Volume

1

BOSTON COLLEGE

Laboratory for Assembly & Spectroscopy of Emergence (LASE)

Vacuum Suitcase Technical Manual (redacted)

Vacuum Suitcase Technical Manual

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N.B – This version of the Suitcase Manual has been redacted to protect proprietary information

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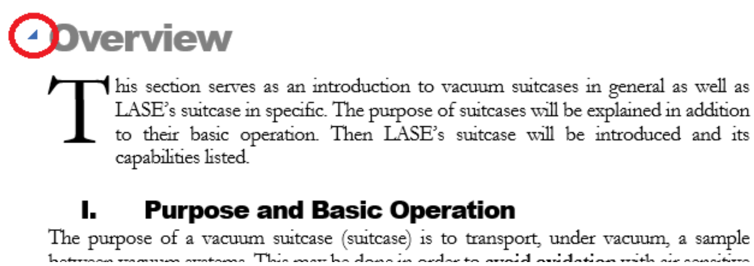
N.B. – Sections of this document can be collapsed / expanded by clicking the triangle next to a given section as seen below. This was done in order to make navigation of this document easier.


Overview

This section serves as an introduction to vacuum suitcases in general as well as LASE's suitcase in specific. The purpose of suitcases will be explained in addition to their basic operation. Then LASE's suitcase will be introduced and its capabilities listed.

I. Purpose and Basic Operation

The purpose of a vacuum suitcase (suitcase) is to transport, under vacuum, a sample

To find documents relevant to this project, see Chapter 6

Chapter

1

Overview

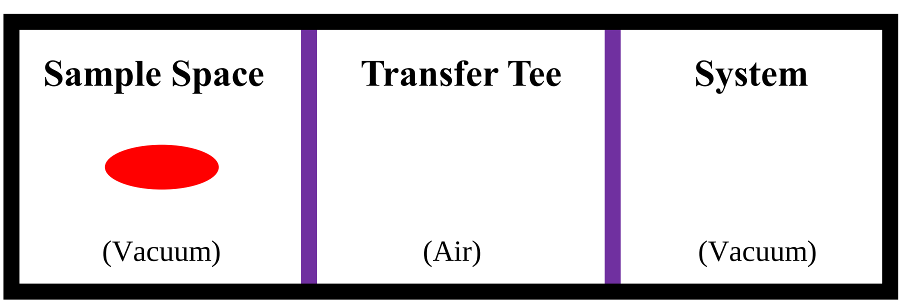
This section serves as an introduction to vacuum suitcases in general as well as LASE's suitcase in specific. The purpose of suitcases will be explained in addition to their basic operation. Then LASE's suitcase will be introduced and its capabilities listed.

I. Purpose and Basic Operation

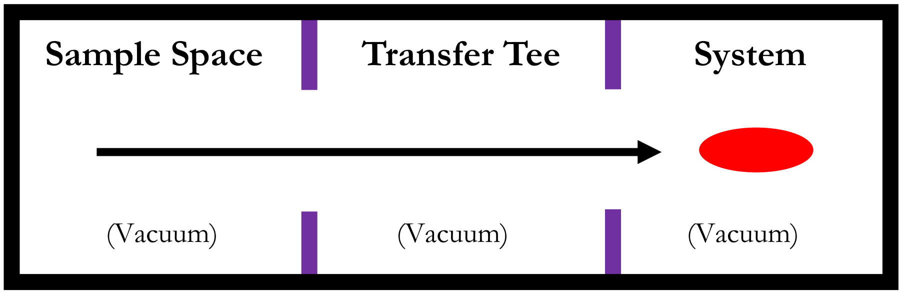
The purpose of a vacuum suitcase (suitcase) is to transport, under vacuum, a sample between vacuum systems. This may be done in order to **avoid oxidation** with air sensitive samples or to **prevent sample degradation** due to air contaminants such as dust or water.

A vacuum suitcase is composed of two basic parts – a **sample space,** which is *always* kept under vacuum and in which samples being transported sit, and a **transfer tee** which is pressurized/vacuumed as necessary to attach/detach the suitcase from whatever system the suitcase might be transferring into/out of. These two parts of the suitcase are separated by a **valve**.

The transfer tee of the suitcase is attached to a valve on whatever system the transfer is occurring. At this point, the sample space and system are under vacuum (as always), and the transfer tee is filled with air. The sample is in red and the valves are in purple below.



The transfer tee can then be vacuumed out, leaving all three volumes under vacuum. At this point, the valves may be opened and transfer of the sample from the sample space into the system can occur:



II. Compatible Systems

LASE's suitcase is compatible with three systems: the **Cleanroom-in-a-Glovebox** (via an intermediate chamber), the **magnet MARTI**, and the **Montana Cryostation**. The glovebox is also equipped to receive Unisoku style sample holders from Prof. Zeljkovic's lab.

III. Warnings

Some basic warnings regarding the operation of the suitcase are listed below:

I. Limiting Factors

Limiting factors are listed below with the responsible component.

1) **Maximum Bakeout Temperature: 150 ºC**
   a) **150 ºC** – CF 4.5 windows
   b) **150 ºC** – Manipulators – no loss of performance but anodizing fades
   c) **250 ºC** – PEEK traveler in manipulator head
   d) **260 ºC** – Manipulator selenium-cobalt magnets
   e) **300 ºC** – Manipulators PTFE bearings

2) **Maximum Temperature Ramp: 3ºC/min**
   a) **3ºC/min** – CF 4.5 windows

3) **Vacuum Levels:**
   a) **5e-7 mBar minimum** – Required for ZVS Ion Pump to operate
   b) **4.1e-8 mBar** – The lowest vacuum the intermediate chamber has reached

4) **Minimum bore hole size: 1.2 in.** - Clamping collar on manipulator head

5) **Manipulator Stroke:**

   a) **24 in** – BVS

   b) **30 in** – Intermediate chamber

6) **Manipulator Stopper to Face of Flange (includes width of stopper):**

   a) **4 in** – BVS

   b) **6 in** – Intermediate chamber

II. Mechanical Warnings

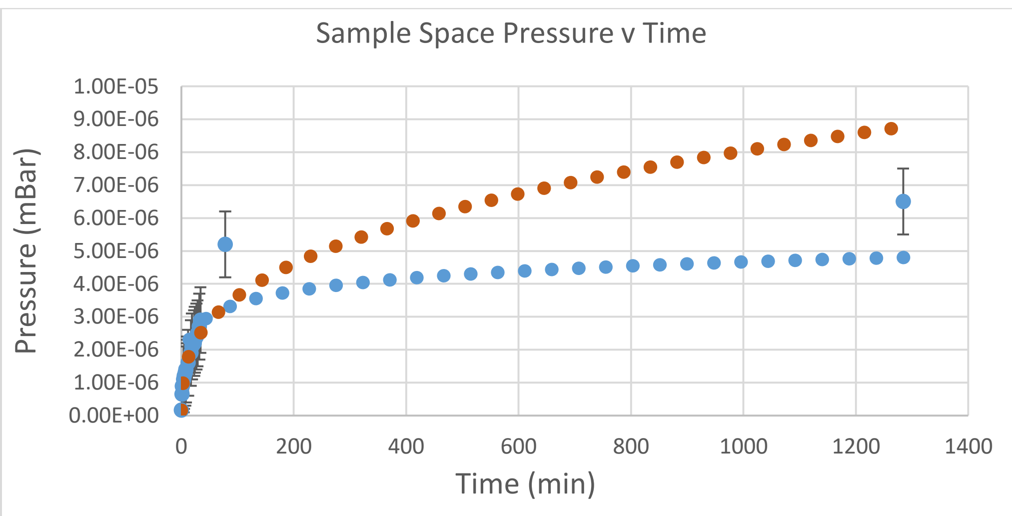
1) If screws are to be replaced, ensure that vented screws are used if the drill holes do not have a venting hole.

2) Manipulators will deflect or "sag" a bit the farther they are extended. The manipulators relevant to this project have an expected deflection of less than 3mm at full extension.

III. Vacuum Degradation

The BVS was not originally built with dedicated pumps on the sample space (although it was designed to accommodate them, see (Sec. 3.V.I). As such, the vacuum in this volume will degrade if it is not actively being pumped.

This degradation was tracked, and graph depicting the data with power law and exponential fits can be seen. It should offer a good estimation of the vacuum level inside the sample space as a function of time when it is not being pumped. Additional information can be found in Appendix III (Sec. 7.III)



Chapter

2

Vacuum Information

I. Standards

There exist two main standards for vacuum systems – **Quick-Flange (QF)**, sometimes called Kwik-Flange (KF), and **Conflat (CF).**

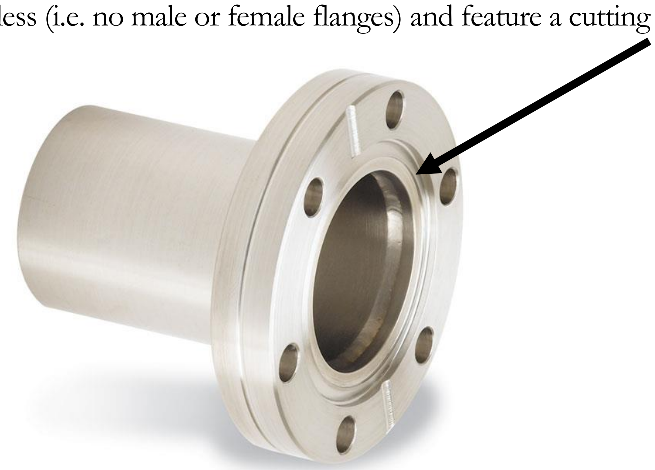
QF flanges are useful when connections need to be made frequently, but are very limited in the vacuum levels they can attain (about 10^{-6} mBar). They are therefore useful for rough-pumping.

The CF standard is required for UHV projects. Conflat connections are made by flanges cutting into a copper gasket placed between them. This allows Conflat systems to achieve pressure levels less than 10^{-11} mBar. Because the flanges cut into copper gaskets to seal, the gaskets can only be used once. Further, care must be taken when making a CF connection which yields long assembly times. Therefore, the CF standard is good for systems that require high vacuum and will not be modified frequently. Sometimes CF flanges are necessary for connections that are frequently broken (often with cryostats that are often removed from systems).

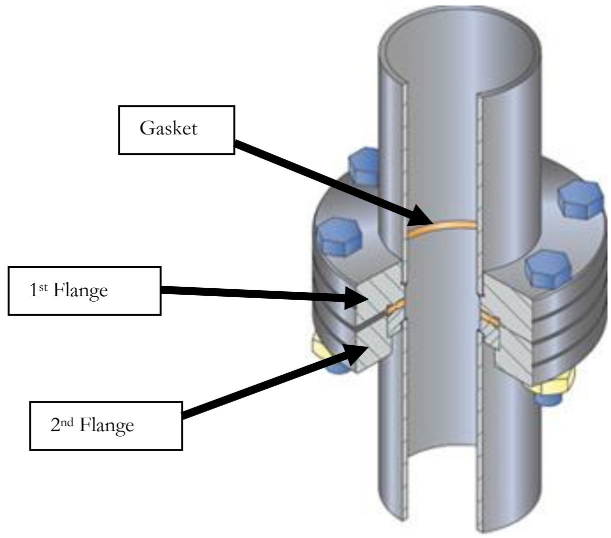
II. Conflat

I. Concept

Conflat flanges are sexless (i.e. no male or female flanges) and feature a cutting edge



To make a connection, an OFHC copper gasket is placed between two flanges. There is a recess in each flange so that the gasket sits properly concentric with the flanges. Inside of the recess lies the flange's cutting edge. As the flanges are tightened together with screws, the cutting edges cut into the copper making a very tight seal.



In this way, extremely low vacuum levels can be attained with seamless connections.

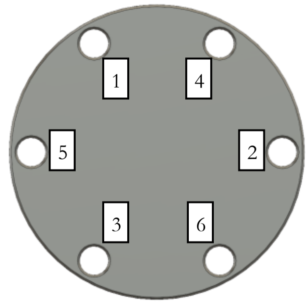
II. Tightening Pattern

Making a proper CF seal is very sensitive to the way the flanges are tightened together. Since the cutting edges cut into the copper, if one side of a flange is tightened very tightly while the opposite side is not tightened at the same time, the copper will not be cut into uniformly and the seal will not hold the greatest vacuum levels possible.

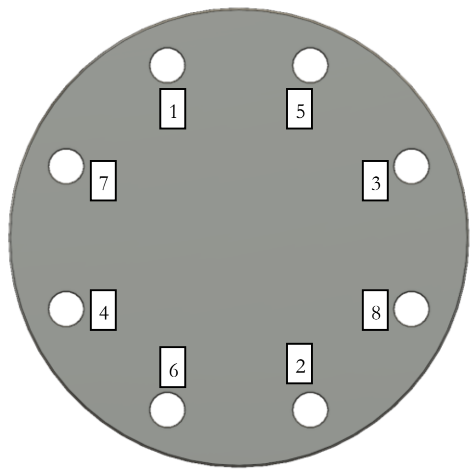
Therefore, it is important to tighten the flanges properly according to the patterns below. Flanges may be marked with sharpie to avoid confusion / loss of progress. If a flange is incorrectly marked, the sharpie should be removed with acetone and the proper pattern marked.

Tighten flanges according to the pattern below, **tightening only 1/8th of a turn at a time at each screw for each iteration of the pattern.**

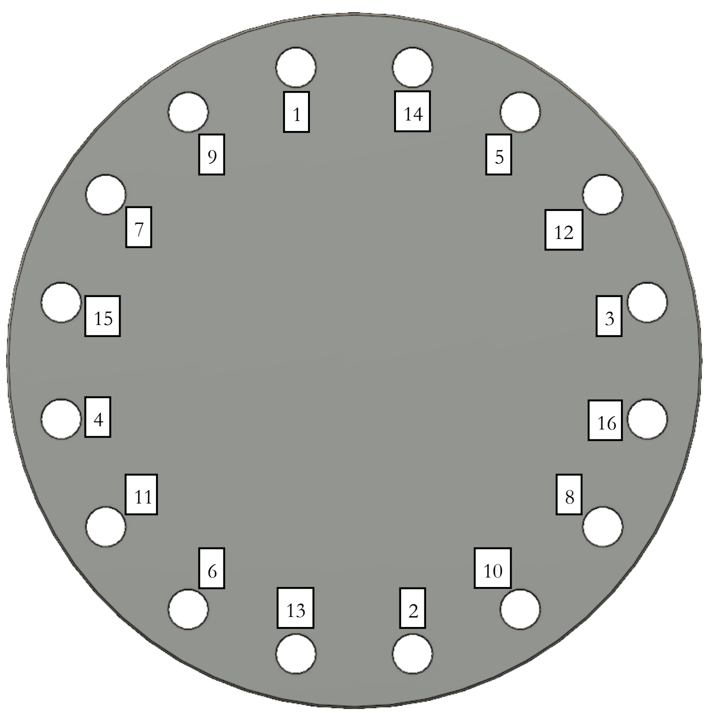
CF 2.75:



CF 4.5:



CF 6:



III. Screw Standards

NOMINAL OD	BOLT SIZE	TORQUE IN INCH / LBS
$1^1/_3$	8-32	28
$2^1/_8$	$^1/_4$ - 28	110
$2^3/_4$	$^1/_4$ - 28	110
$3^3/_8$	$^5/_{16}$ - 24	190
$4^1/_2$	$^5/_{16}$ - 24	190
$4^5/_8$	$^5/_{16}$ - 24	190
6	$^5/_{16}$ - 24	190

III. Cleaning for Vacuum

It is imperative that all parts being placed in vacuum be thoroughly cleaned beforehand, especially a part that is to be placed in and left in vacuum indefinitely.

