Residual Gas Analyzers and the LIGO Interferometer

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Abstract

A major part of the interferometer is the ultra high vacuum (UHV) system, which provides the conditions and environment required for low noise operation of the interferometer. Residual gas analyzers (RGAs) are installed at different parts of the UHV in order to monitor the type and quality of the various molecules and atoms present in the system. Proper calibration of the RGA is essential for a number of reasons. The three main ones are; reduce residual gas noise, prevent contamination from hydrocarbons that coat the optics of the interferometer, detect leaks from venting and general leak detection. There have been a total of two detections as of today; thus, even more sensitive equipment is sought after to acquired better data sets. In order to reach design sensitivity, we will need to carefully measure and understand the impact of residual gas on the sensitivity of the detector. The process for preparing an RGA for installation, the initial scans and the process by which the results are calibrated will be described.

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Introduction

The Laser Interferometer Gravitational Wave Observatory (LIGO) is a government funded physics experiment that consists of two testing sites that are widely separated. LIGO is a "large-scale" physics experiment that detects and observes gravitational waves at a cosmic and astronomical level. The two sites that these experiments take place are located in Hanford, California (LHO) and Livingston, Louisiana (LLO). The part of LIGO used for the investigation of gravitational waves is the interferometer, which is a more sophisticated version of the 1880's Michelson Interferometers. An interferometer is a device that merges light sources to create interference. This interference is read and collected as data and is used to detect as well as differentiate gravitational waves on earth and in space. The interferometer is operated under ultra high vacuum (UHV) conditions, which is the pressure region less than 10^{-9} torr. This is achieved by pumping out gases from the systems chambers. The different equipment used to achieve UHV conditions will be looked at in more detail later on in the paper.

A Residual Gas Analyzer (RGA) allows the user to measure the gases present in low-pressure environments. It is an essential tool to measure performance of the ultra high vacuum (UHV) systems. It allows one to know the chemical species involved in gas phase reactions and can help one to determine which reactions are most important. The principle of operation is the same for all RGA instruments: A small fraction of the gas molecules are ionized (positive) and the resulting ions are separated, detected and measured according to their molecular masses.

Equipment and Methodology

To begin setting up the RGA we first took all the parts being used to a clean room. This is to prevent contamination of the sensitive parts. Parts such as the 'O' rings are to be clean and absent of dust particles hence, the use of a clean room. Below is a picture of the filament and calibrated leak;

Fig 1: Filament

Fig 2: Calibrated Leak

The calibrated leak and filament are bolted together with other valves and other vacuum components to make the RGA manifold. Below is a picture if the coupled calibrated leak and the filament to give the RGA manifold. It should be noted that the filament has not yet been baked.

Fig 3: RGA manifold

It is good vacuum practice to leak check all components that are going to be added to the main volume to ensure that there are no leaks or defects with the part to be installed. Therefore, it should be noted that the RGA manifold pictured above was leak checked

even before baking the filament as well as after installation and baking. The leak check procedures will be outlined later in the paper.

