Report on first gXe flow through RF-funnel

March 6, 2013, TB and DF

Over the past weeks the RF-funnel has been installed inside of chamber B and the vacuum system has been upgraded. Chamber B is evacuated by a Pfeiffer HiPace 300 (~255l/s for N_2) TMP while chamber C is pumped by an Edwards STP800 MagLev (~800l/s for N_2). The gas outlet of the MagLev pump can be directed either to a scroll pump or back into chamber B. This allows one to use the pump either to evacuate chamber C or to move Xe gas back into chamber B where it gets captured by the cryo pump for later recirculation. A schematic of the Xe and vacuum piping is shown in Figure 1. Chamber D is not yet installed.

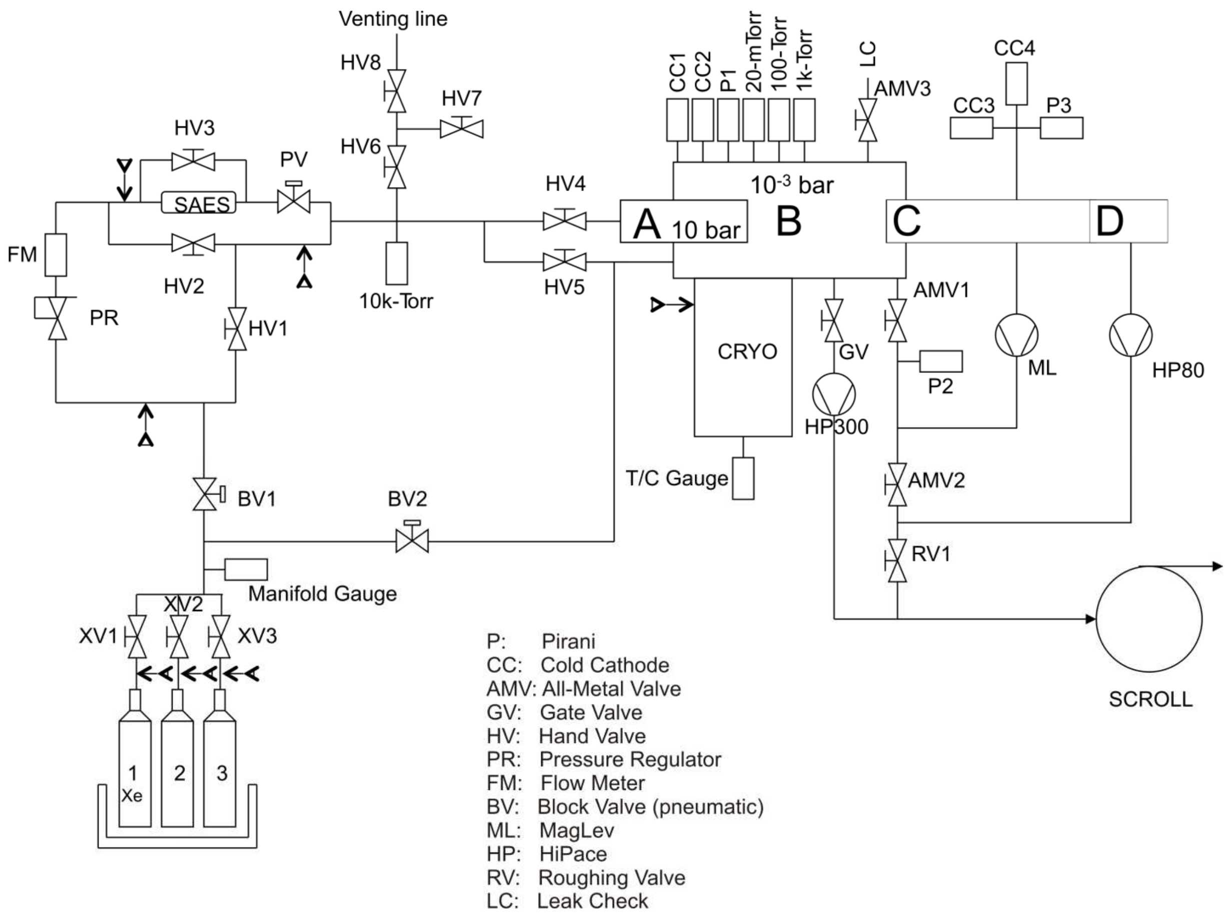

Figure 1 Piping diagram of the gXe setup at Stanford.

Vacuum readings before Xe gas flow

Prior to operating the Xe gas jet, all connections in the system were checked for He leaks. No leaks on a level of $2x10^{-10}$ Torr were found. During initial pumping the Xe gas supply lines were pumped independently through a small turbo pump connected to HV7. HV4 and HV5 were closed. The final pressures in chambers B and C were $5.7x10^{-8}$Torr and $4.3x10^{-8}$Torr, respectively. The vacuum in the Xe supply line was $3.5x10^{-7}$Torr with the small turbo pump being the limiting factor.

Prior to cooling the cryo pump and Xe gas jet operation the system was put in recirculation mode, i.e., AMV2 was closed and then AMV1 was opened. The resulting pressures in chambers B and C were $3.2x10^{-7}$Torr and $4.9x10^{-8}$Torr, respectively. Xe supply lines were still pumped through the test stand connected to HV7 at a pressure of $3.2x10^{-7}$Torr.