Latex gloves should be used at all times and cleaned pieces should be left on clean kim-wipes. Further, only sterilized tweezers and Allen keys should be used. Ideally parts should be cleaned immediately before being placed in vacuum.

Metal parts should be sonicated in acetone and then IPA. Parts that cannot be exposed to acetone (e.g. rubber O-rings) should skip the acetone wash.

The utility of a finish-wash with water after IPA is debated – on one hand water should remove any IPA left on the component; but on the other hand the IPA is expected to evaporate off anyway, and water's polarity makes it more "adhesive", lowering vacuum. The greatest success on this project has come with **NOT** performing a finish-wash with water.

If cleaning the inside of a chamber, long sleeves should be worn at all times.

Kim wipes may not be used on the cutting edge of Conflat flanges because they fray and leave fibers on the edge which can limit vacuum. Instead, lens paper should be used on cutting edges with care taken to properly clean sharp corners.

If assemblies are being inserted into a vacuum environment, they should be fully disassembled and each part (screws and washers included) should be cleaned separately before re-assembly. Care should be taken to ensure drill holes and the like are completely devoid of solvents before re-assembly.

Windows should be cleaned with acetone and then IPA using lens paper

When not in use, conflate flanges should be covered tightly with tinfoil and then a plastic cap should be placed over the tinfoil/flange.

IV. Designing for Vacuum

There are several design considerations that should be considered if designing a part for vacuum.

Any drill holes into which a screw will be placed should have a small venting hole that tunnels into the deepest part of the hole. This is to allow the air trapped between screw threadings to be removed. Otherwise the trapped air will slowly leak over time, raising base pressure. If a venting hole is not possible, vented screws should be used.

Whenever there is a flange that is only accessible from one side (e.g. on a valve or an embedded flange), set screws should be used. This is to make sure full compression of the copper gasket is attained. Further, set screws are easier to remove than threaded rods if they strip.

3D printed parts are normally not permissible in vacuum systems. Plastic parts will sublimate, and 3D printed metal is too porous and raises base pressure. If 3D printing is planned, make sure to confirm that the materials to be used are vacuum-compatible.

All copper components need to be fabricated from OFHC (**o**xygen-**f**ree **h**igh thermal **c**onductivity) copper.

V. Bakeout

Bakeout is the process of heating a vacuum chamber or component to a high temperature (at least the boiling point of water) to remove contaminants from a vacuum system. The heat bakes contaminants and evaporates water off of chamber walls which are then removed by a vacuum, a process that allows for a lower base pressure. Bakeout is absolutely essential to achieving low vacuum – it can decrease base pressure anywhere from ½ to 3 orders of magnitude. Bakeout is performed with electrical heating tape, the temperature of which is modulated by a variac transformer.

To achieve optimal vacuum levels, a bakeout should be performed prior to each transfer; however, if expeditious transfer is the priority, then intermittent bakeouts suffice **as long as the chamber has not been exposed to air since the most recent bakeout**.

Samples should be removed from a chamber before baking it out in order to avoid the sample being contaminated by the contaminants being removed from the walls of the chamber.

Chapter 3

Design

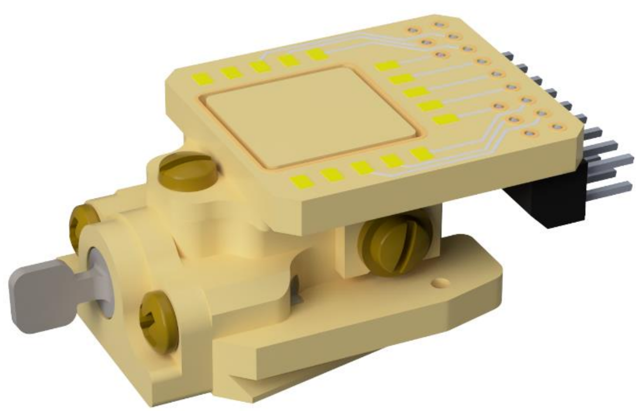
This section serves as an overview of the design of all relevant components of the transfer process. This section also highlights important and relevant dimensions for each of these components.

I. Montana Sample Holder Assembly

The driving force of this project was to accommodate the new lab standard of sample holder that was implemented upon the acquisition of the Montana Cryostation optical measurement system. The sample holders below were designed by Montana Inc. with input from LASE and provided much of the design scaffolding on which all other aspects of the project were designed.

I. Sample Holder

Below is an image of the sample holder



An exploded view can be seen in Sec. 5.V.

On top is the **circuit board** on which the sample sits. Around it, we see 15 contacts to which a sample can be wired, which feed into an electrical connector.

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All of the aforementioned components are made of OFHC copper, a UHV compatible high thermal conductivity material, because a sample is cooled through the sample holder. (expanded upon in Sec. 3.I.II). All screws are made of **non-magnetic brass** to allow usage of these holders in LASE's magnet.

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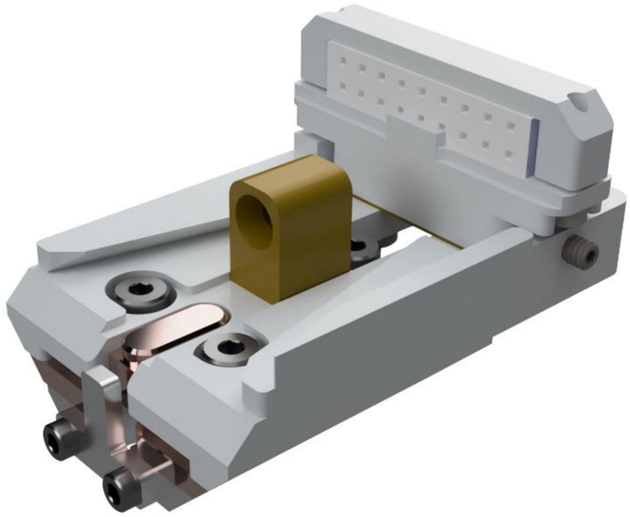
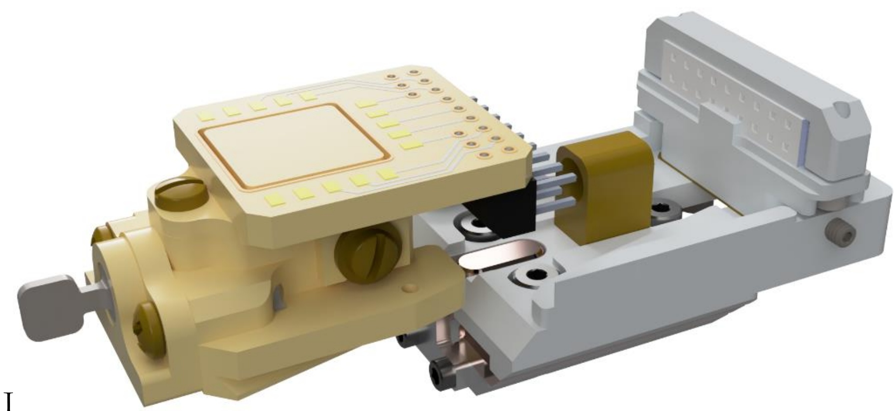
II. Sample Receiver

Below, is the component which receives the sample holder, called the **sample receiver (receiver)**.



The receiver features a dovetail complementary to the dovetail on the sample holder in order for the sample holder to be inserted as seen below.



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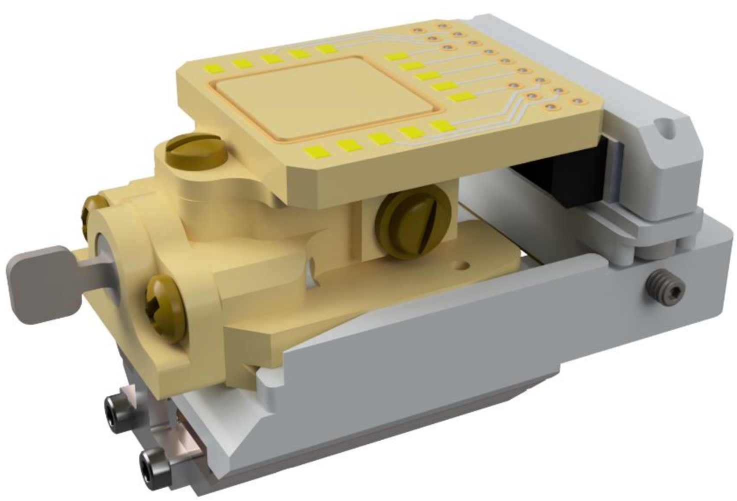

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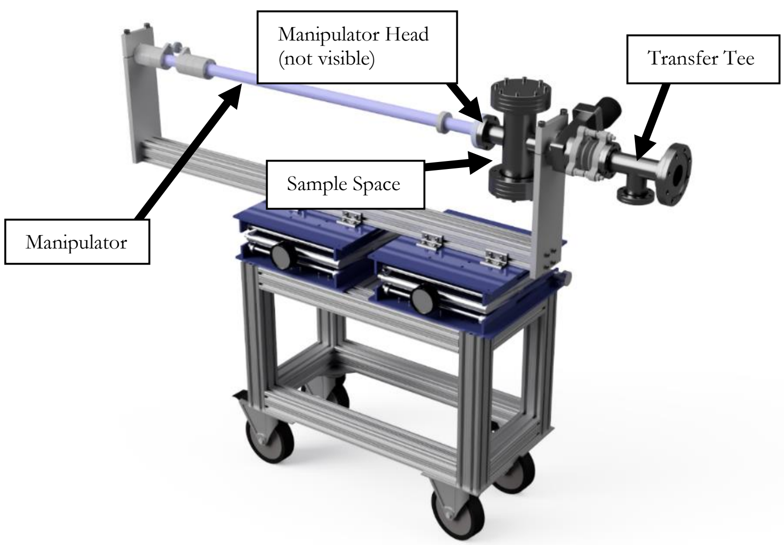
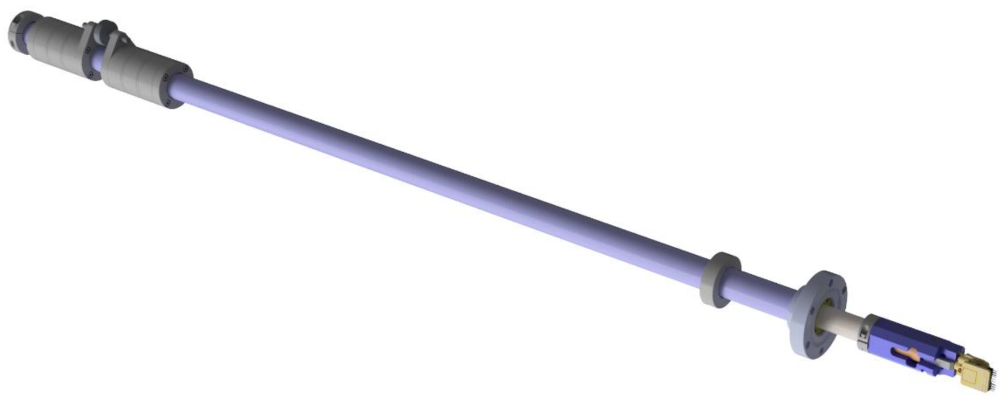
II. Suitcase

Below we see the LASE suitcase, referred to as the **BVS** (= Burch Vacuum Suitcase). Starting at the bottom, there are four 360 degree pivot wheels allow for dexterous movement. These wheels attach to a frame, on top of which sit two blue lab jacks. These jacks allow for the vertical range of motion necessary to attach the BVS to all systems it is compatible with. Further, adjusting each lab jack independently allows for extra tilt which helps (1) attach the suitcase to a compatible system and (2) align the sample holder during transfer. The remaining parts of the suitcase are labeled, each with its own subsection below.



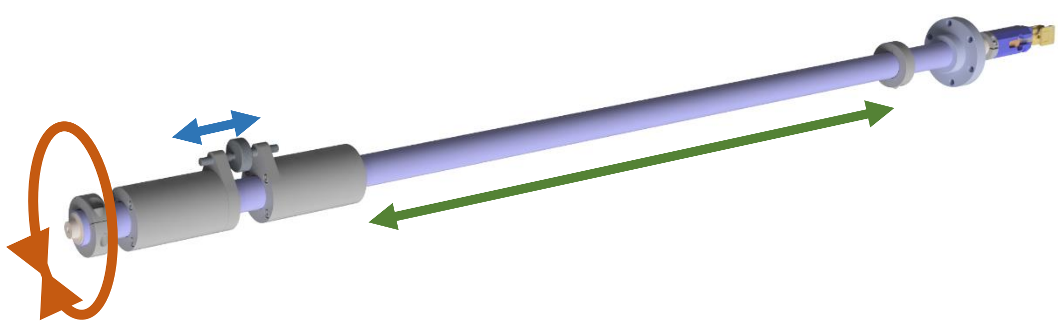
I. Manipulator

The **manipulator**, seen below, is responsible for **transferring/holding the sample holder**



The manipulator features two handles which couple magnetically to two coaxial rods inside of it, an **outer rod** and an **inner rod**. The manipulator features three degrees of freedom:

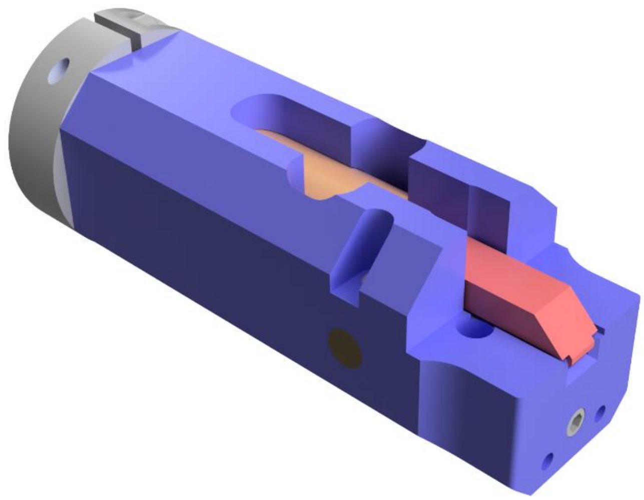
1. A linear axial degree of freedom (24 in.)
    a. This is used to move the sample holder from the sample space to a compatible system during transfer
2. An infinite continuous angular degree of freedom in the axial direction
    a. This is used to advance the lead screw in the sample holder to secure it during transfer, outlined in Chapter 4
3. A relative linear separation between the handles of the manipulator
    a. Each handle independently couples to one of two coaxial rods (the "outer" and "inner" rods) inside the manipulator. The relative position between these rods is used to grip/release the sample holder during transfer, as outlined below Chapter 4



The manipulator has an expected **deflection** of less than 1mm at full extension when holding the estimated mass of the sample holders, which is 32g (Sec. 3.IV.II).