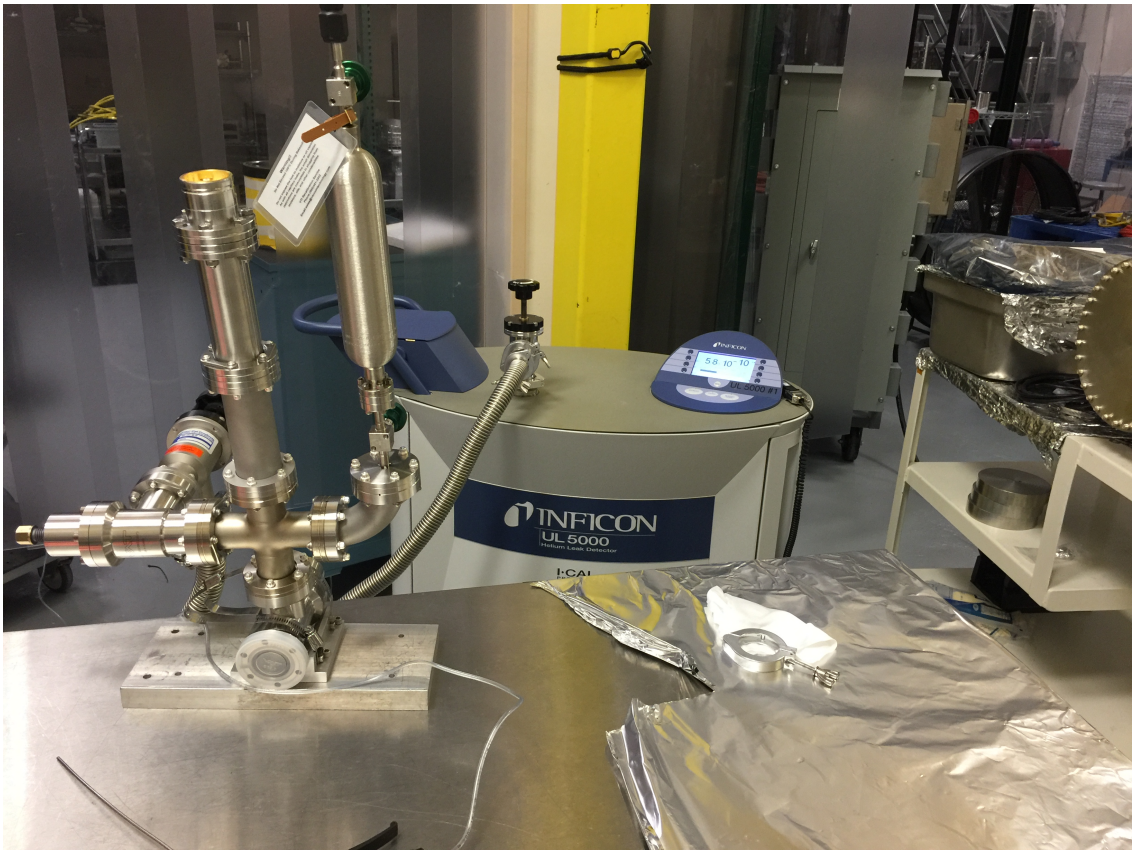


Fig 4: Leak Checking RGA Manifold

Upon passing all leak checks required, the RGA manifold will then be installed on the main volume. The locations of the RGAs installed for the purpose of this paper are the vertex and HAM 6.

Leak Detection

In Vacuum, leak detection is usually done with the use of helium. Hence, the term helium leak detection. Helium is the best choice of tracer gas to find leaks due to its small atomic size. Thus, helium passes easily through leaks.

Isolating the various parts that are to be leak checked is the first step to leak checking. This isolation is done by wrapping said part with airtight material such as a plastic bag and some tape, to prevent outside air from interfering with the leak checking process. After ensuring that the part to be leak checked is airtight, a helium detector is contacted to the desired part and the desired pressure of helium is input to the detector and recorded. Helium is then spared at a controlled rate unto the part being checked, if a leak exists, the helium detector pressure will change (increase). It should also be noted that this detection is done under vacuum conditions.

After the leak checking, the RGA manifold needs to be installed and baked to get rid of impurities that the filament may have. With the help of members from the vacuum team at LLO, we installed the RGA manifold pictured below unto HAM 6 located in the LVEA. Another RGA was built and installed unto the vertex. Since the RGAs are going to be introduced to the main volume, their installation was done in a clean room with the parties involved wearing a full bunny suit. To also prevent contamination of the main volume, there is a gate valve in-between the RGA manifold that was installed on HAM 6.

