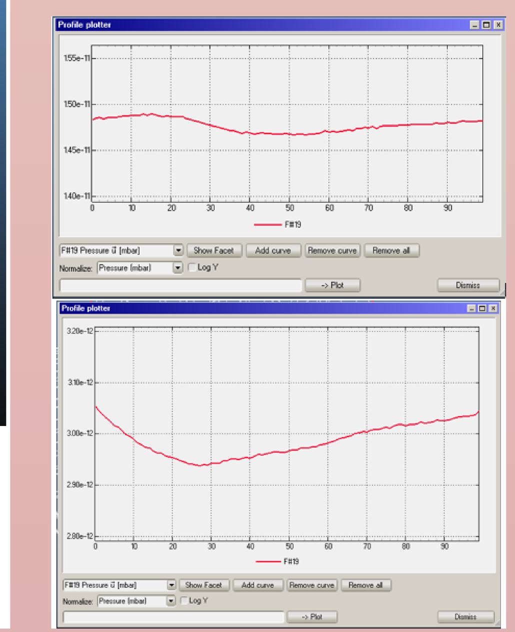


Figure 4: Geometry of the System. NEG, Ion and Cryopumps.

We simulated the expected pressure both with the cryopump on and off, using data from previous tests of this cryopump to determine the effective sticking coefficient.



(a) Cryopump off (left) and cryopump on (right)



(b) Pressure distribution on side of the chamber, cryopump off (top), cryopump on (bottom).

Figure 5: Simulations of the flow in the system.

Results

The results of the MolFlow+ simulation show that the pressure in the system is better in the system with the cryopump on, as expected, but these simulations indicate that the pressure might not reach the XHV pressures. This model is more going to be used as a description of the system rather than a prediction.

We found that the system reaches a pressure of 1.6×10^{-11} Torr with the cryopump off, and a pressure of 2.7×10^{-12} Torr with the cryopump on. The x-ray limit of the extractor gauge is 1.5×10^{-12} so the real pressure inside the chamber is 1.2×10^{-12}.

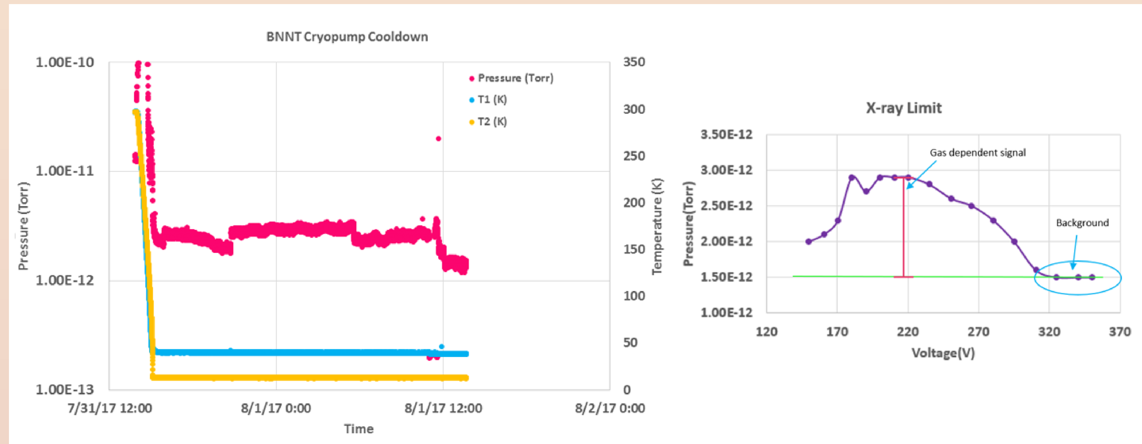


Figure 6: The pressure evolution in the system as measured by the Extractor gauge plotted with the temperature evolution (Left), X-ray Limit of the extractor gauge, pressure measured varying the voltage (Right).

Discussion and Conclusion

This cryopumped chamber did not reach the pressures previously measured in JLab NEG/ion pump chambers with the cryopump at room temperature, but when the cryopump was turned on, the chamber achieved pressure near 1×10^{-12} quickly.
This first attempt at using BNNT cryopumping in addition to the NEG/ion pump system previolusy used at Jefferson Lab showed that we can achieve similar pressures with the prior technology, and will continue to be used to test the limitations of pumping systems for reaching XHV.

Forthcoming Research

This is a prototype of using BNNT for a cryopump cryosorber. The amount of BNNT and the mounting should be optimized to improve the performance. This shows potential for a good alternative to the traditional cryopump.

Acknowledgements

This project is supported by the JSA Initiatives Fund Program, a commitment from the JSA owners, SURA and PAE Applied Technologies.

First of all I want to thank my lovely mentor Marcy Stutzman for all the knowledge she shared to me and for all the kindness and patience she has. Thanks to Carlos Hernández García, Phil Adderley and all the Injectors Group members.
Thanks to Hari Areti and Lisa Surles-Law, the U.S. Department of Energy, the Jefferson Lab, Old Dominion University and the RESFAC Staff.

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[2] R. Kersevan, "Molflow Users Guide., (2013). Website: cern.ch/molflow

[3] Veronica Over, "Using Monte Carlo Simulation to Find the Sticking Coefficient of Boron Nitride Nanotubes (BNNT) as a Cryosorbent, (2016).

[4] M. Knudsen, "Effusion and the Molecular Flow of Gases through Openings." *Ann. Physik* **28, 75, 999**, (1908).