Preparations to discharge the test mass at LHO ETMY and possible hypotheses for the charging of the test masses.

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After shipping from MIT and the last use of the ionizer in 2010 we decided to test the instrument for contamination before mounting it on the ETMY test mass chamber. An RGA was mounted on the ionizer after the gate valve. The entire system including the RGA was baked at 100C for a weekend. The low bake temperature was used because of Viton O rings in the ionizer and soft solder joints between the series resistors and the needles in the ionizer head. **Figure 1** shows the residual pressure difference with the gate valve on the ionizer open and closed which gives the ionizer outgassing .

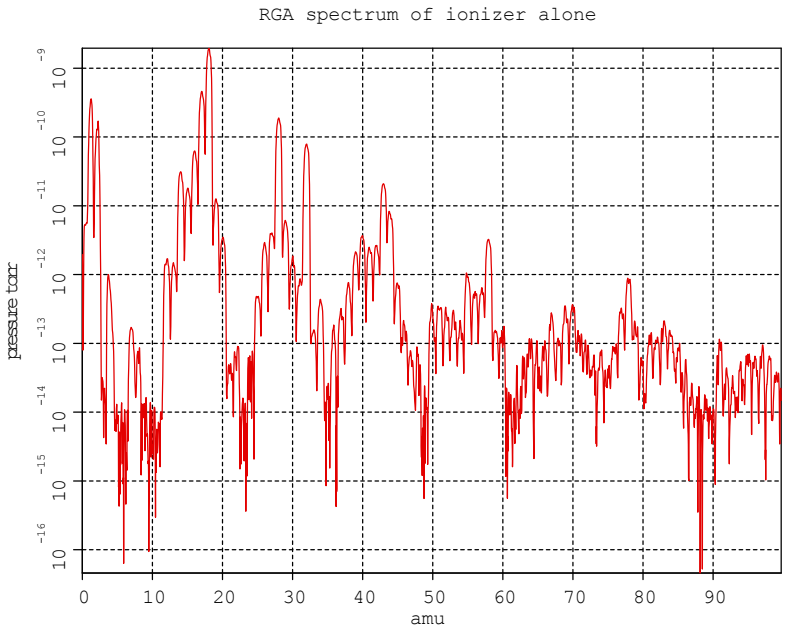

Figure 1 The RGA spectrum of the ionizer assuming 2.3 x 10^{-3} torr/amp with a SEM voltage of 1600 Volts. The hydrocarbon pressure is approximately 10^{-13} torr with a pumping speed of 10 liters/sec. The fraction of hydrocarbons in the nitrogen stream going into the test mass chamber will be about 10^{-15} .

Kate Gushwa and Calum Torrie placed a glass witness plate at the output of the ionizer to measure dust. The ionizer was run for 4 hours under the flow conditions expected when filling the test mass chamber. The sample (Serial # 245) will be analysed at Caltech in the next few days but did not show an easily seen amount of dust when it was removed from the ionizer. Kate and Calum did see metallic shards in the ionizer tubing which we believe came from the silver plated screws holding the Conflat flanges together.

An additional contamination reducing strategy we had hoped to use was a helical heat exchanger comprised of a pair of nested tubes with liquid nitrogen flow in the outer tube to trap frozen water or oil coming from the liquid nitrogen boil off gas. This gas is the carrier for the ions into the test mass chamber. A second heat exchanger was placed in series to bring the gas back to room temperature. It turns out the liquid nitrogen storage dewar allows an over pressure of 100 psi on the boil-off gas which was not enough to give the 300 to 400 torr pressure on the needles to achieve balance of the positive and negative ions into the ionizer output stream. The tubing impedence is too large. The dust test mentioned above was done without these additional components. In the final installation when we discharge the test mass, a simple one loop trap at liquid nitrogen temperature will be used in the feeder line to the ionizer. (if the instrument passes the dust test).