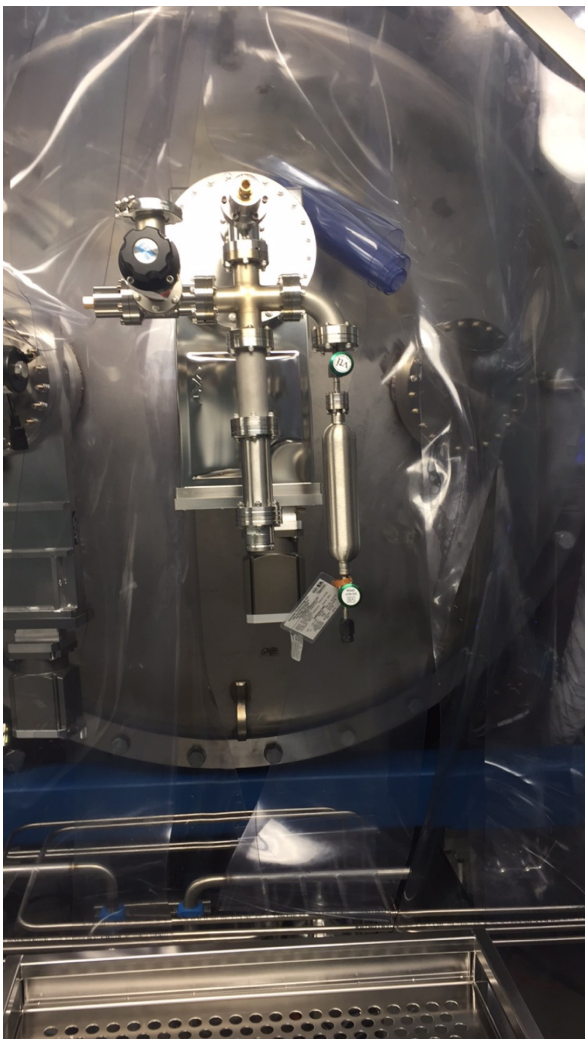


Fig 5: RGA manifold on HAM 6

After the installation, we prepared the RGA for baking by wrapping it in heat tape and foil. A cold cathode gauge as well as a turbo pump was used to pump down and monitor the pressure of the RGA during baking. Also, temperatures in Fahrenheit and Celsius were monitored as baking is to be done at a temperature of about 150^{o}C. Prior to baking, scans were taken for understanding as well as to know if the RGA was functioning properly.