Once the cryo pump was turned on and had cooled down, the pressure readings were $9.5x10^{-9}$Torr (chamber B) and $4.4x10^{-8}$Torr (chamber C). At this point we closed GV and started gas jet operation.

Xe gas flow at 10 bar

During operation, the pressure in chamber A was set to 7505 Torr (10 bar). The gas flow rate through the converging-diverging nozzle was constant at 0.33g/s (Figure 2). Pressure in chamber B increased from 0.00232Torr to 0.00243Torr over 20 mins of Xe jet operation (see Figure 3). No pressure could be measured in chamber D because the pressure was out of range of the gauges installed on the chamber, i.e., higher than 10^{-4} Torr, too high for the cold cathode to measure, and below 10^{-3} Torr, where the Pirani gauge P3 bottoms out. The temperature of the cryo pump increased during Xe gas flow (see Figure 4). At around 18:28 the temperature of the 1st stage spiked to about 80K. The time roughly correlates to the time when we performed RF tests at a constant output voltage. During these measurements the output voltage of the frequency generator was kept constant while the frequency was increased. We will monitor this behavior closely in future Xe jet operations. Gas-flow rate and pressure in chamber B stayed more or less constant during the spike of the temperature reading of the 1^{st} stage.

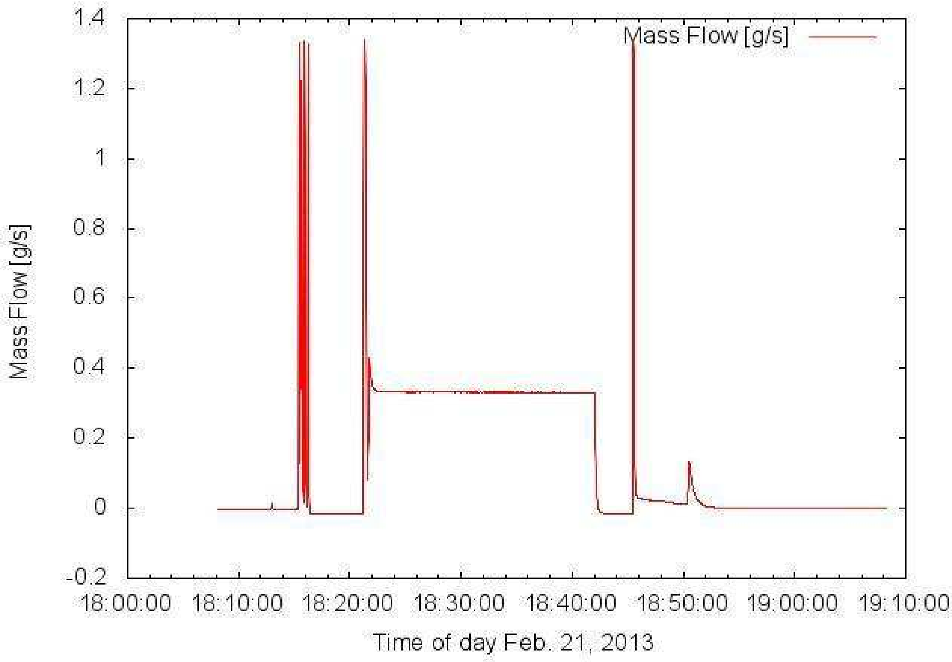

Figure 2 Mass flow during Xe gas jet operation (18:22 to 18:42).

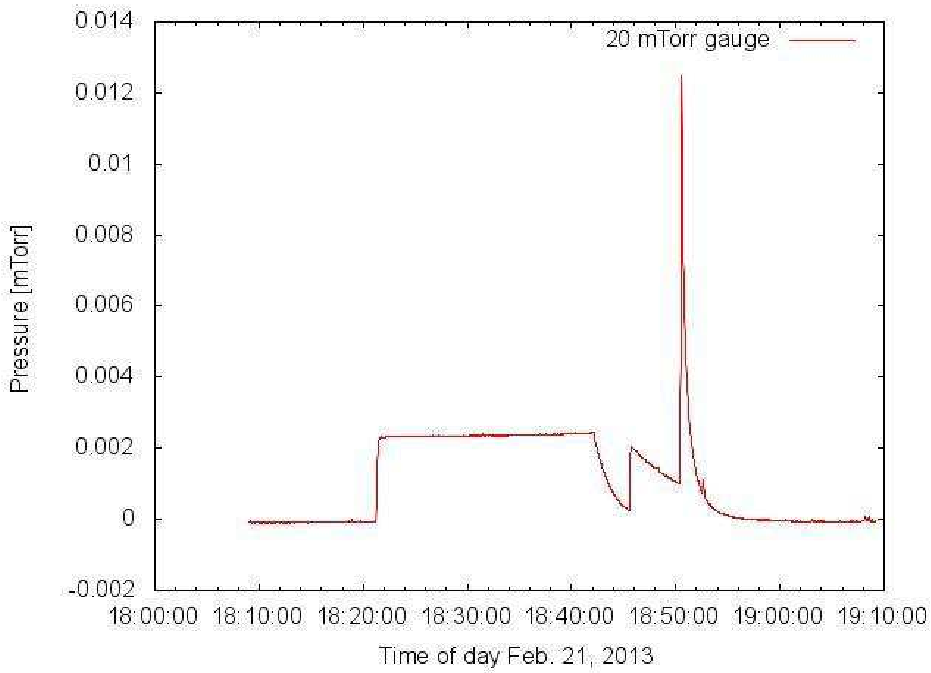

Figure 3 Pressure in chamber B during 10bar Xe operation (18:22 to 18:42).