II. Manipulator Head

The **manipulator head**, seen below, is what physically holds the sample holder inside the suitcase



As seen in the cross section below, the manipulator head is secured to the **outer rod** of the manipulator via a **clamping collar**. The outer rod couples to the front handle of the manipulator. The **inner rod** of the manipulator is threaded into the **traveler** of the manipulator head, which was machined from a UHV compatible and bakeable plastic **polyetheretherketone (PEEK)**. The inner rod couples to the rear handle of the manipulator.

Gripping or releasing the sample holder is performed by moving the handles of the manipulator relative to each other via the **thumbscrew** that separates them.

The gripping force is parameterized by a set screw which applies pressure to the spring highlighted below. Additional information on the manipulator head can be found in Appendix I (Sec 7.I).

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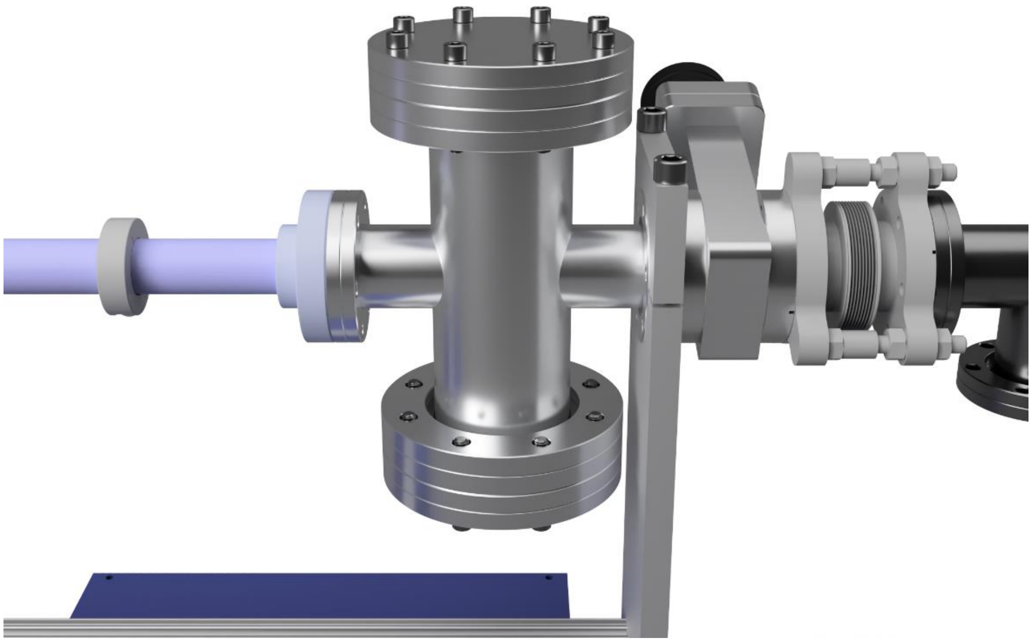
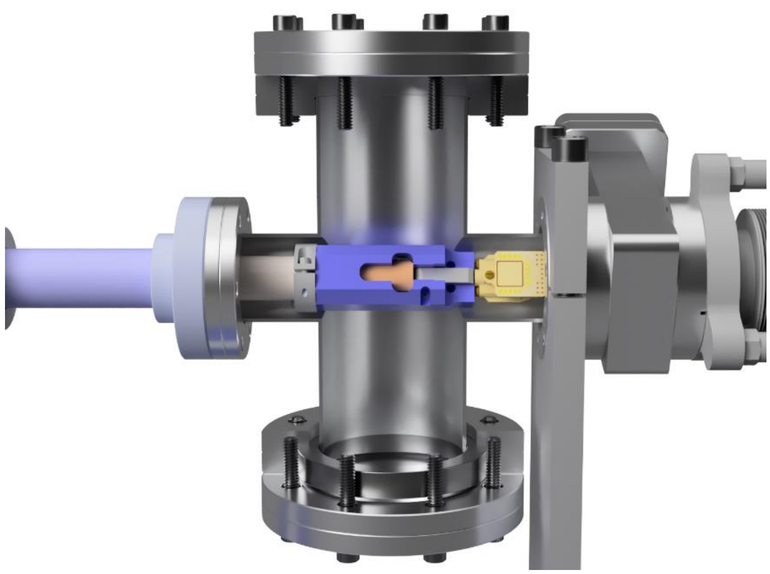
III. Sample Space

The sample space, seen below, is a CF 4-way in which the sample is housed during transportation.

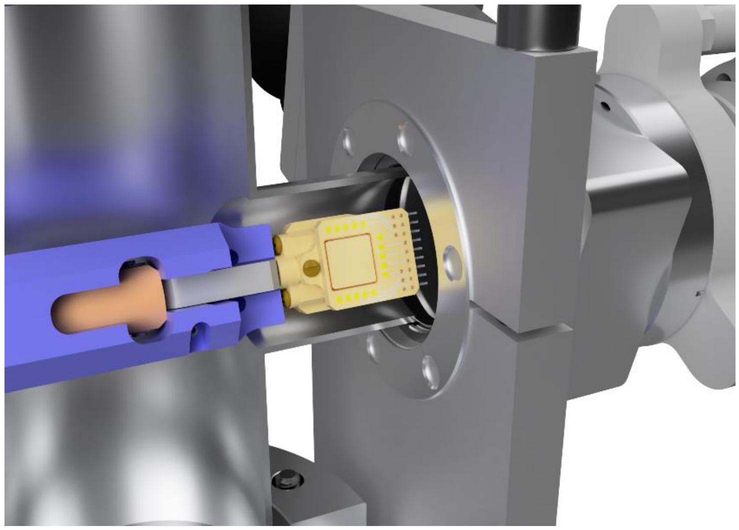


Two of the CF ports are CF 4.5 and currently blanked off, although can accommodate pumps (Sec. 3.V.I). The other two ports are CF 2.75. To one of these the manipulator attaches, and to the other a valve which provides the seal which keeps this volume under vacuum during transportation.



The suitcase was designed such that, when the manipulator is fully retracted and holding a sample holder, **the sample holder is very close to intersecting the closed valve (about**

0.75 in. away). This design feature is intentional and was implemented in order to reduce the required stroke of the manipulator as much as possible (to limit the size of the suitcase and the degree of manipulator deflection). **It is therefore imperative that, when holding a sample holder, the manipulator should be fully retracted before the valve (Valve A) is closed.**



IV. Transfer Tee

Below is the transfer tee. This is the area that is **pumped and flushed** to allow for attachment/detachment to compatible systems.

The tee features a **port aligner** which works in conjunction with the lab jacks to properly align the sample holder with the sample receiver.

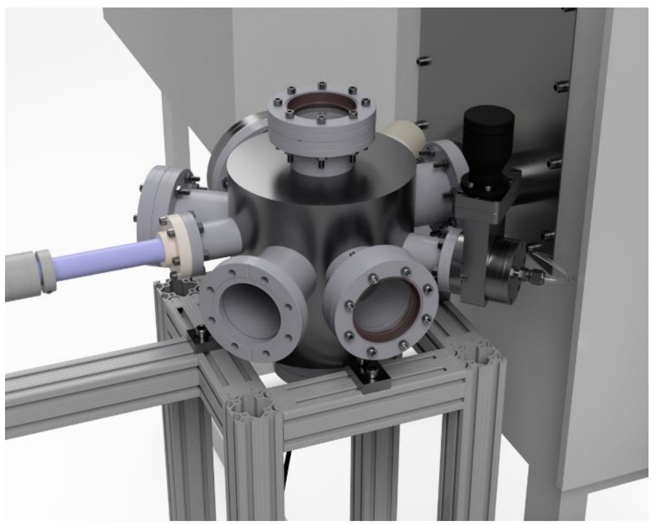
III. Intermediate Chamber

The intermediate chamber is attached to the glovebox to allow for transfer into/out of the glovebox. The suitcases (the Burch Lab's and the Zeljkovic Lab's) cannot transfer directly into the glovebox because this would require that the sample spaces be flooded with argon, and, although the argon in the glovebox is very clean, the sample spaces need to remain under constant vacuum to avoid contamination by water vapor, dust, and nanolithographic developer vapors. This is especially important for the Zeljkovic vacuum suitcase (ZVS) which attains 10^{-11} mBar range pressures.

Samples are transferred into the intermediate chamber under vacuum which is then isolated from the suitcase and flooded with argon so that transfer into the glovebox may occur. The design of the intermediate chamber is outlined below.

I. Ports / Hardware

The intermediate chamber is a 10-port chamber and can be seen below.



Looking down from the top of the chamber, each flange is labeled with corresponding information on port usage, size, azimuthal angle, and height (from the bottom of the main chamber). The polar angle of each port is 90 degrees is therefore omitted.

1. **CF 4.5 (0°, 5.335 in.)**
   a. Equipped with a valve connected to the glovebox
2. **CF 2.75 (45°, 4.35 in.)**
   a. Blanked. Can be replaced with a window to help with transfer (Sec. 3.V.V).
3. **CF 6 (90°, 4.35 in.)**
   a. Blanked. Allows for attachment of a TwisTorr turbo pump (Sec 3.V.III).
4. **CF 4.5 (145°, 4.35 in.)**
   a. Window. To help with transfer. Note that this port is **NOT** normal to the transfer axis (it had to be moved 10° CCW to accommodate the CF 6 port)

5. **CF 2.75 (180°, 5.03 in.)**
    a. Manipulator. The height difference here is intentional and explained in [Chapter 4: Operation]
6. **CF 4.5 (225°, 4.35 in.)**
    a. Valve. This is the port to which the suitcase attaches.
7. **CF 4.5 (270°, 4.35 in.)**
    a. Window. To help with transfer.
8. **CF 2.75 (315°, 4.35 in. in. in.)**
    a. Valve. For argon venting.

There is also a CF 4.5 port on top of the chamber, featuring a window to assist with transfer, and a CF 4.5 port on the bottom of the chamber. This port is blanked and was incorporated in case another manipulator is needed for vertical movement in the chamber, or for another method of direct pumping. (Sec 3.V)

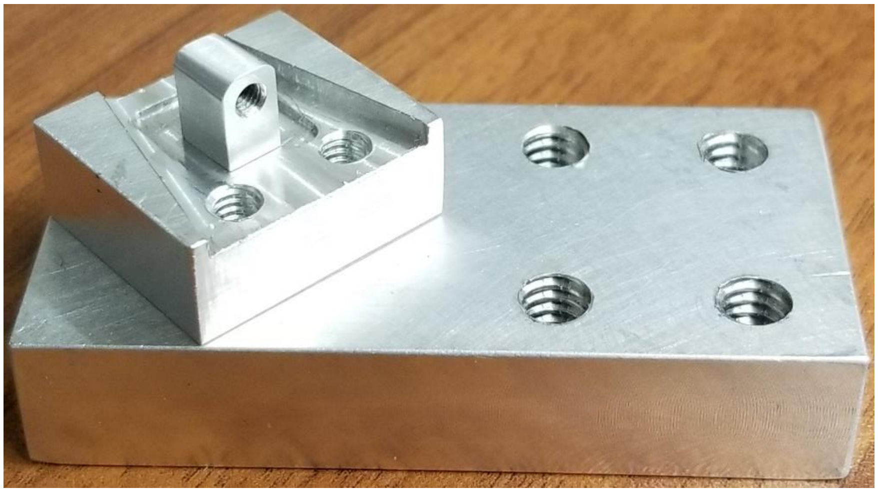
II. Manipulator

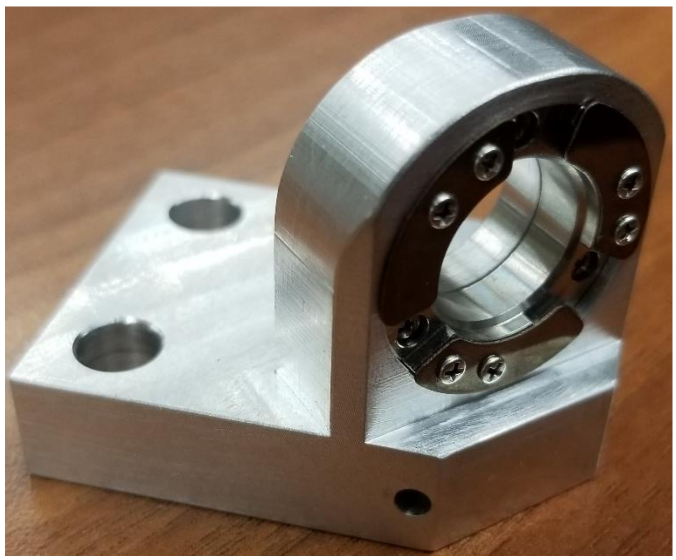
The manipulator is what transfers a sample **from intermediate chamber to glovebox**. It features an infinite continuous angular degree of freedom and a linear degree of freedom (30 in. stroke). The end of the manipulator features a **¼ in. clearance hole** into which a rod is inserted. This rod is slotted on the side which is inserted into the manipulator and is held in place by a **6-32 UNC** set screw in the end of the manipulator. The other side of this rod features a **¼ -20 threading** onto which sample blocks screw.