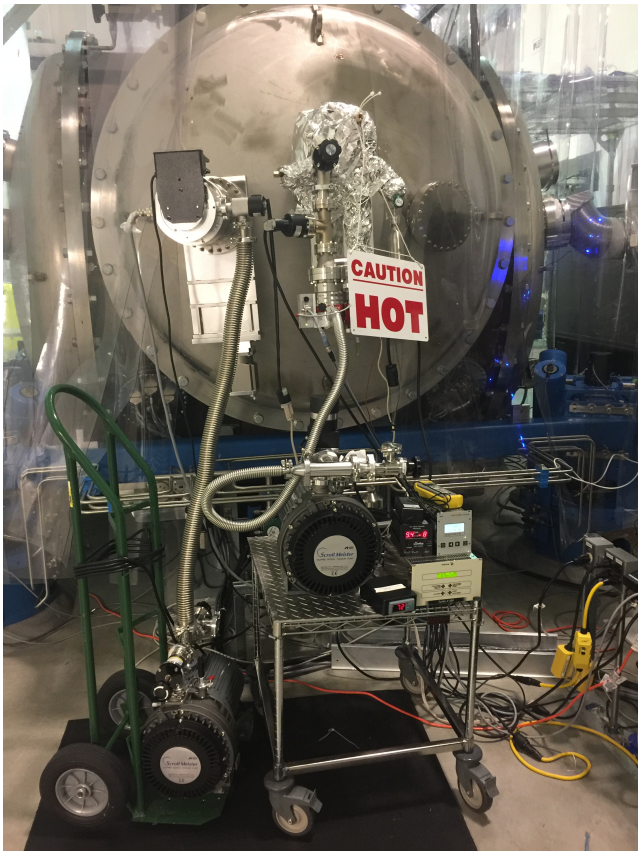
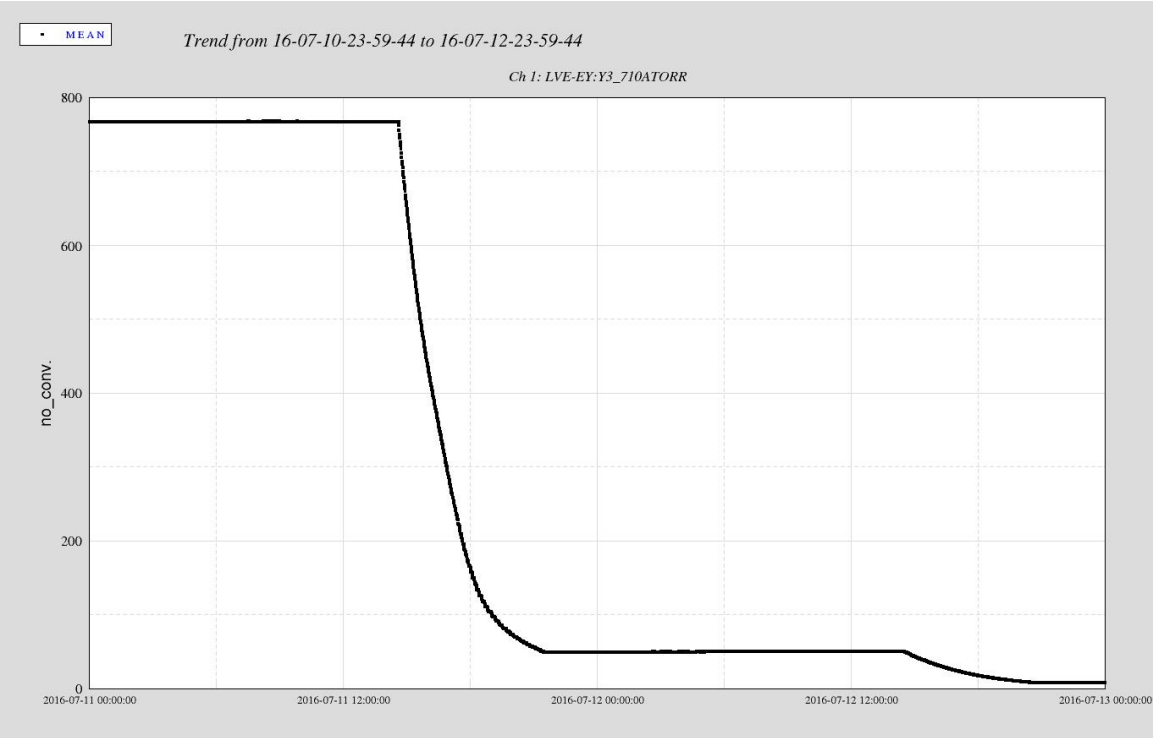


Fig 6: Baking of RGA

Results and Discussion

In this section we will be looking at the scans taken from the RGA set up. Also, the trend of roughing down a BSC will be looked at and discussed. The graph below shows the trend of a typical rough down. The excel file showing the data of the rough down pressures is also present.