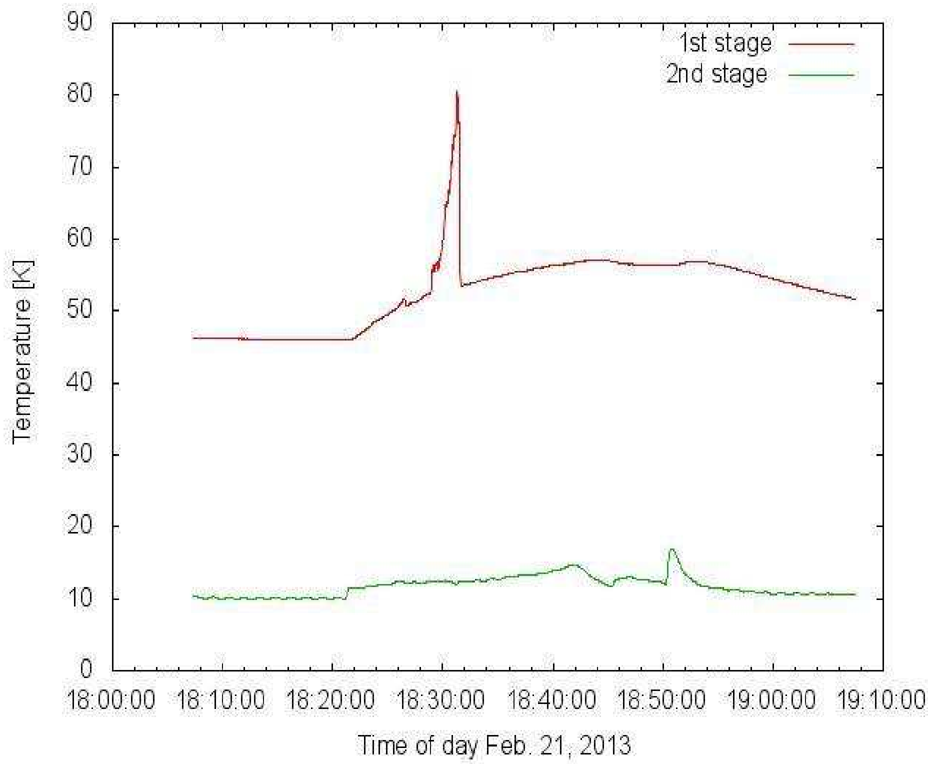

Figure 4 Temperature of the cryo pump during Xe gas jet operation (18:22 to 18:42).

Capacitance of RF-funnel setup

The capacitance of the RF-funnel stack including the Cu wires was measured at various moments during the installation. Typically, an Agilent U1732A device was used to measure the capacitance. All measured values are listed in Table 1. We measured the capacitance of the funnel stack with and without Cu wires while the RF funnel was assembled on a table. Afterwards, the capacitance was measured with the funnel assembly mounted inside of chamber B. Measurements were taken with chamber B at atmosphere, under vacuum and during operation of the 10 bar Xe gas jet.

Table 1 Capacitance of the RF-funnel.

Location of RF funnel	**Capacitance @ 1kHz**	**Capacitance @ 10kHz**
Funnel on table without Cu wires	6.026nF	
Funnel on table with old Cu wires connected	6.086nF	
Funnel on table with 10 bar N2	6.055nF	
Funnel installed inside vacuum chamber at air with new Cu wires connected	6.046nF	6.059nF

Funnel installed inside chamber B at vacuum (2.8x10^{-8}Torr (B) and 7.9x10^{-9}Torr (C))	6.041nF	6.052nF
Funnel installed inside chamber B with Xe gas flowing at 0.33 g/s (10bar)	6.016nF	6.028nF

Electrical short tests

Prior to the Xe-gas flow tests the setup was checked for electrical shorts: none were found. In addition to measuring the capacitance of the funnel mounted inside chamber B, the proper connections of Cu wires were verified by measuring the conductance while shorting the stacks of electrodes.

RF applied to the funnel

A function generator (HP 3325A) created a given sinusoidal waveform at a given frequency. This was then fed to an amplifier (EIN 350L RF-power amplifier), and then coupled into the RF funnel through a balun (Balun Designs Model 1413t 1:4/3kW). RF voltages were applied to the funnel in several conditions.

RF applied to funnel on table

Two tests were performed while the RF funnel was still mounted on the assembly table. In one test the frequency was kept constant at 2.6MHz while increasing the amplitude output of the frequency generator. In the other test, the output voltage of the frequency generator was kept constant while varying the frequency. The peak-to-peak voltage on the funnel was measured, as well as the power at the amplifier. The resulting plots are shown in Figures 5-8, with this run being labeled “air 1”. At 2.6MHz and a frequency generator output of 540V_{PP} the measured voltage at the balun was 55V while the voltage measured at the funnel electrodes was 58V.