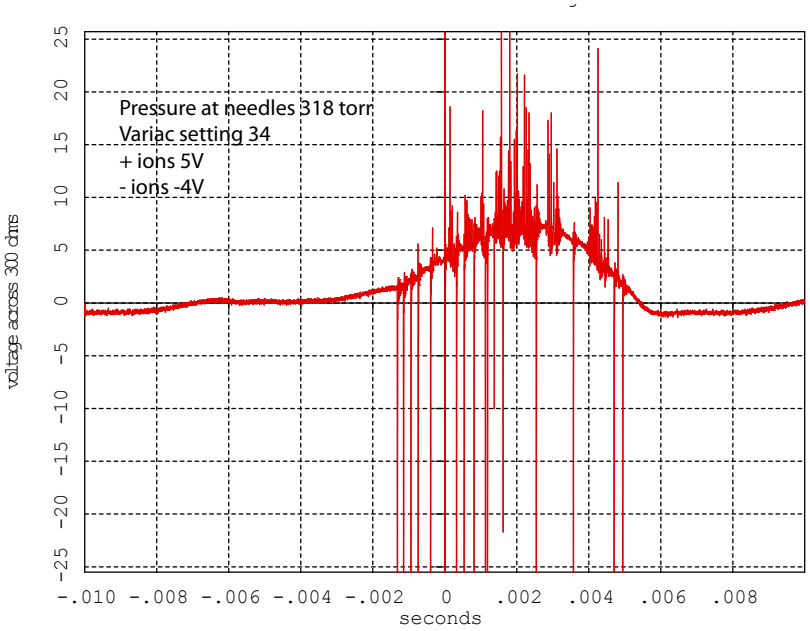

Figure 2 The current from the needles to ground over one period of the 60Hz excitation. 1 volt corresponds to 3 ma. Under the operating conditions of 318 torr pressure at the needles and a voltage of approximately 3KV peak on the needles, the output stream has approximately equal number of positive and negative ions . The positive and negative ion current is about 10^{-10} amperes assuming a collection efficiency of 1/300 in the electrometer sampling system.

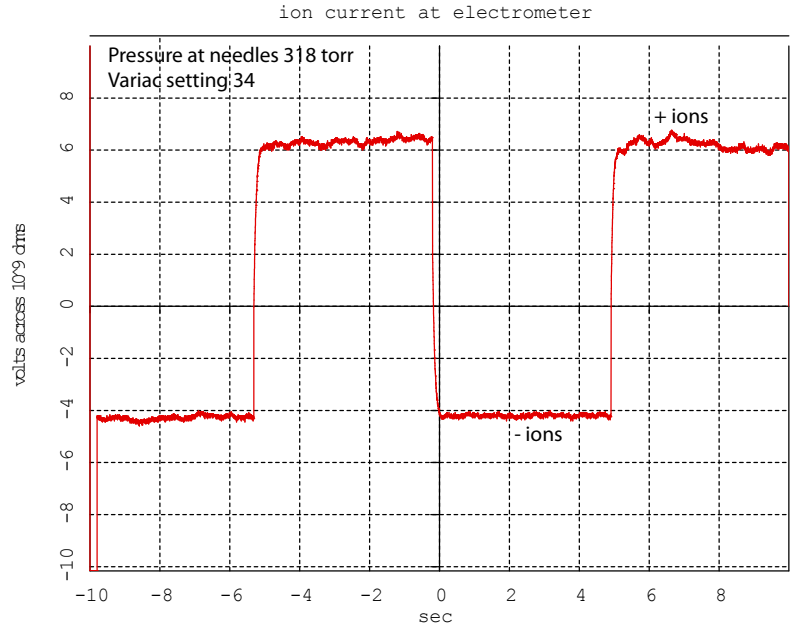

Figure 3 The electrometer output when the control electrodes are driven by a 20 volt p-p square wave at 0.1 Hz. The sampling resistor is 10^9 ohms and the voltage gain =1.

Speculations on why the test mass charge is so large compared to the tests done at MIT

The most likely reason is the first contact mirror surface cleaning process which was not yet being used when the LASTI suspension prototype was assembled. The plastic film as it is removed from the optic leaves significant charge on both the film and the optic. This was known when the technique was invented and a process of deionizing was applied as the film is removed. A portable electrometer measures the remaining charge. The sensitivity of the electrometer is 100Volts which translates to a surface charge of 4×10^{-12} coulombs/cm^2. The surface charge densities that cause the masses to be charged are significantly smaller than the best sensitivity of this electrometer. If the charge is on the front face of the mass it is about 1/50 and if on the same side as the electrodes 1/500 the sensitivity of the electrometer.

The other hypothesis is double quantum emission due to the green (2eV) photons used in the lock acquisition which were not used in the initial tests at MIT. The quantum efficiency of the process need not be larger than 10^{-12} to cause the charging observed. There are no good numbers for the work function of the fused silica surface other than a measurement made by Robert Noyce (yes, the same guy who started INTEL) at the Research Lab for Electronics at MIT in the middle 1950's. He measured a work function of 4.5 eV but could not really account for surface layers and other contamination which might have been on the surface. If the two photon process is responsible the external injection of a neutralizing gas will not work for LIGO as the charge will reappear with each locking event. It is quite unlikely that two photon emission is the problem but once the masses are discharged we should test to see if they reacquire a charge after the green light is incident on the masses.