x- axis: Time

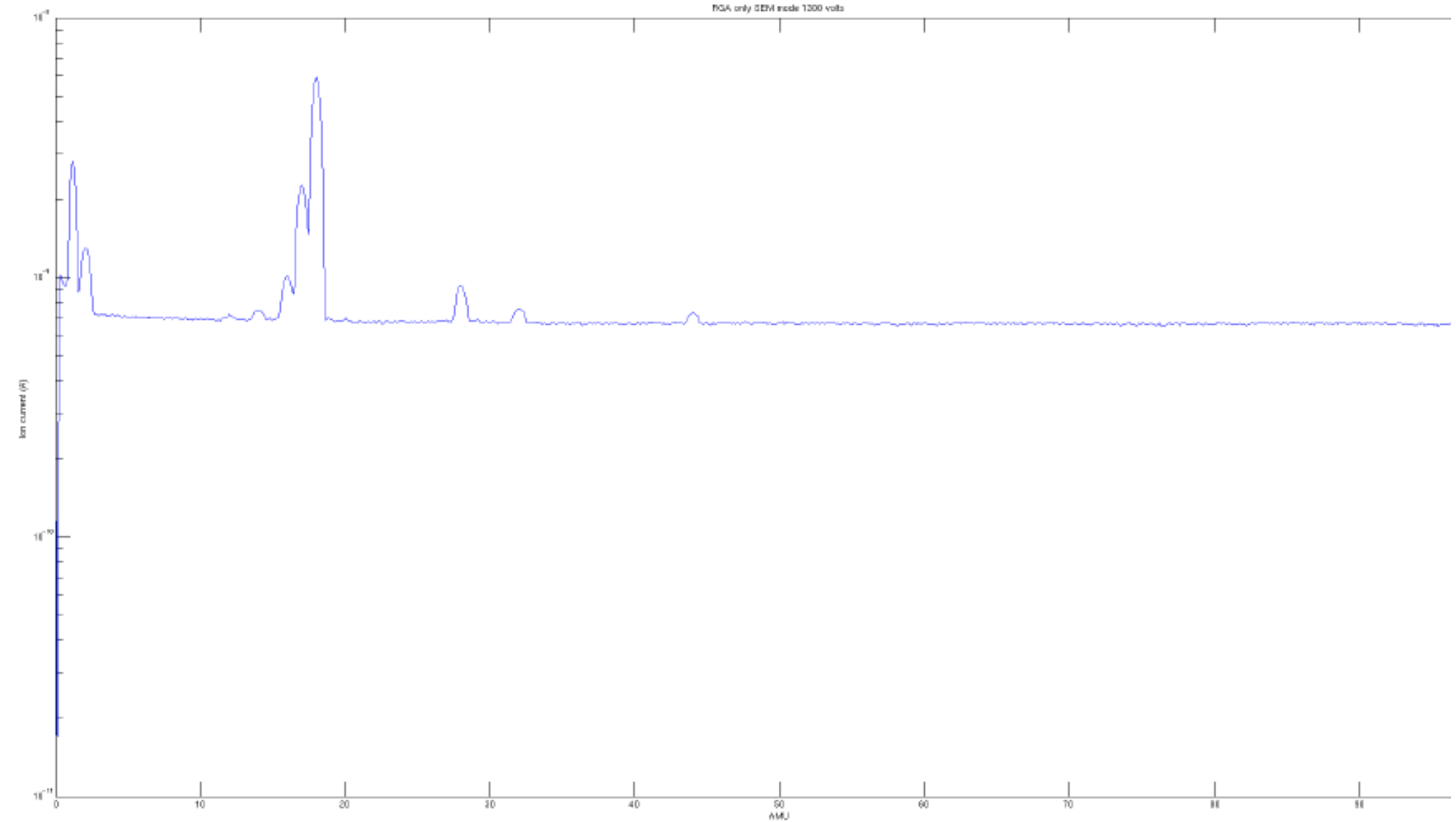
y-axis: Torr

Rouging Down of BSC 5

Date	Time	SEIKO (P1 and P2) (torr)		Baratron(mmHg)	Annulus Cold Cathode (
11/7/16	9:30	OPEN MAIN GV and EQUALIZING			
	9:50	P1: 6.8 E+2	P2: 6.7 E+2	-28	
	10:00	P1: 6.4 E+2	P2: 6.3 E+2	-28	
	10:30	P1: 5.4 E+2	P2: 5.3E+2	-29	
	11:00	P1: 4.3 E+2	P2: 4.3 E+2	-30	
	11:30	P1: 3.6E+2	P2: 3.6E+2	-30	
	12:00	P1: 3.1 E+2	P2: 3.1 E+2	-30	
	12:30	P1: 2.8 E+2	P2: 2.8 E+2	-30	
	13:00	P1: 2.6 E+2	P2: 2.6 E+2	-30	
	13:30	ROUGHING STARTED			
	13:30	P1: 2.3 E+2	P2: 2.3 E+2	-30	2.60E-10
	14:00	P1: 2.0 E+2	P2: 2.0 E+2	-30	1.50E-10
	14:30	P1: 1.8 E+2	P2: 1.8 E+2	-30	1.20E-04
	15:00	P1: 1.6 E+2	P2: 1.6 E+2	-30	8.90E-05
	15:30	P1: 1.3 E+2	P2: 1.3 E+2	-30	7.30E-05
	16:00	P1: 1.1 E+2	P2: 1.1 E+2	-30	6.30E-05
	16:30	P1: 9.2 E+1	P2: 9.1 E+1	-30	5.60E-05
11/7/16	16:35	PUMPING FOR THE DAY WAS STOPPED			
12/7/16	9:30	P1: 9.2 E+1	P2: 9.1 E+1	-30	2.40E-05
	9:32	OPEN MAIN GV			
	10:00	P1: 7.4 E+1	P2: 7.4 E+1	-30	2.40E-05
	10:30	P1: 6.1 E+1	P2: 6.0 E+1	-30	2.30E-05
	11:00	P1: 4.7 E+1	P2: 4.7 E+1	-30	2.30E-05
	11:30	P1: 3.8 E+1	P2: 3.8 E+1	-30	2.30E-05
	12:00	P1: 3.0 E+1	P2: 3.0 E+1	-30	2.20E-05
	12:30	P1: 2.4 E+1	P2: 2.4 E+1	-30	2.20E-05
	13:00	P1: 2.0 E+1	P2: 2.0 E+1	-30	2.10E-05
	13:30	P1: 1.8 E+1	P2: 1.8 E+1	-30	2.10E-05
	14:00	P1: 1.5 E+1	P2: 1.5 E+1	-30	2.10E-05
	14:30	P1: 1.3 E+1	P2: 1.3 E+1	-30	2.10E-05
	15:00	P1: 1.0 E+1	P2: 1.0 E+1	-30	2.00E-05
	15:30	P1: 8.9 E 0	P2: 8.9 E 0	-30	2.00E-05