RF applied to funnel inside chamber B at air

After installing the RF funnel inside chamber B we changed the copper wires. At atmosphere, with one CF8” port still open, the initial voltage tests were repeated. The voltage was measured directly at the funnel. In the plots shown in Figures 5-8, this run is referred to as “air2”.

RF applied to funnel inside chamber B in vacuum

The RF voltage tests were repeated with chamber B at a pressure of 4x10^{-7}Torr. Here, the voltage is measured at the balun, as the funnel is no longer accessible. In the plots shown in Figures 5-8, this run is referred to as “vac”.

RF applied to funnel inside chamber B with Xe gas flowing

The RF voltage tests were repeated with the Xe gas jet on. Here the voltage is measured again at the balun, as the funnel is no longer accessible. In the plots shown in Figures 5-8,this run is referred to as “gXe”.

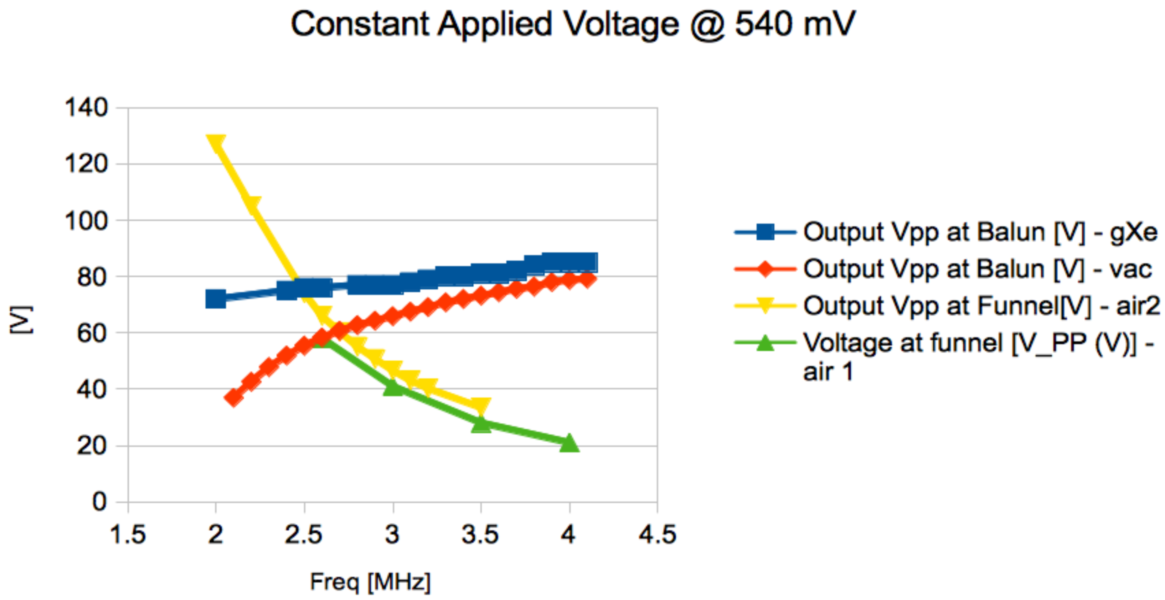

Figure 5 Output voltage as a function of frequency for constant amplitude of the frequency generator of 540mV. Note that the curves labeled as 'air' were measured directly at the funnel while the other two curves were measured at the output of the balun.

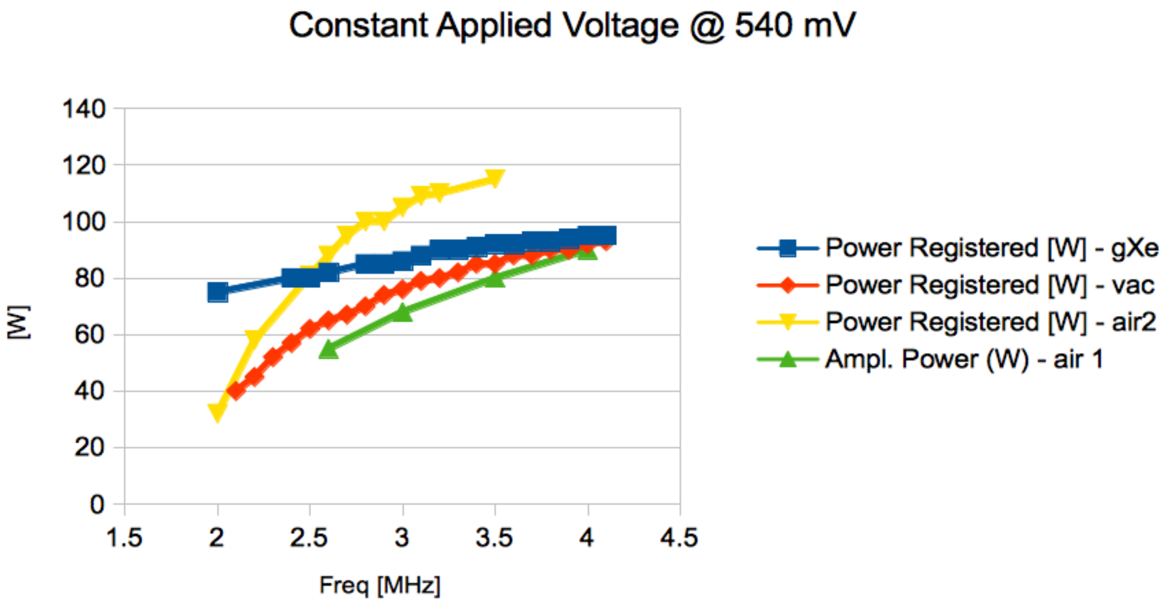

Figure 6 Amplifier power reading as a function of frequency for constant amplitude of the frequency generator of 540mV.