III. Sample Blocks

The intermediate chamber has been designed in order to accommodate the transfer of both LASE's sample holders and the Zeljkovic Lab's **Unisoku** sample holders. This is made possible through so called "**sample blocks**" which allow, in principle, for any appropriately sized sample holder to be transferred into the glovebox.

A different sample block is required for each type of sample holder. The sample blocks are metal blocks with ¼-20 threaded holes. A block is placed on the end of the manipulator via this threaded holes. The rest of the block is just a receiver that is machined to receive whatever sample holder is desired. The blocks machined for the Montana and Unisoku holders can be seen below in that order.





If machining a new block in the future, it is important to design it in such a way that the **vertical height difference** between the axis of the port to which the suitcase attaches and the axis of the port to which the manipulator is attached (Sec. 3.III.I) is accounted for.

IV. Important Dimensions / Quantities

Dimensions important to the design and potentially useful in the future have been listed below:

I. Intermediate Chamber

a. Axial distance between suitcase port and manipulator port: **0.680 in.**
b. Axial distance between glovebox port and manipulator port: **0.305.**
c. Stroke of manipulator: **30 in.**

d. Minimum manipulator stopper distance from flange: **6 in.**

II. Sample Holder

e. Mass: **32 g**
f. Vertical center of mass: **2 mm** above axis of screw
g. Minimum bore hole diameter: **1.2 in** (driven by manipulator head clamping collar)
h. Titanium screw threading: **M3 x 0.4 mm**

III. Suitcase

i. Vertical stroke of lab jacks: **16.5 in.**
j. Stroke of manipulator: **24in.**
k. Minimum manipulator stopper distance from flange: **4 in.**
l. Distance fully retracted sample holder to face of transfer tee valve: **.75 in**
m. Expected deflection on manipulator: **< 1mm**

V. Future Possibilities

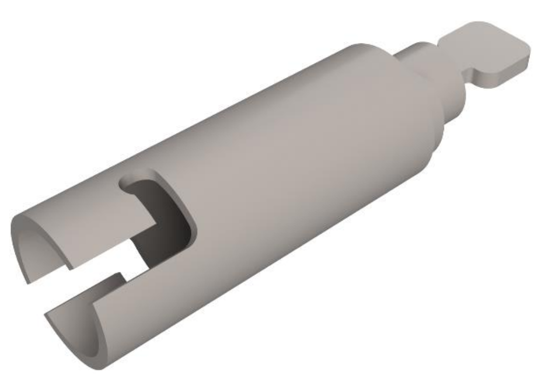
The vacuum suitcase was designed to incorporate future upgrades without the need for redesign. Some of the possible upgrades that may be implemented are listed below:

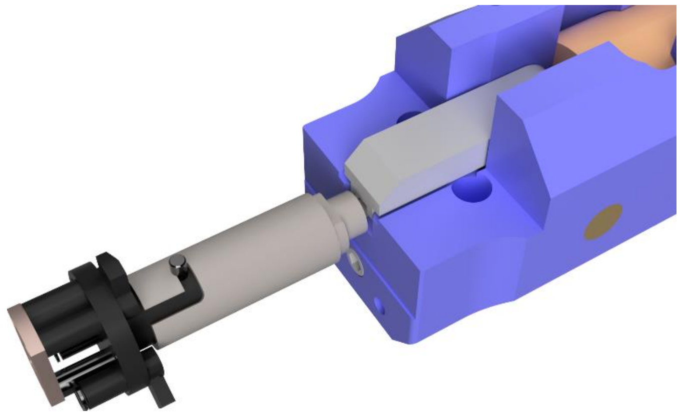
I. Ion / Getter Pump

As mentioned above (Sec. 3.III.I), the sample space has 2 CF 4.5 ports. These ports are intended to be used with getter and ion pumps should the need arise. Since the pumping occurs through the transfer tee, as soon as the CF 2.75 valve between the sample space and transfer tee is closed to detach the suitcase from a system, the sample space volume is no longer being pumped on and thus the vacuum degenerates quite quickly (Sec. 1.III.III). Therefore, a getter and/or pump may be utilized in order to (1) counteract this degenerative effect, and (2) increase the vacuum levels that may be attained.

II. Unisoku Adapter

Dr. Zeljkovic's collaborating lab has two suitcases of their own, which are designed to be able to transfer into /out of our glovebox with the appropriate intermediate chamber block (Sec. 3.III.III). In order to prevent the need to wait for a Zeljkovic Lab suitcase to become available, an adapter may be created in order to allow the BVS to hold Unisoku holders and transfer into the Zeljkovic Lab's STM.





This adapter was originally proposed by He Zhao, and a preliminary 3D design was created by Ryan O'Connor. See Sec. 6.III for 3D file information. **The Zeljkovic Lab should be consulted** prior to undertaking this project both to ensure that the BVS vacuum levels are sufficient and that the BVS can fit in the STM room

III. Chamber Pump

Currently, the intermediate chamber can be pumped in two ways: (1) through the transfer tee during sample transfer (Sec. 4.II.I), or (2) directly with the use of the bottom port and a reducer. As with the sample space, the vacuum in the intermediate chamber will degrade when not actively pumped (Sec. 1.III.III). The higher the steady-state pressure of the chamber, the more often bakeout will need to occur (Sec. 2.V), and the higher the base pressure will be. Further, transfer could be expedited if the intermediate chamber remains constantly under vacuum, and therefore not filled with argon that must be pumped at the beginning of a transfer. The addition of a chamber pump to the system would solve these issues. The glovebox plate with the half nipple to which the intermediate chamber attaches was dimensionally designed to allow for a TwisTorr to be placed on the CF6 flange on the intermediate chamber (which is normally blanked off) without intersecting the glovebox protrusion in which the plasma preen previously sat. A gauge may be placed on the free CF 2.75 port (Sec. 3.III.I)

IV. Chamber Tee

Alternatively to the above (Chamber Pump), a tee may be placed on the bottom of the intermediate chamber to allow for direct pumping of the chamber. If a CF2.75 tee is placed on the bottom of the chamber, two valves may be attached to the remaining ports on the tee, one for the Argon line used for flushing and one for attaching the pump when necessary.

Although this method is less costly than a pump directly on the chamber, it is also less useful because the vacuum will degrade over time (Sec. 2.V), and there is no way to monitor the degradation of this vacuum over time. These issues are only relevant if using the BVS because the pump is required to attach/detach the BVS. If using the ZVS, the Burch Lab pump may be left attached to the chamber because the ZVS has its own pumps for its transfer tee. More coordination would be required in order to prepare the chamber under vacuum before a transfer if using the BVS.

V. Chamber Window

Port 2 (Sec 3.III.I) is directly opposite and coaxial with the port to which the suitcase attaches on the intermediate chamber. A window may therefore during transfer to make sure the axis of the suitcase has been properly aligned to be coaxial with the axis of the CF port to which the suitcase attaches.

VI. Transfer Tee Flushing

The ZVS features nitrogen flushing on its transfer tee. Upon replacing the transfer tee with a 4-way and the purchase of a valve, this capability could be incorporated into the BVS. This feature would omit the need for any portion of the suitcase to be exposed to air and would lower overall base pressure. Care should be taken before undertaking this project to ensure that the implementation of a 4-way in place of the tee would not increase the length of the suitcase by an amount that would prevent transfer.

VII. Other Sample Types

The intermediate chamber was design such that any sufficiently sized sample holder can be brought into / out of the glovebox. By machining a sample block (Sec. 3.III.III) designed for the given sample holder, taking into account the angle of the suitcase port to the manipulator port (ports 5 and 6) and the height differences between these ports as well as the manipulator port and the glovebox port (ports 5 and 1), a sample holder of any type may be brought into the glovebox.

Chapter

4

Operation

This section serves as a manual for the operation of the BVS with respect to all relevant systems, and for the ZVS with respect to glovebox transfer

I. Prior to Transfer

I. Cleaning

Before any parts are put in the intermediate chamber or any vacuum environment, they require cleaning. See Sec. 2.III

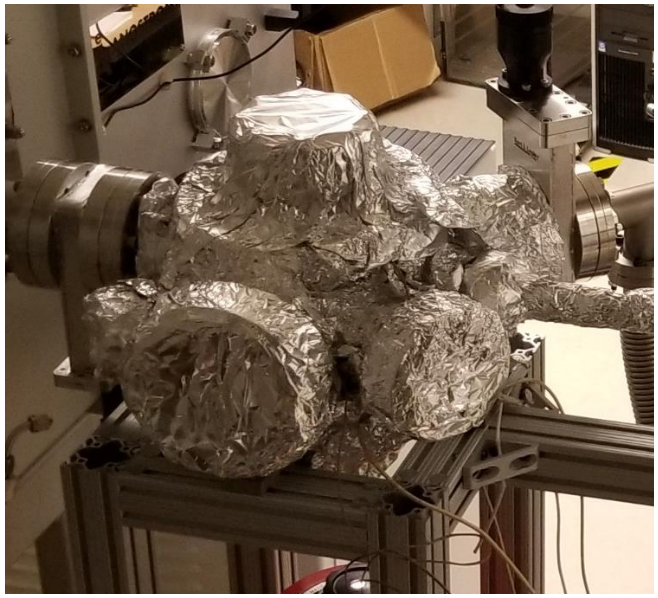
II. Bakeout

Whenever the vacuum chamber is exposed to air, water vapor, or other contaminants, a bakeout procedure should be followed. More information on bakeout can be found in Sec. 2.V. The limiting factor regarding the bakeout temperature can be found in Sec. 1.III.I. The bakeout procedure is outlined here:

1. If the heating tape is not already wrapped around the chamber, do so, ensuring that the tape does not cross itself (fire hazard) and taking care to ensure the windows will be heated sufficiently (a disproportionate percentage of contaminants are located on windows).

2. If not already in place, wrap the entire chamber in aluminum foil as seen below.

   This is done in order to distribute the heat evenly and keep it contained. Make sure to cover windows and to be generous with the amount of foil used.



3. Pump out the chamber with a turbo pump until it reaches base pressure.

   Technically waiting to plateau in pressure before turning on the heating tape is not necessary, but it is good practice to get a baseline in order to determine how much the bakeout improved the vacuum.

4. Turn on the Variac controller to redacted.

5. Monitor the chamber pressure

   It should begin rising within minutes (because the temperature is increasing). Eventually it will stop rising and begin decreasing. This is because contaminants are being removed from the system through the vacuum. Eventually, the pressure will plateau at some pressure. This usually occurs after a day or so of bakeout, although will depend on the duration of and time since the previous bakeout, amount of environmental exposure, chamber geometry (in general), etc.

6. Once the pressure has plateaued, turn off the Variac controller and allow the temperature cool back down to room temperature.

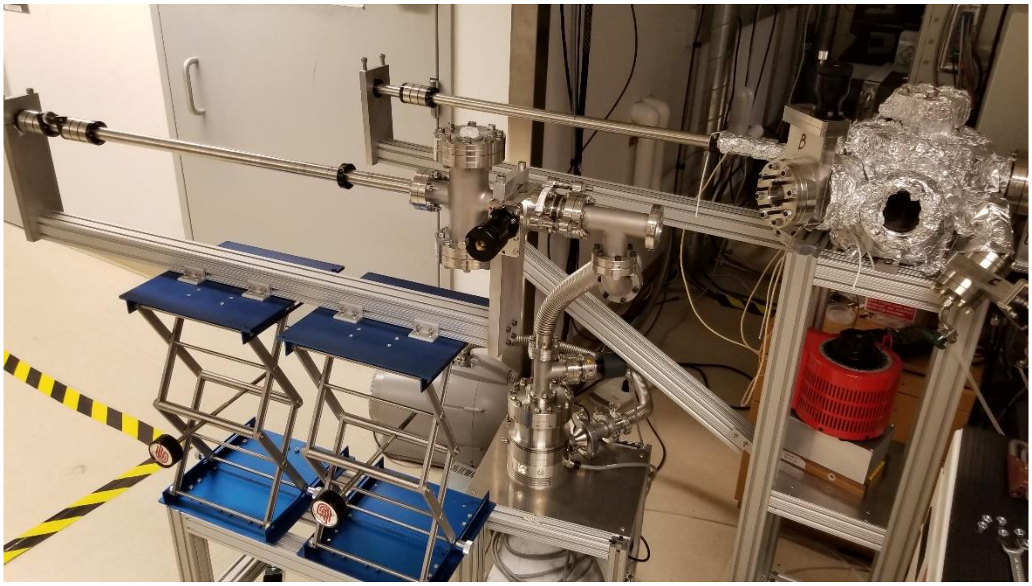
II. Glovebox Transfer – BVS

I. Insertion

This section will outline the transfer process into the glovebox if using the BVS

1. Attach the BVS to the intermediate chamber:

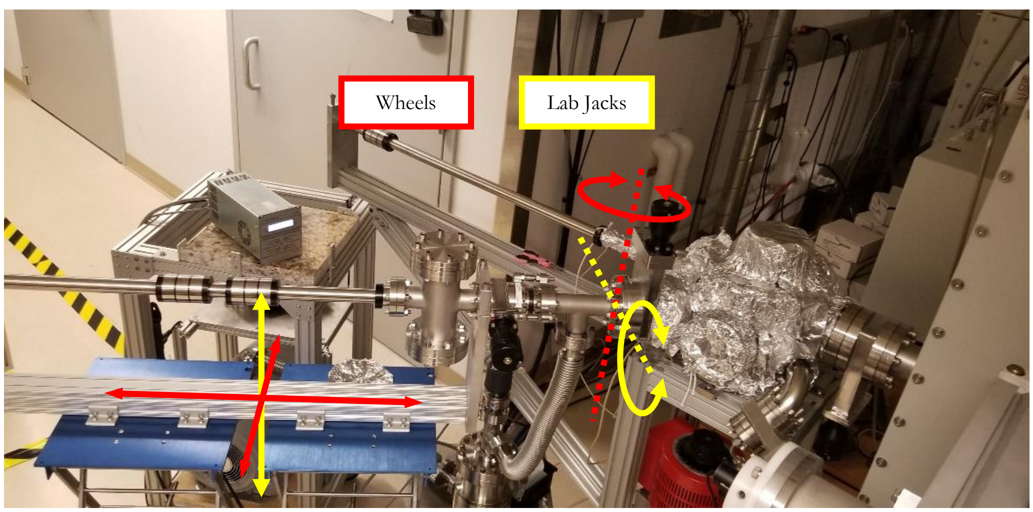
   a. Wheel the BVS over to the intermediate chamber.