	16:00	P1: 8.0 E 0	P2: 8.0 E 0	-30	2.00E-05
12/7/16	16:15	PUMPING FOR THE DAY WAS STOPPED			
13/07/2016	10:19	OPEN MAIN GV TO SEIKO TP			1.50E-05
	10:20	START PUMPING			1.50E-05
	11:00	P1: 6.7 E 0	P2: 6.7 E 0	-30	1.40E-05
	11:30	P1: 5.6 E 0	P2: 5.6 E 0	-30	1.40E-05
	12:00	P1: 4.8 E 0	P2: 4.9 E 0	-30	1.40E-05
	12:30	P1: 4.1 E 0	P2: 4.1 E 0	-30	1.40E-05
	13:00	P1: 3.6 E 0	P2: 3.6 E 0	-30	1.40E-05
	13:30	P1: 3.1 E 0	P2: 3.1 E 0	-30	1.40E-05
	14:00	P1: 2.8 E 0	P2: 2.8 E 0	-30	1.40E-05
	14:30	P1: 2.4 E 0	P2: 2.4 E 0	-30	1.40E-05
	15:00	P1: 2.2 E 0	P2: 2.2 E 0	-30	1.40E-05
	15:30	P1: 1.8 E 0	P2: 1.8 E 0	-30	1.30E-05
	16:00	P1: 1.3 E 0	P2: 1.3 E 0		1.30E-05
13/07/2016	16:20	TURBO PUMP STARTED			
		P1: 8.2E-1	P2 :2.8E-1	-30	1.30E-05