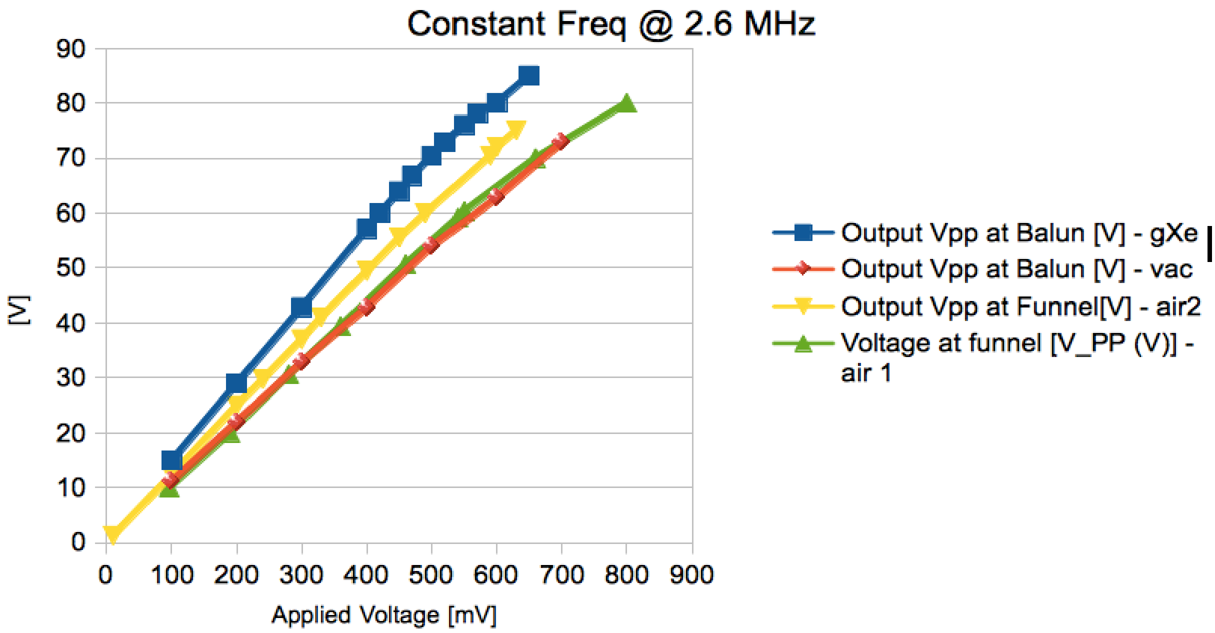

Figure 7 Output voltage measured at balun or funnel as a function of frequency generator voltage amplitude. The frequency was kept constant at 2.6MHz.

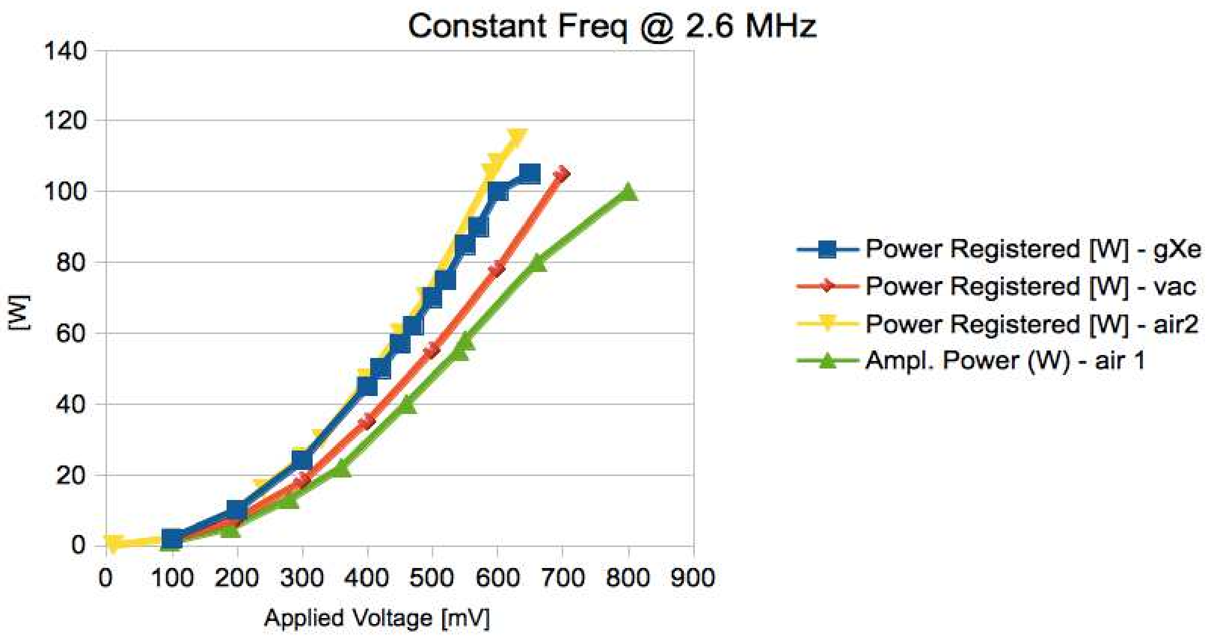

Figure 8 Power reading at the amplifier as a function of frequency generator voltage amplitude. The frequency was kept constant at 2.6MHz.