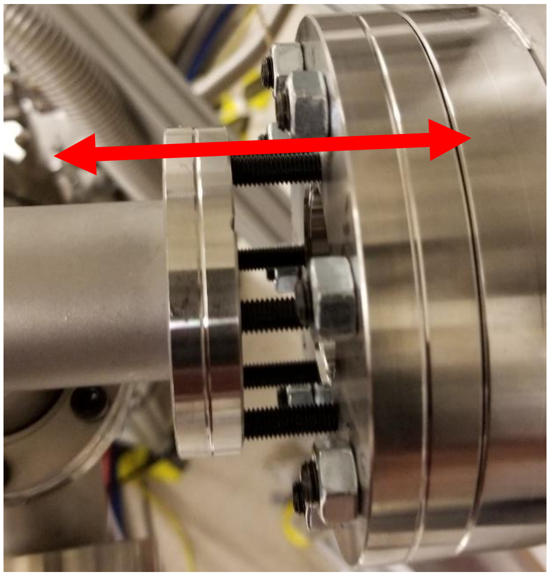
Turn the lab jacks **simultaneously** in order to raise the operational part of the suitcase up to be in line with the attachment port on the intermediate chamber. Take care to turn the lab jacks simultaneously to keep the manipulator level to the ground, using a level if necessary.

By placing a kim-wipe box on the lab jacks and aligning the jack cross-bar with the marker line labeled "glovebox", proper attachment height can be attained.

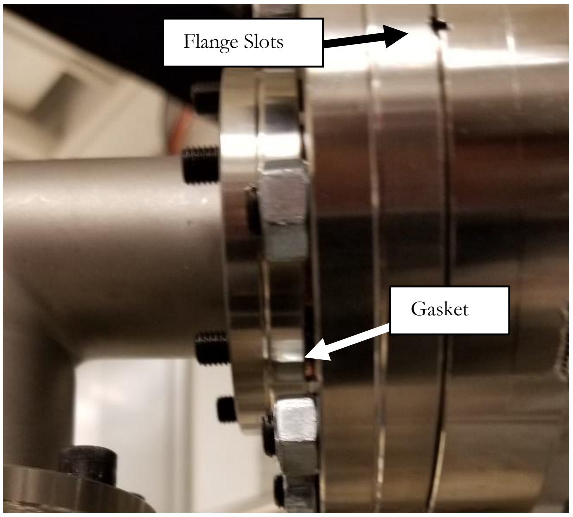
b. Ensuring both of the CF flanges are clean ([Sec. 2.II.III](#)), align the BVS and intermediate chamber flanges together so that they are flush. Rotation about the vertical axis is done via manipulation of the cart wheels, and the tilt in line with the manipulator is done by finely tuning the lab jacks



The suitcase **should be able to slide onto and off of the chamber valve set screws freely**. If this is not possible, the manipulator is not coaxial with the valve and needs to be tilted up or down or rotated left or right.



c. Place a copper gasket in between the flanges and bring the suitcase in to the chamber so that the gasket is trapped between the flanges, ensuring that the slots in the flanges line up.

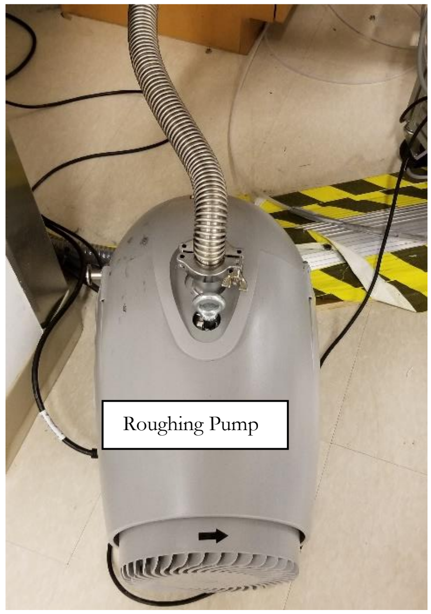


The copper gasket should be exposed equally around in the small gap between the flanges if the faces of the flanges are coplanar. Sometimes the gasket can fall out of place before it is sufficiently squeezed between the flanges. If this happens, use a very small, clean Allen key to push it into place while moving the suitcase forward to squeeze the gasket between the flanges.

Take care to tighten the bolts no more than a quarter-turn at a time and in a star pattern to ensure proper sealing. (Sec. 2.II.II).

2. Attach the turbo pump to the transfer tee.

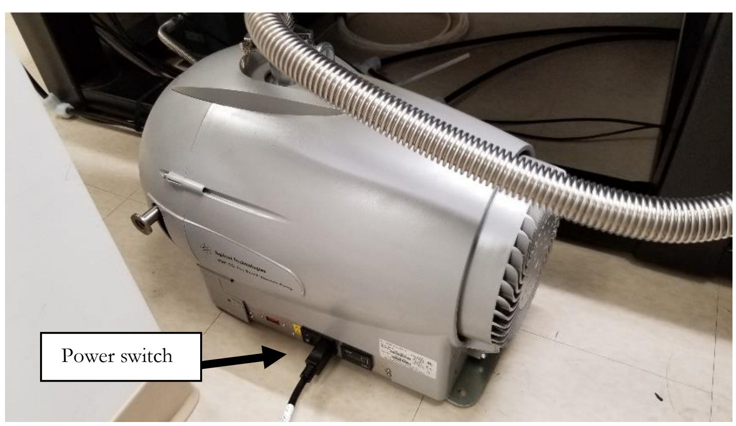
a. The roughing pump should connect to the turbo as such.



b. The turbo is attached to the free port on the transfer tee via CF 2.75. Insert a gasket and tighten the flange screws properly to ensure proper sealing (Sec. 2.II.II)

3. Ensure that the Montana sample block is attached to the manipulator inside the intermediate chamber by looking through the chamber windows. **If it is, skip to step 4. If it is not, follow the below procedure.**

   a. Turn on the roughing pump to get the transfer tee to about 10^{-2} mBar in order to expose the chamber to air as little as possible. Turn off the roughing pump **without venting**.

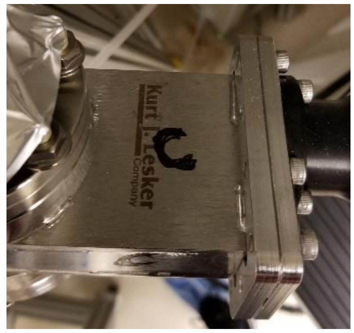


   b. Open **Valve B** between the chamber and transfer tee.

c. Turn **<u>on</u>** the roughing pump again and let the pressure get to the 10^{-2} mBar range.

d. Turn **<u>off</u>** the roughing pump and flush the chamber with argon by first opening the **Swagelok valve** connected to **Valve C**,

and then opening **Valve C** **<u>slowly</u>**

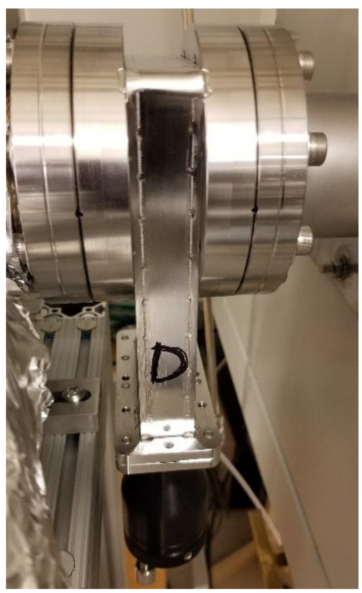


e. Once the chamber is flooded (when the valve line stops making noise, which is due to argon rushing into the chamber), close **Valve C** and the **Swagelok valve**

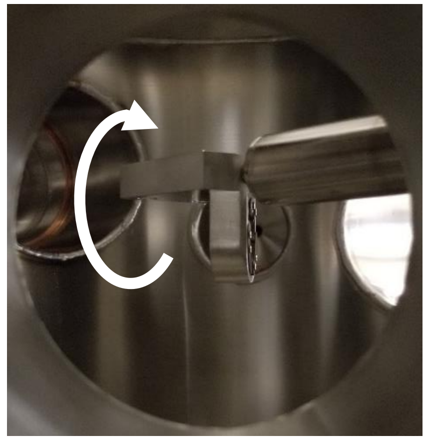
f. Repeat steps (c) though (e) twice more to pump and flush three times

g. Close **Valve B** to isolate the chamber from the pump

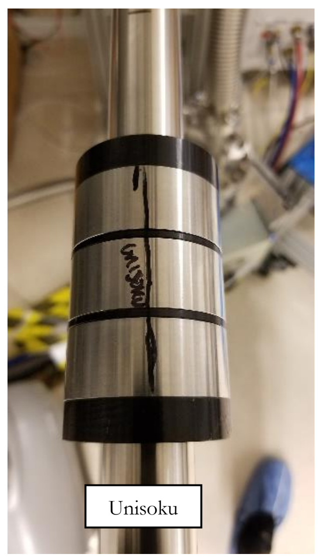
h. Open **Valve D**



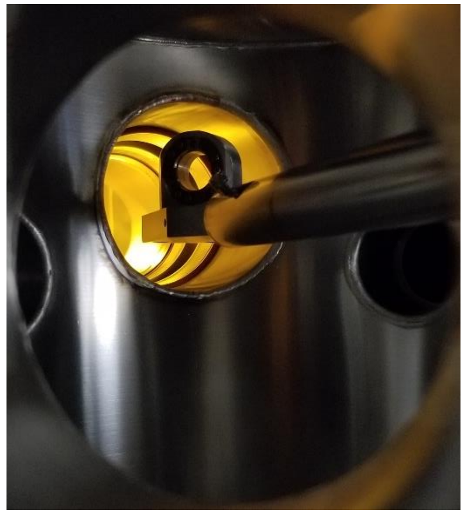
i. Ensure the intermediate chamber manipulator is rotated such that the Unisoku sample block that is **facing upwards** - i.e. the bulk of the holder is as high as it can be off the ground of the lab. This design feature was implemented to circumvent the insufficient lab jack range of motion.



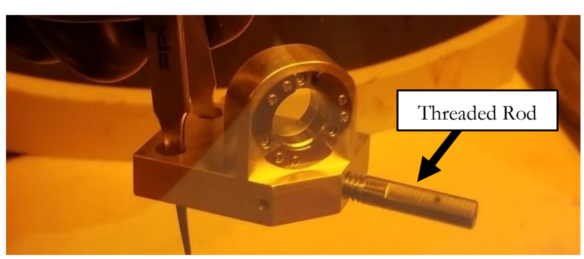
Lines are drawn on the manipulator handle to get into roughly the proper position.



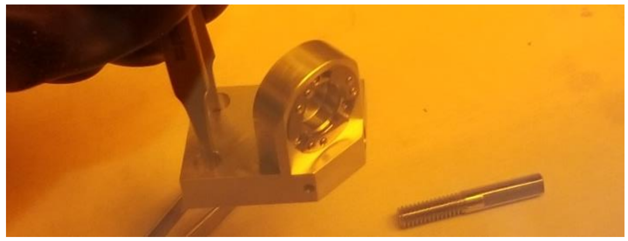
j. Slowly extend the manipulator into the glovebox, looking both through **Port 4** (Sec. 3.III.I) and from the front of the glovebox to ensure the sample holder is not going to hit the wall of the CF nipple.



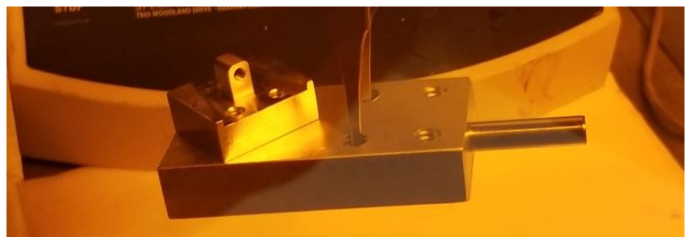
k. Using the gloves of the glovebox **with additional latex gloves on over them to ensure sterility**, remove the sample block by loosening the set screw on the side of the manipulator slightly. The blocks can be held by **sterile** tweezers



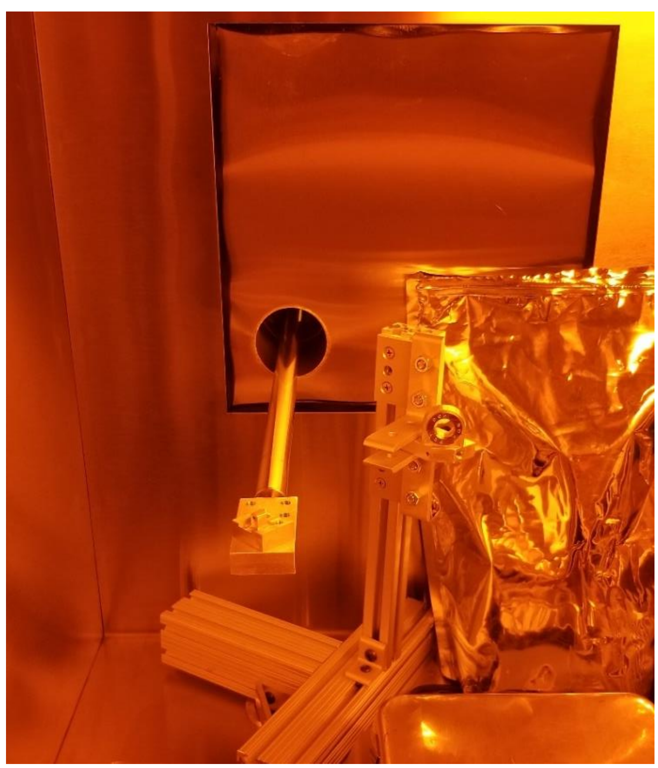
l. Remove the half-threaded rod from the sample holder by unscrewing it, and then put this sample holder in a safe place (e.g. wrapped in a kim-wipe in a plastic bag) to isolate it from developer splashes etc.