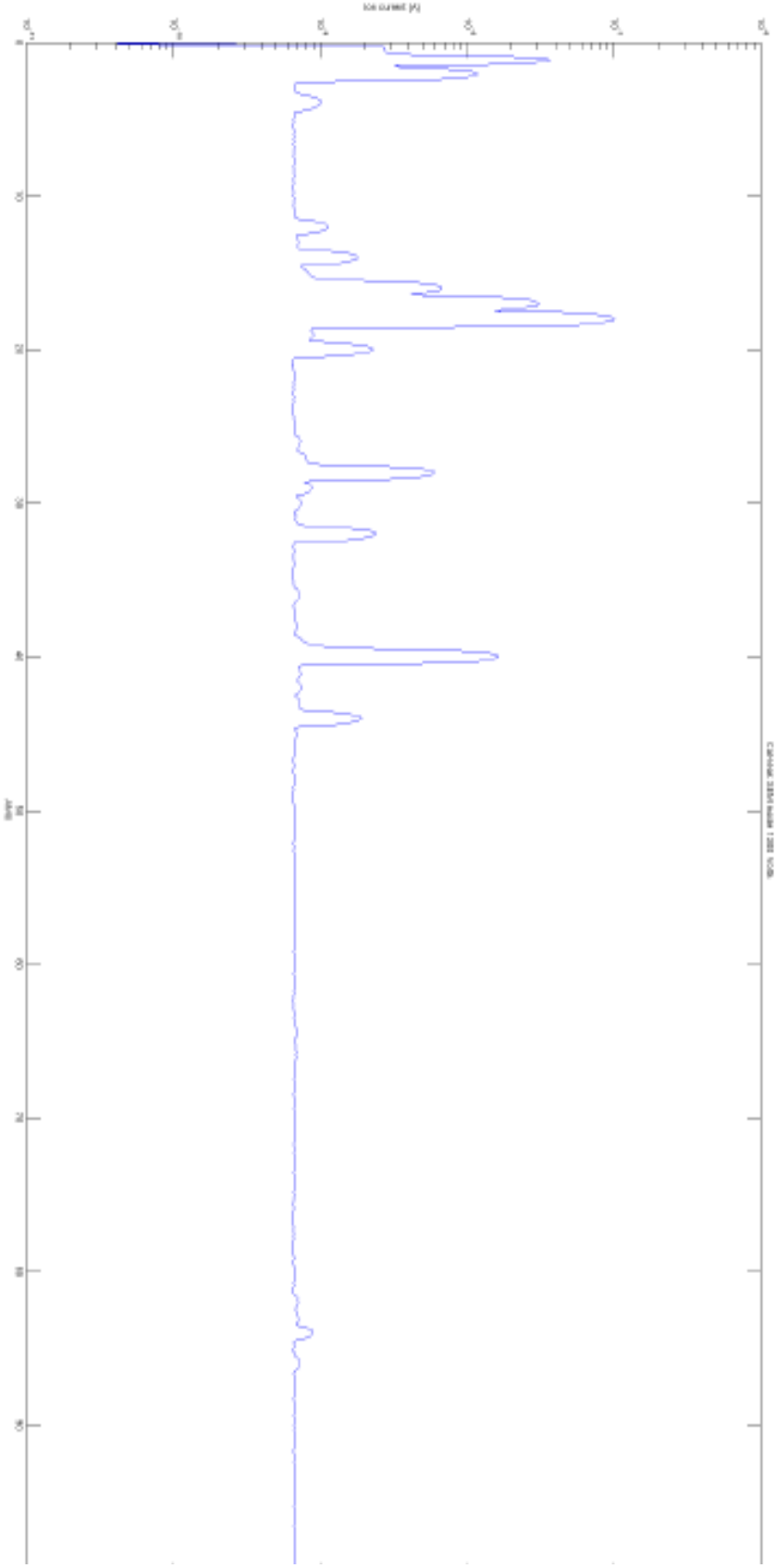
It should be noted that roughing down is a process that takes chambers such as BSC 5 to the required conditions for operation. In this case, vacuum pressures and molecular flow need to be achieved before the turbo pumps and tuned on. It can be seen on the trend above when the turbos ere turned on because of the sudden drop in the trend on the graph.


RGA only SEM mode 1300 volts
Ion current (A)
AMU
0
10
20
30
40
50
60
70
80
90

The above graph (turn anti-clockwise) shows the SEM pre bake scan for one of the RGAs installed. It can be noticed that there is a presence of a high noise floor. This high floor means that there are impurities present in the RGA and thus the filament needs to be baked. Therefore, baking the RGA filament is an essential step to ensure proper working and sensitive equipment. The result is an analogue scans data set. The RF/DC amplitude at which a peak appears is directly related to mass/charge on the ion. Amplitude is directly related to the number of ions produced within the ion source.

The next graph shows the SEM scan with the cal leak introduced. It is noticed that there are new a different peaks at different AMU. The cal leak for LIGO is a certain mixture of gasses.

RGA scans are taken post and pre bake. This is to have a visualization of how the volume being looked at by the RGA. Scans also help to know the level of impurities and potential leaks that maybe present.



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