Status and Plans

The system is currently being evacuated with GV open and AMV1 closed. Chamber C and the Xe gas lines (HV5 open) were pumped together and the base pressures were 2.2×10^{-8}Torr (B) and 4×10^{-9}Torr (C). The test stand is at 1.3×10^{-7}Torr.

We are currently working on manufacturing a single-Ba ion source based on the principle of the Gd-driven Ba ion source developed at Stanford (Rev. Sci. Inst. **81** 113301 (2010)). This source will be fabricated in week 11. In the meantime we will install the source holder inside of chamber A and re-run the Xe gas to verify that the holder does not reduce the gas flow. We will also repeat the RF measurements to verify our original observations.

For the downstream ion transport we are developing an RF-ion guide. Simion simulations are converging. The current concept applies a sixtupole-ion guide (SPIG). Simulations show that an additional electrostatic longitudinal drag field increases the transport efficiency from ~50% to ~70%. We investigated the possibilities of using resistive PEEK or graphite rods as ion guide material to create such a drag potential. However, these were ruled out for failure to couple RF in, and requiring too much current to create the desired voltage drop, respectively. Another option that we are currently investigating is a SPIG with diagonally split rods. This concept is similar to the one used at LEBIT/NSCL (http://dx.doi.org/10.1016/S0168-583X(02)02114-6 and http://dx.doi.org/10.1016/j.nima.2004.06.046). A schematic of the concept is shown in Figure 12 and Figure 13. We plan to hand the drawings to the machine shop by the end of next week. By the end of April we are planning to install the SPIG and will then start initial tests on the transmission of the setup in May.

Appendix

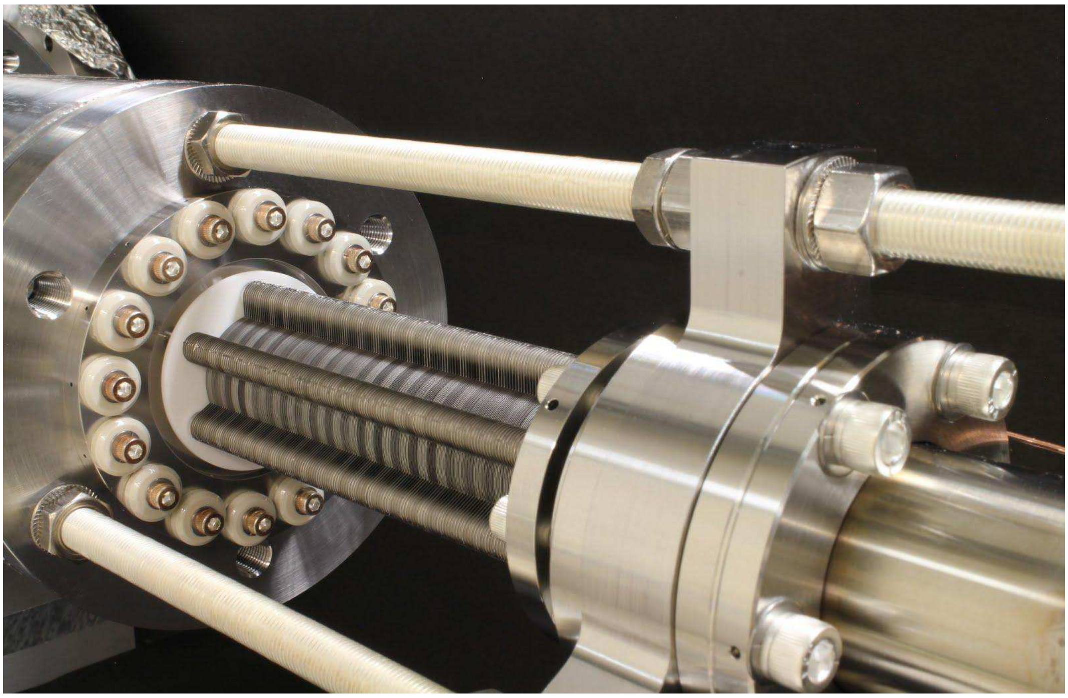

Figure 9 Picture of the RF funnel assembly.