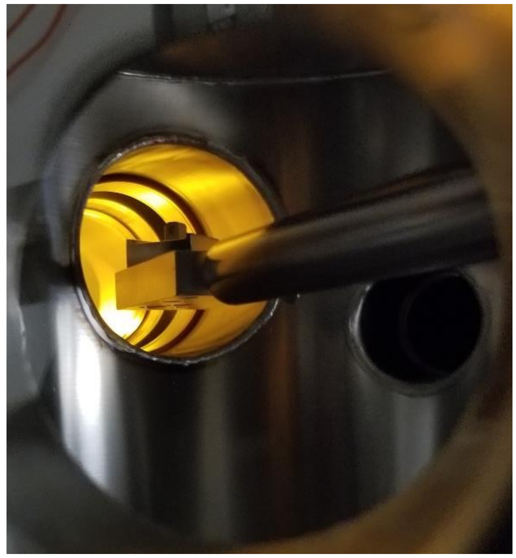
m. Take the Montana sample holder and insert the half-threaded rod into it



n. Insert the half-threaded rod with the sample holder into the manipulator, ensuring the manipulator set screw aligns with the slot on the rod. Tighten the set screw thoroughly with a **sterile** Allen key, affixing the sample block to the manipulator.



o. Retract the manipulator, again ensuring that the sample block will not hit the CF nipple, and close **Valve D**.



4. Commence the pumping procedure.

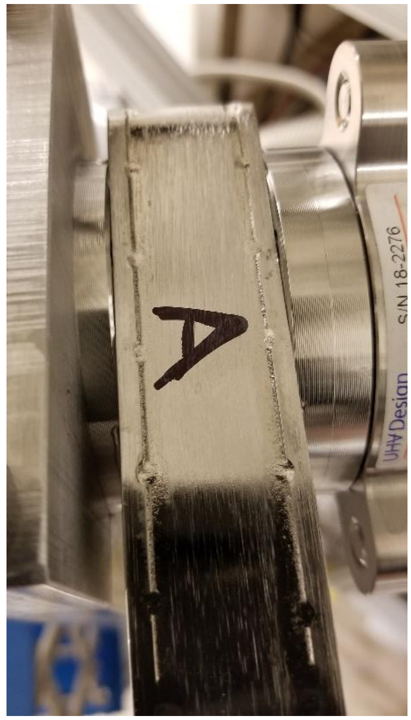
    a. Turn on the roughing pump to get the transfer tee to about 10^{-2} mBar in order to expose the chamber to air as little as possible. Turn off the roughing pump **without venting**.

    b. Open **Valve B** between the chamber and transfer tee.

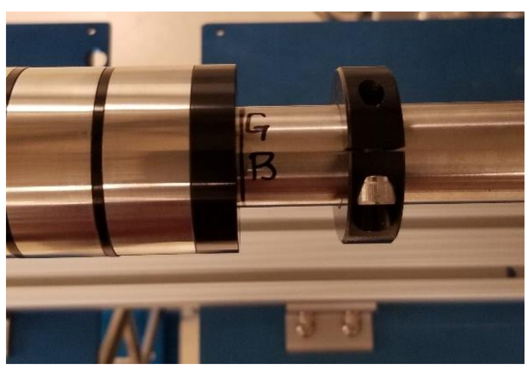
c. Immediately turn the roughing pump back on. Currently, all valves except **Valve B** should be closed so that the pump is acting on the transfer tee and chamber together.

d. When the pressure gets to low 10^{-2} mBar range, turn on the turbo and let the transfer tee be pumped down to the same level as the sample space. (about 10^{-7} mBar). Now all chambers are under the same high vacuum.

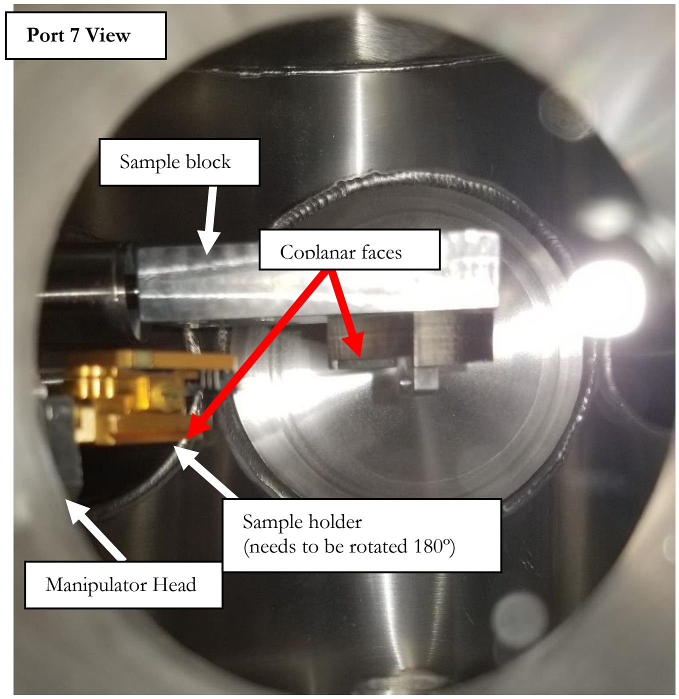
e. Open **Valve A**. Now transfer into the chamber can commence.

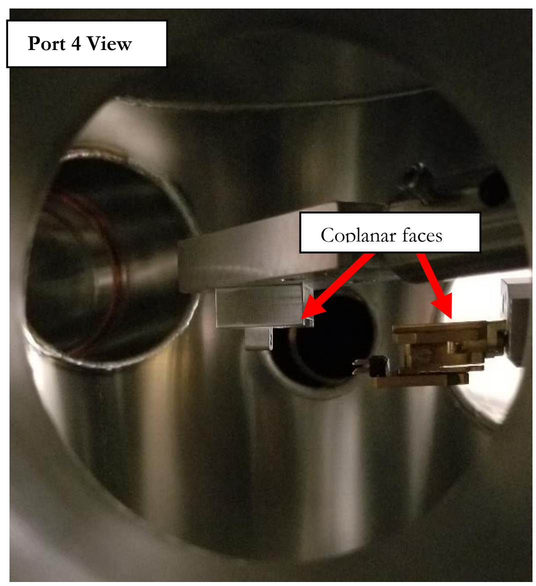


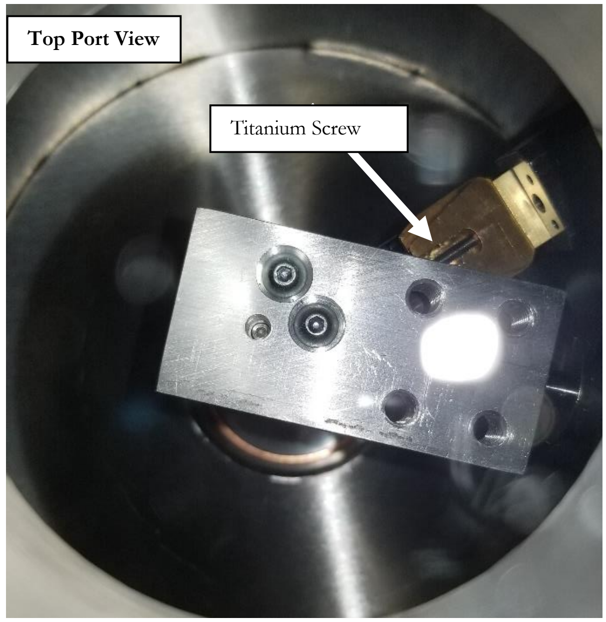
f. Slowly extend the BVS manipulator into the intermediate chamber, looking through the windows to monitor progress. There is a line drawn on the manipulator which gives the approximate distance the manipulator may be advanced before the sample holder enters the chamber. If any resistance is felt, stop advancement of the manipulator and check to make sure all valves are, in fact, open and the port aligner does not deviate too greatly from being straight.



g. Looking through the window, align the sample holder with the sample holder receiver. At this point, many parameters should be tuned to ensure the sample holder is properly aligned with the sample block. The bottom face of the sample holder should be coplanar with the complementary face of the receiver and the manipulator should be coaxial with the CF port it is attached to.


Port 7 View
Sample block
Coplanar faces
Sample holder
(needs to be rotated 180º)
Manipulator Head

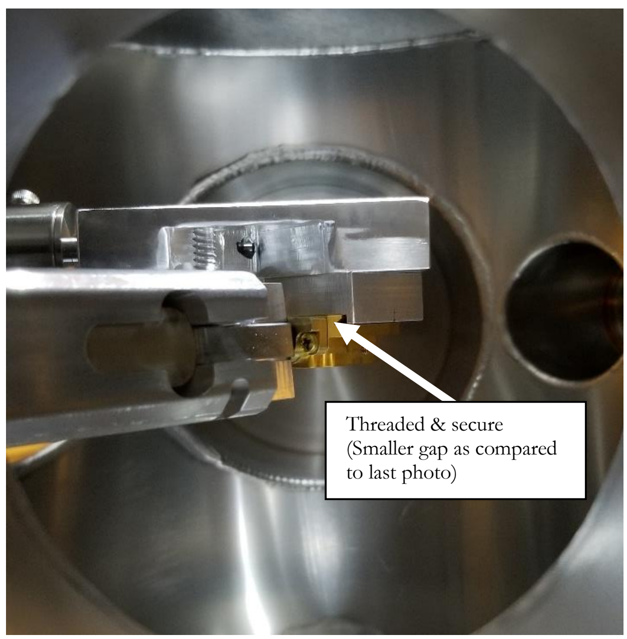

Port 4 View
Coplanar faces



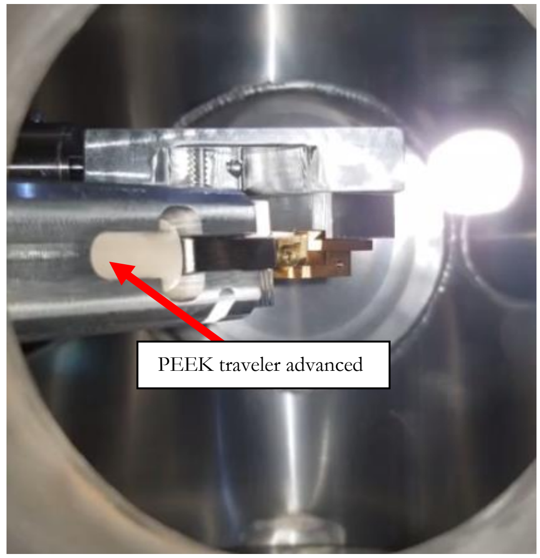
To fine-tune this alignment, the height of the lab jacks may be adjusted slightly, the port aligner can be adjusted, and the angle of the chamber manipulator may be adjusted.

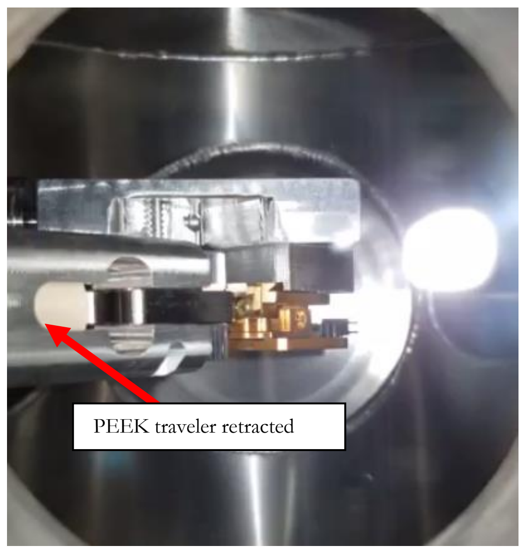
h. Advance the sample holder until it sits inside of the receiver slightly. Rotate the BVS manipulator clockwise as viewed from behind while pushing forward very lightly to advance the Ti screw of the sample holder into the threaded boss on the sample block.

i.



j. Once the sample holder is secure, let go of it with the manipulator by screwing the thumbscrew to advance the handles relatively away from each other. The PEEK traveler on the manipulator head can be monitored to determine when the head is no longer holding the sample holder – when the PEEK traveler is fully retracted, the head has released the sample holder.





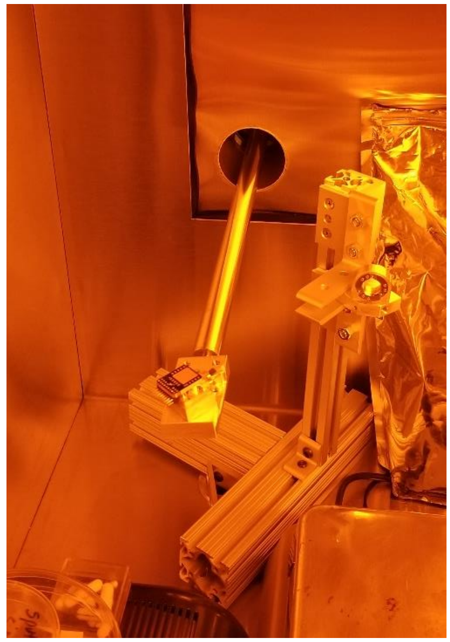
k. Very slowly retract the BVS manipulator. If necessary, the chamber manipulator may be rotated very slightly and advanced a tiny increment to tease the holder out of the BVS manipulator head, which can be difficult because the tolerances are so small. **Note that pushing the chamber manipulator forward does not push the sample holder directly out of the BVS manipulator head because these ports (5 and 6) are 45 degrees apart and not 180 degrees opposite each other**. Therefore, extreme care should be taken. A titanium lead screw has been broken in the past because of this.

l. Ensure the BVS manipulator is **fully retracted** and then close **Valve A and Valve B**. The transfer tee may now be vented through the turbo and the BVS removed (if a transfer *out* of the glovebox will be happening, it is smart to leave the BVS attached, as long as the magnet is not to be used)

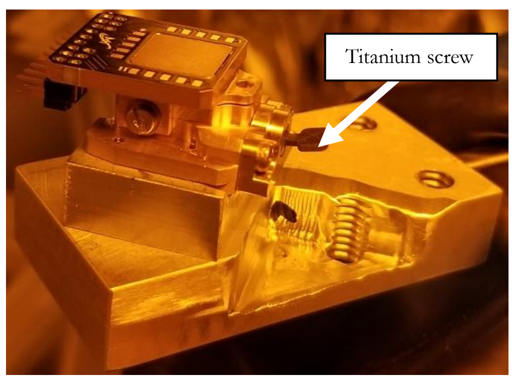
m. Flood the intermediate chamber with argon by first opening the **Swagelok valve** connected to **Valve C**,

and then opening **Valve C** **<u>slowly</u>**

n. Open **Valve D** and extend the chamber manipulator into the glovebox, ensuring that the sample block or holder is not going to hit the CF nipple.



o. Using the gloves of the glovebox **with additional latex gloves on over them to ensure sterility**, remove the sample block by loosening the set screw on the side of the manipulator slightly. The blocks can be held by **sterile** tweezers. Once the block is in hand, the sample holder may be removed by unscrewing the titanium screw.



II. Removal

This section will outline the transfer process out of the glovebox if using the BVS

Redacted Section

III. Glovebox Transfer – ZVS – Section not reviewed yet

I. Insertion

Redacted Section

II. Removal

Redacted Section

IV. Magnet Transfer

I. Insertion

Redacted Section

II. Removal

Redacted Section

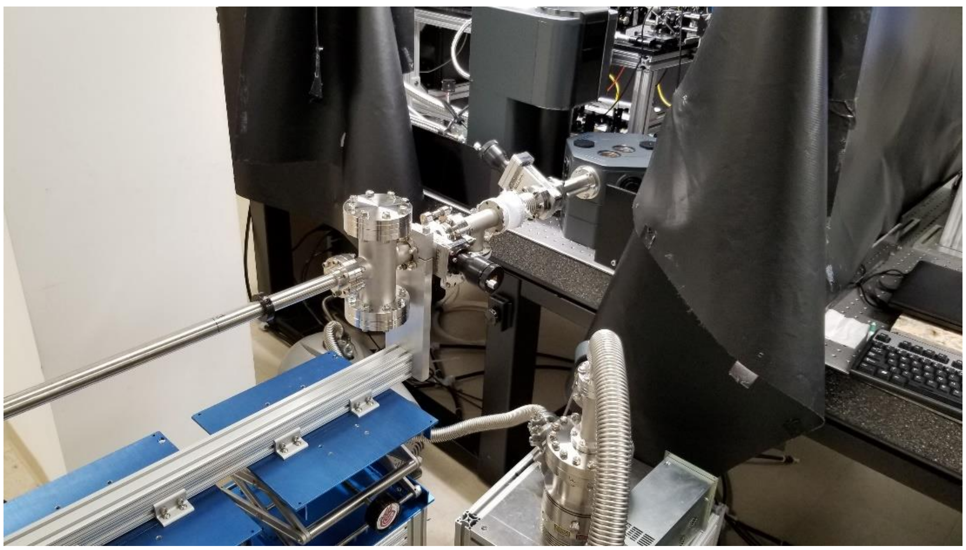
V. Montana Transfer

I. Insertion

This section will outline the transfer process into the magnet using the BVS

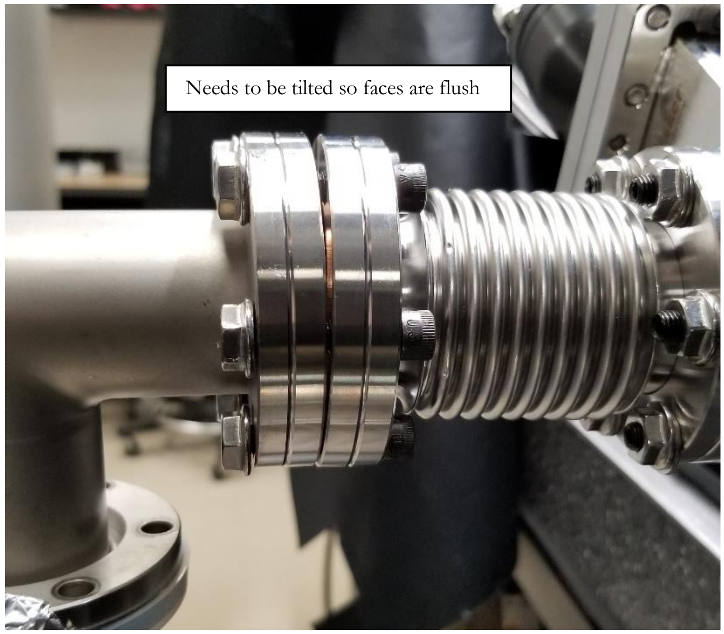
1. Attach the BVS to the Montana:

    a. Wheel the BVS over to the Montana. Turn the lab jacks simultaneously in order to raise the operational part of the suitcase up to be in line with CF 2.75 bellows attached to the CF 2.75 valve on the Montana. Take care to turn the lab jacks simultaneously to keep the manipulator level to the ground, using a level if necessary

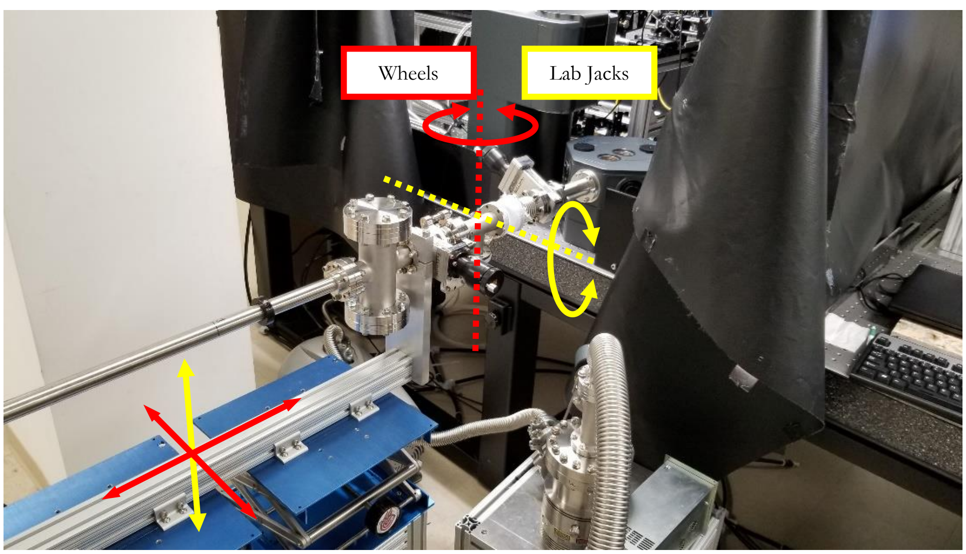


By placing a kim-wipe box on the lab jacks and aligning the jack cross-bar with the marker line labeled "Montana", proper attachment height can be attained.

b. Ensuring both of the CF flanges are clean (Sec. 2.III), align the BVS and bellows flanges together so that they are flush.

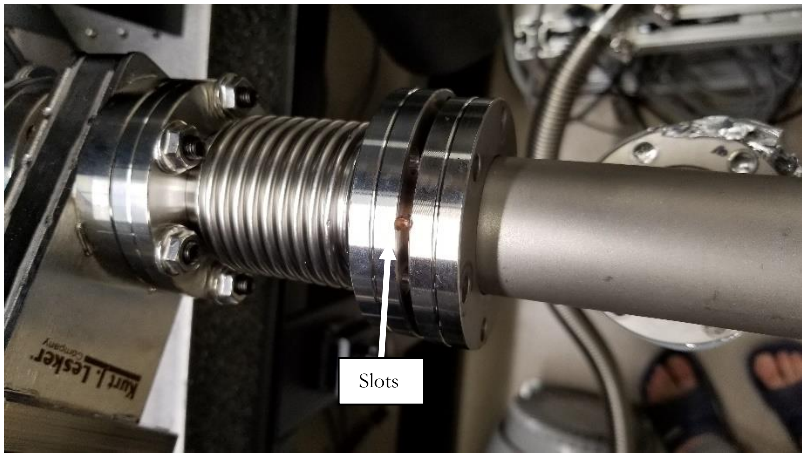


Rotation about the vertical axis is done via manipulation of the cart wheels, and the tilt in line with the manipulator is done by finely tuning the lab jacks



The suitcase should be able to slide onto and off of screws placed through the bellows flange freely. If this is not possible, the manipulator is not coaxial with the bellows and needs to be tilted up or down or rotated left or right.

c. Make sure a copper gasket is in between the flanges and tighten the bolts which bring the flanges together. Ensure that the slots in the flanges line up.



The copper gasket should be exposed equally in the small gap between the flanges if the faces of the flanges are coplanar. Sometimes the gasket can fall out of place before it is sufficiently squeezed between the flanges. If this happens, use a very small, clean Allen key to push it into place while moving the suitcase forward to squeeze the gasket between the flanges.

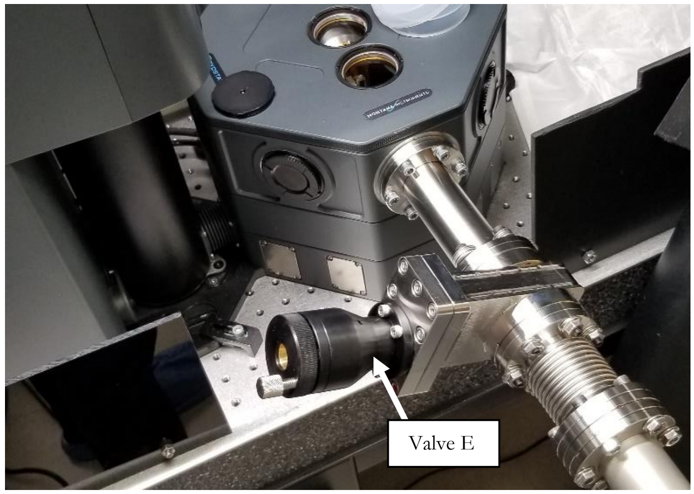
Take care to tighten the bolts no more than a quarter-turn at a time and in a star pattern to ensure proper sealing. (Sec. 2.II.II).

2. Commence pumping sequence

    a. Attach the turbo pump to the transfer tee via CF 2.75 and turn on the roughing pump

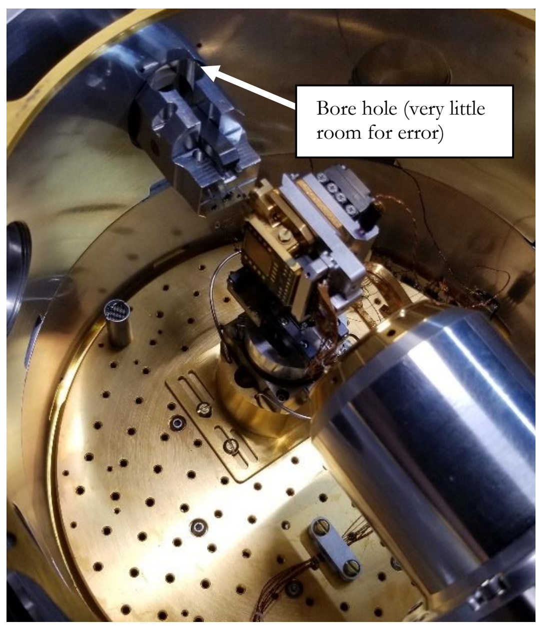
    b. Once the pressure in the tee reaches about 10^{-2} mBar , turn on the turbo and let the transfer tee be pumped down to about 10^{-6} mBar . Open **Valve A** when the transfer tee is at vacuum roughly comparable to the sample space, and let both of these chambers pump down together.

    c. Once the transfer tee and sample space are both at about 10^{-7} mBar of pressure (the Montana pressure), open **Valve E**.



3. Transfer

   a. Ensure the lab jacks are positioned so that the axis of the suitcase manipulator is coaxial with the axis of the valve on the Montana. Also ensure that the two faces of the port aligner are parallel. These checks are to prevent the sample holder from running into a bore hole inside the Montana

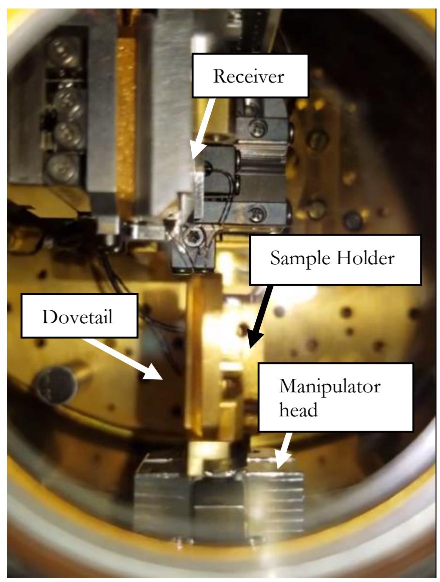


   b. Making sure **Valve A and Valve E** are open, slowly advance the BVS manipulator into the Montana. There is a line drawn on the manipulator which gives the approximate distance the manipulator may be advanced before the sample holder enters the Montana chamber space.

If any resistance is felt, stop advancement of the manipulator and check to make sure all valves are, in fact, open and the port aligner does not deviate too greatly from being straight. There is very little room for error when transferring into the Montana, so great care must be taken during this step to ensure everything is aligned.

c. Looking through the windows atop the Montana chamber space, monitor the bore hole through which the manipulator head will enter. When the head approaches this bore hole, fine tune the port aligner to ensure that the manipulator head is centered on this hole. The manipulator head is only slightly smaller than the bore hole, so care should be taken here.

d. Advance the manipulator so that the sample holder approaches the receiver. Looking through a windows of the Montana chamber space, bring the sample holder close to the receiver for fine alignment. The bottom face of the sample holder should face the "tower" of the Montana.

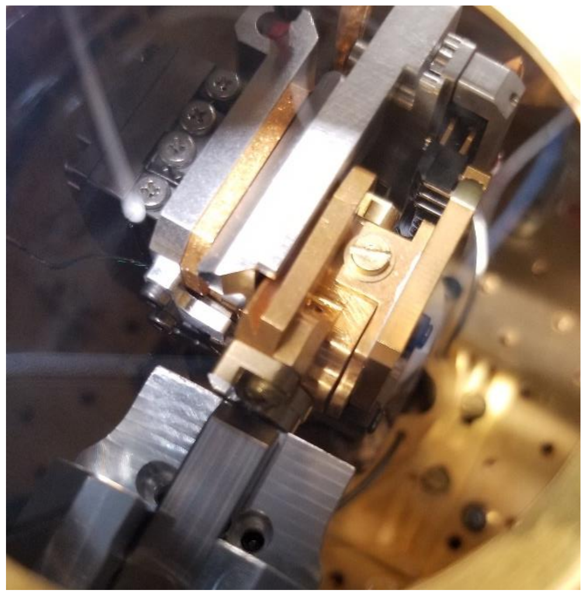


e. Using the piezo stages, fine tune the position of the receiver to accept the sample holder. Bring the receiver as close as possible to the sample holder to keep it away from the objective. The receiver may be pushed back by the sample holder as transfer is attempted while the receiver position is being dialed in, so it may be necessary to intermittently move the receiver away from the objective.