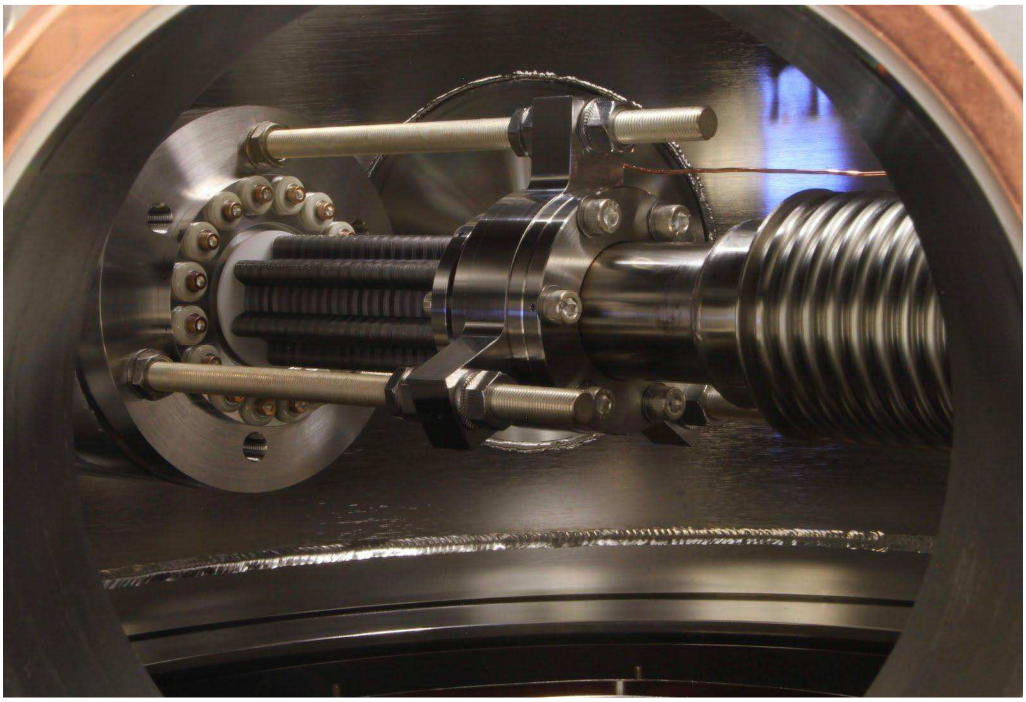

Figure 10 RF-funnel assembly installed inside of chamber B. At the bottom of the picture the metal sheets of the cryo pump are visible.

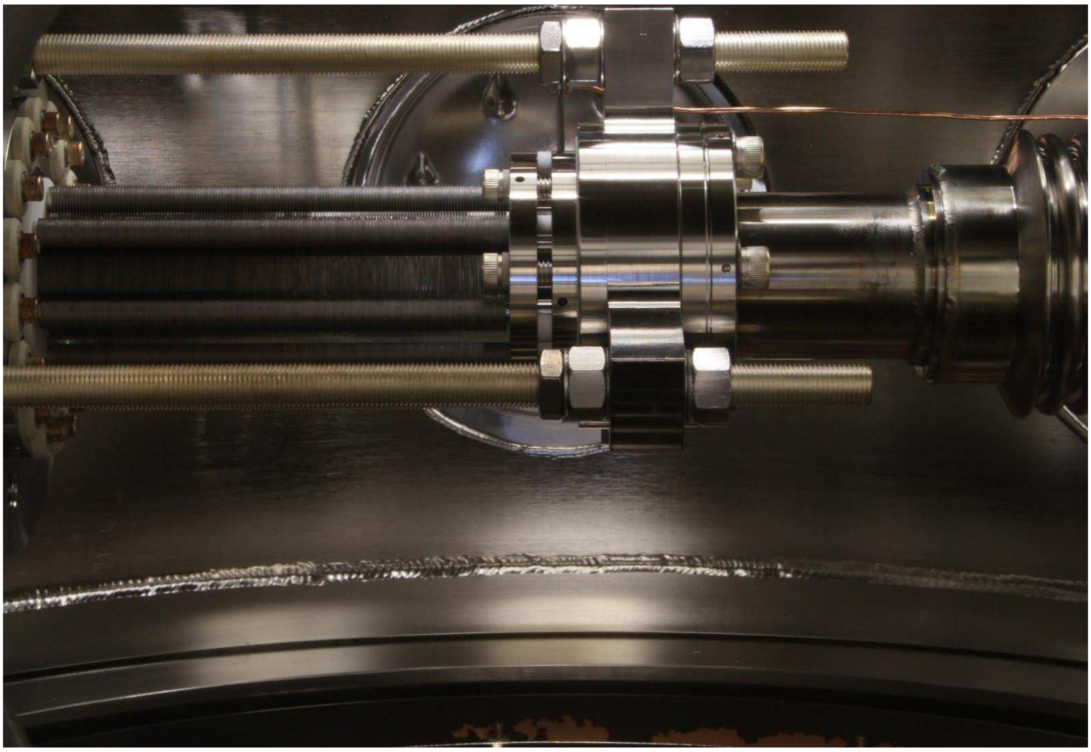

Figure 11 Side view of the funnel installed inside chamber B.

SPIG concept

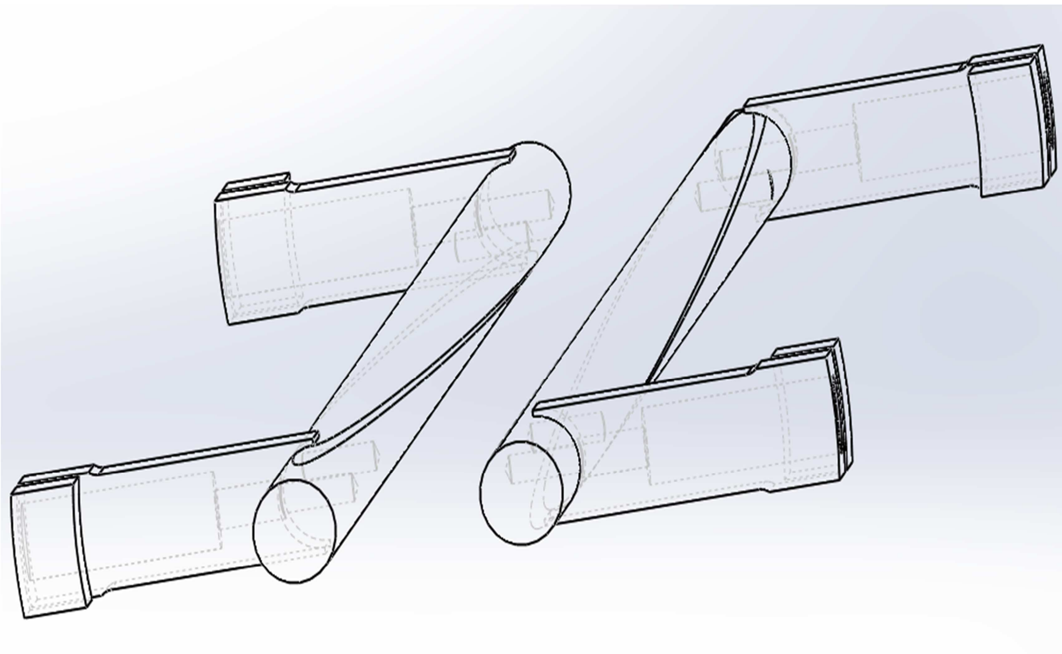

Figure 12 Two poles on opposite sides of the split SPIG, showing what the splitting looks like.

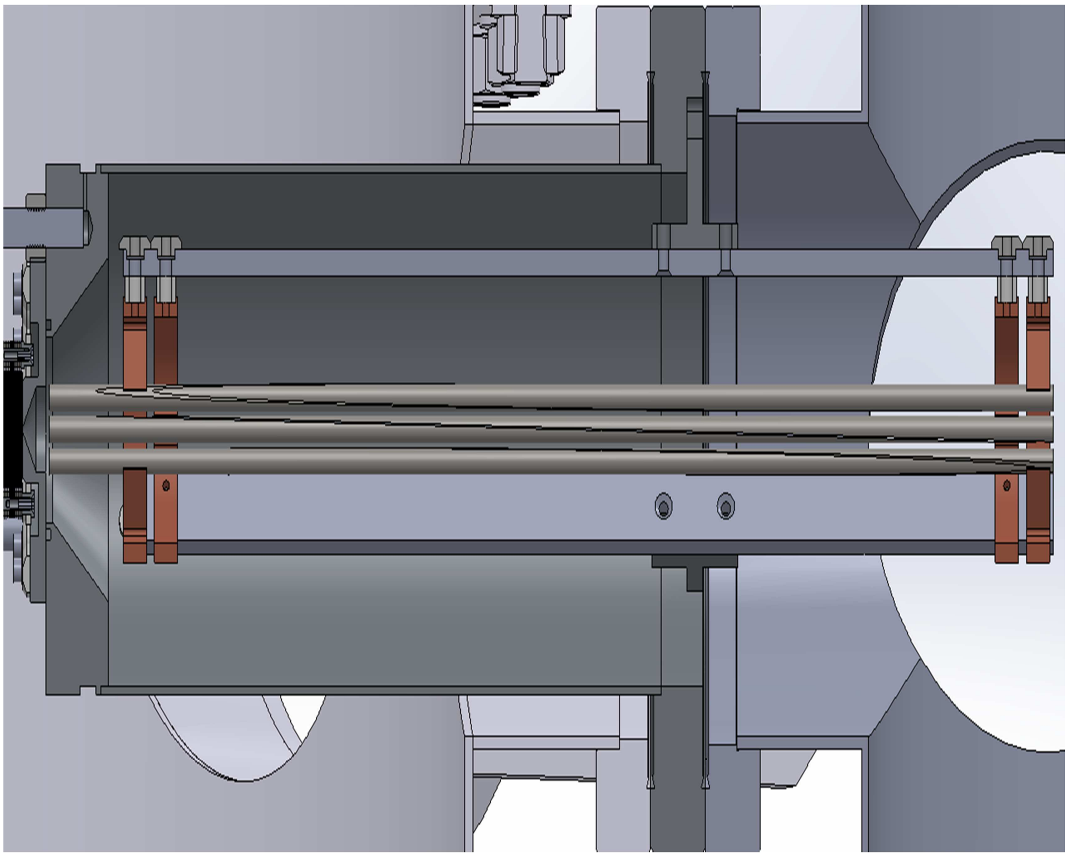

Figure 13 Sectioned side view of the segmented SPIG installed inside of chamber C. The exit aperture of chamber B is shown on the left side of the picture.