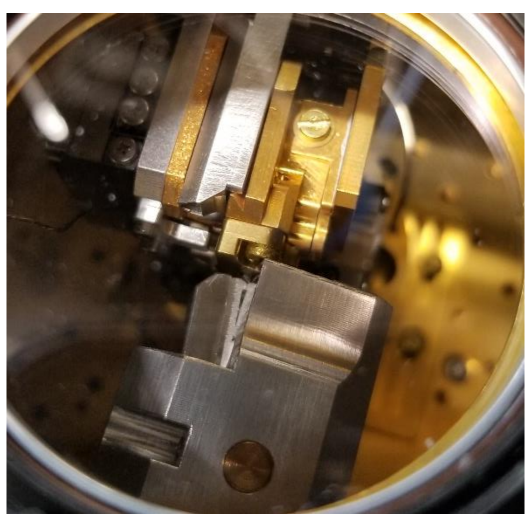
For additional information on using the piezo controls see Appendix II (Sec. 7.II)

f. If transfer is very difficult, it may be necessary to fine-tune the height of the lab jacks and the port aligner positioning to bring the positon of the sample holder into a positon that can be accommodated by the operational range of the piezos.

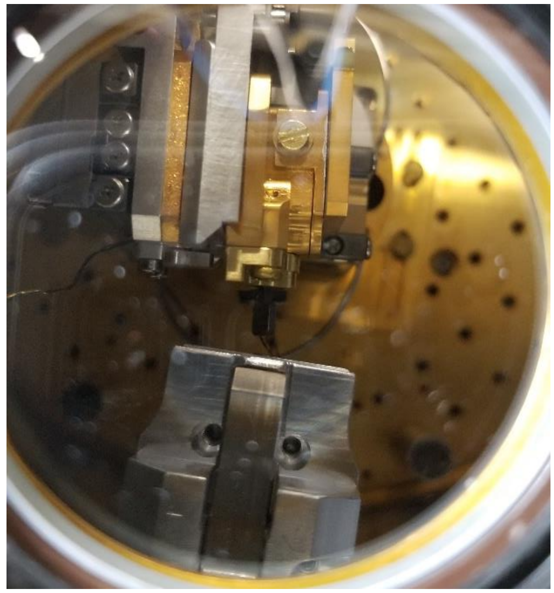
g. Once properly aligned, advance the sample holder until it sits inside of the receiver slightly. Rotate the BVS manipulator clockwise as viewed from the back to secure the lead screw of the sample holder into the threaded boss on the receiver.



h. Once the sample holder is secure, let go of it with the manipulator by screwing the thumbscrew to advance the handles relatively away from each other. The PEEK traveler on the manipulator head can be monitored to determine when the head is no longer holding the sample holder – when the PEEK traveler is fully retracted, the head has released the sample holder.



Slowly retract the BVS until the titanium screw is fully out of the manipulator head



i. Very slowly retract the BVS manipulator.

j. Ensure the BVS manipulator is **fully** retracted and then close **Valve A and Valve E**. The transfer tee may now be vented through the turbo and the BVS removed.

   If the suitcase is not needed elsewhere it is useful to keep the connected so that alignment is already tuned when the sample needs to be removed from the Montana.

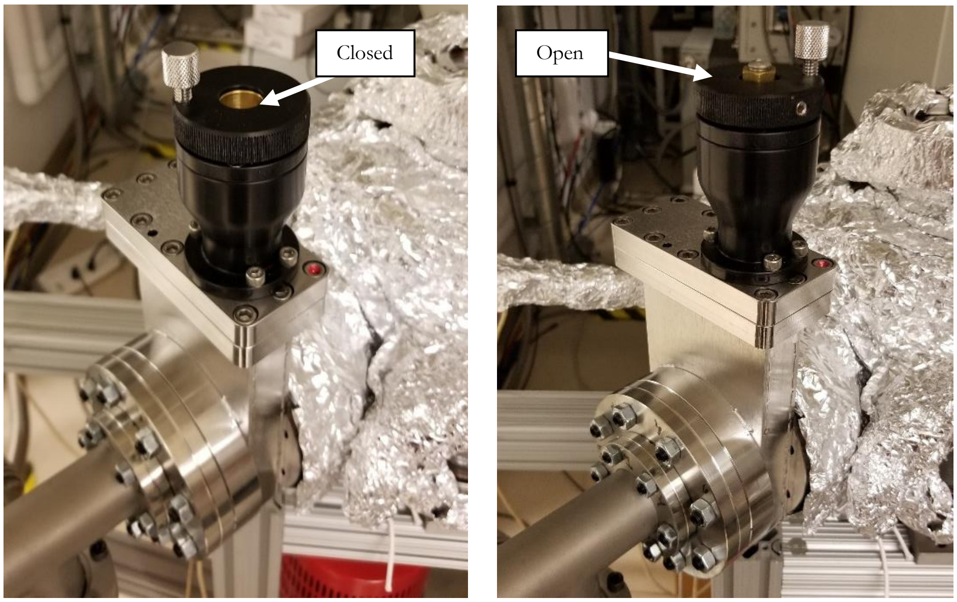
k. Measurements may now be taken after the sample has been moved to face the objective.

II. Removal

Redacted Section

VI. Transfer Tips and Tricks

1) It is possible to tell if a CF valve is open by looking at it from the outside. The screw in the handle will protrude if the valve is open, and it will be recessed if the valve is closed.



2) Ensure that the port aligner is straight before any transfer.

3) The PEEK traveler may be monitored to determine whether or not the manipulator head is opened or closed

4) If necessary, the top assembly of the suitcase can slide along the L-brackets which hold it to the lab jacks. Currently, the position of the top assembly is retracted to keep its center of mass close to the center of the frame, but sliding the assembly may be necessary in the future to e.g. transfer into Prof. Zeljkovic's MBE

5) Ensure that electrical connection was successful via breakout box if transferring into the magnet or Montana

6) In the Montana optical system, the receiver is oriented such that the dovetail plane is perpendicular to the ground in the lab frame, and in the magnet it is oriented such that the dovetail plane is parallel to the ground in the lab frame. In each case, chamfers exist to "catch" the sample holder to account for manipulator sag. (Sec. 1.III.II).

7) Videos of successful transfers can be found in the Drive folder

Chapter

5

Parts List

I. Vacuum Suitcase

I. Frame

Redacted Section

I. Top Assembly

Redacted Section

II. Intermediate Chamber

I. Frame

Redacted Section

I. Chamber & Components

Redacted Section

III. Glovebox

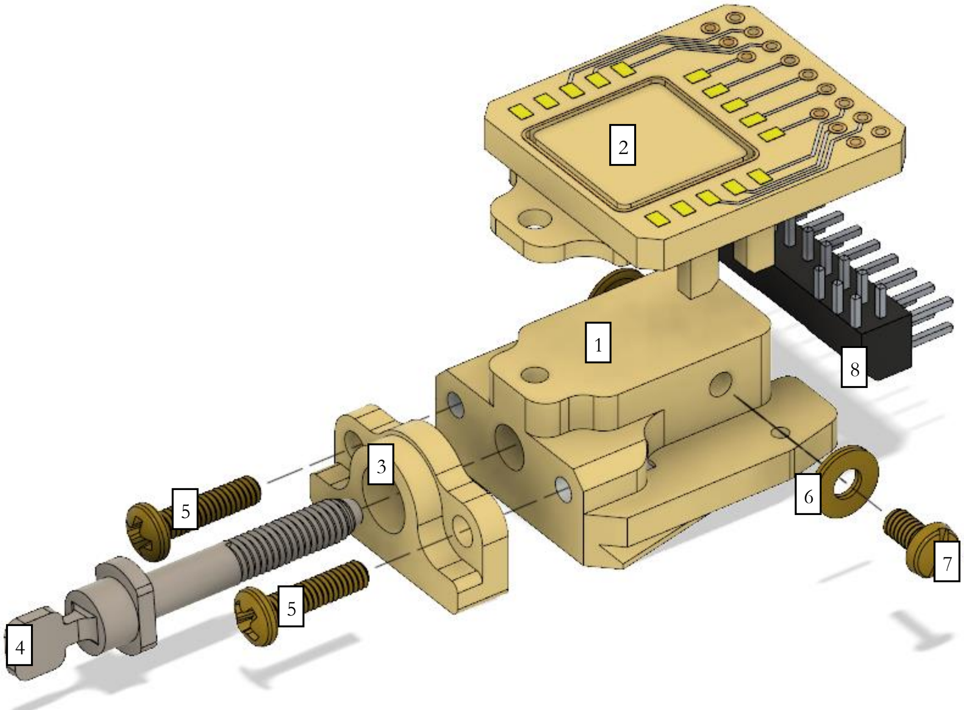
Redacted Section

IV. Magnet

I. Receiver

Redacted Section

V. Montana Sample Holder



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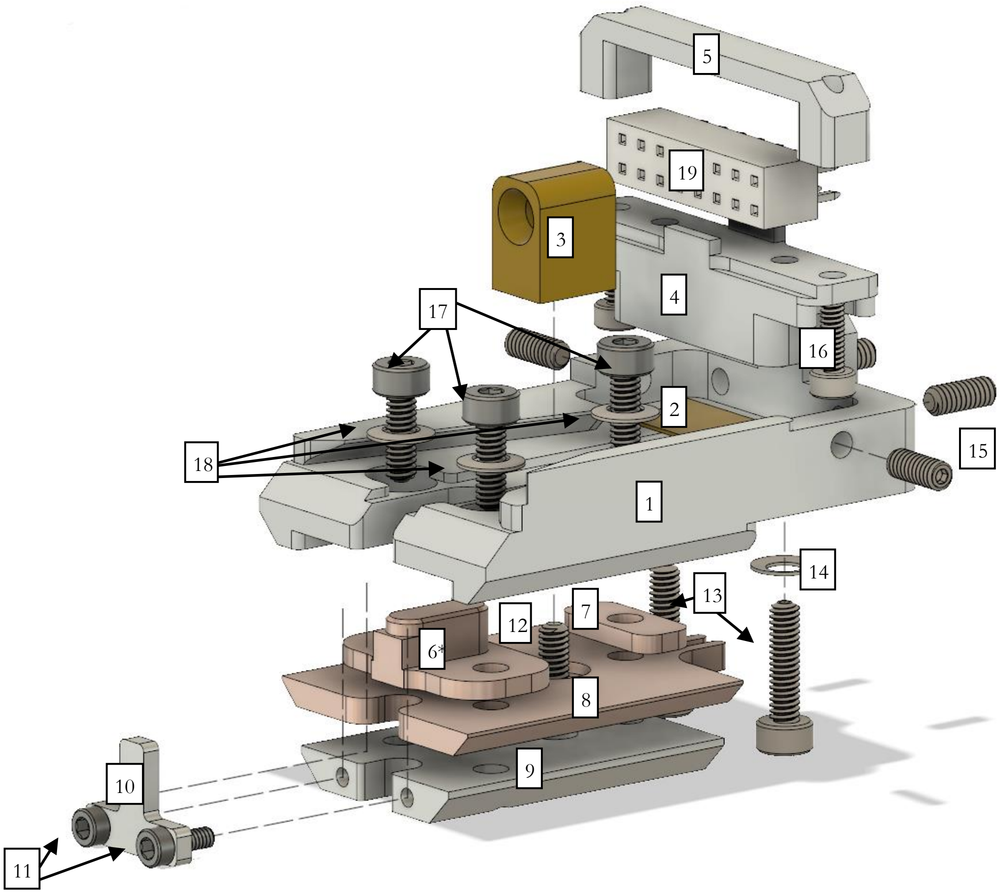
VI. Montana Sample Receiver



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Chapter

6

Quotes and Files

Google Drive

A link to a Google Drive folder containing all files mentioned in this manual as well as additional files can be found here. Note that anyone with access to this link can view these files, so this link should only be used internally by the lab.

Machining Files and DXFs

The Drive folder contains all files needed to machine additional copies of the Montana Sample Holders (not including the PCB on top), the Sample Holder Receivers as used in the Cryostation, and the Magnet receiver as used in the magnet (different from the Cryostation receiver – machined from one piece of OFHC copper.

3D CAD Files

The Drive folder contains 3D files relevant to the project in both .STEP and .f3d file formats.

Quotes

The Drive folder also contains all quotes related to this project, including those which were not ordered.

Email Threads

In addition to quotes, there are some email threads which have been saved for future reference. These include emails that are relevant to the design process from American Magnetics and Montana. These too can be found in the Drive.

Chapter

7

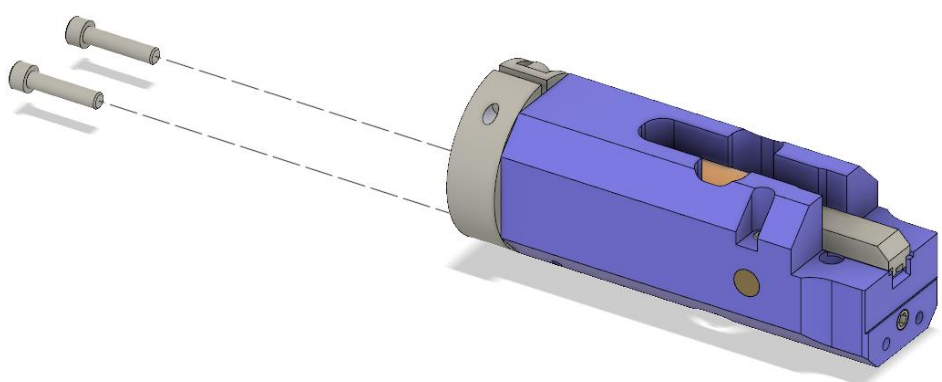
Appendices

I. Suitcase Manipulator Head

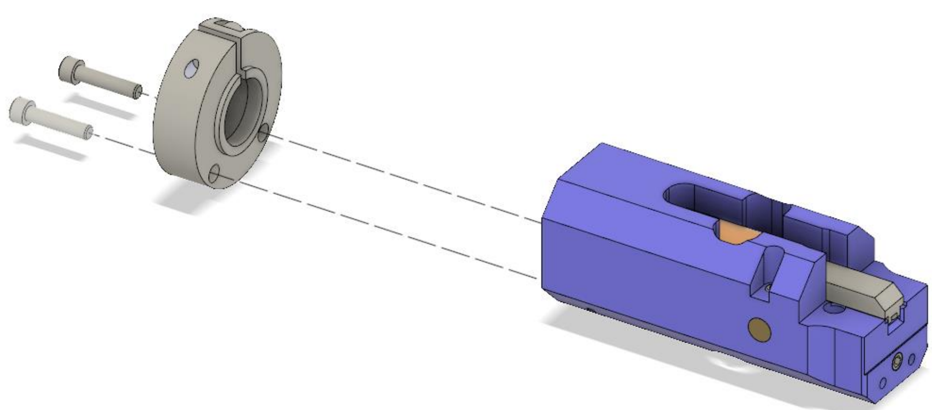
How to modify to make work better

I. Disassembly

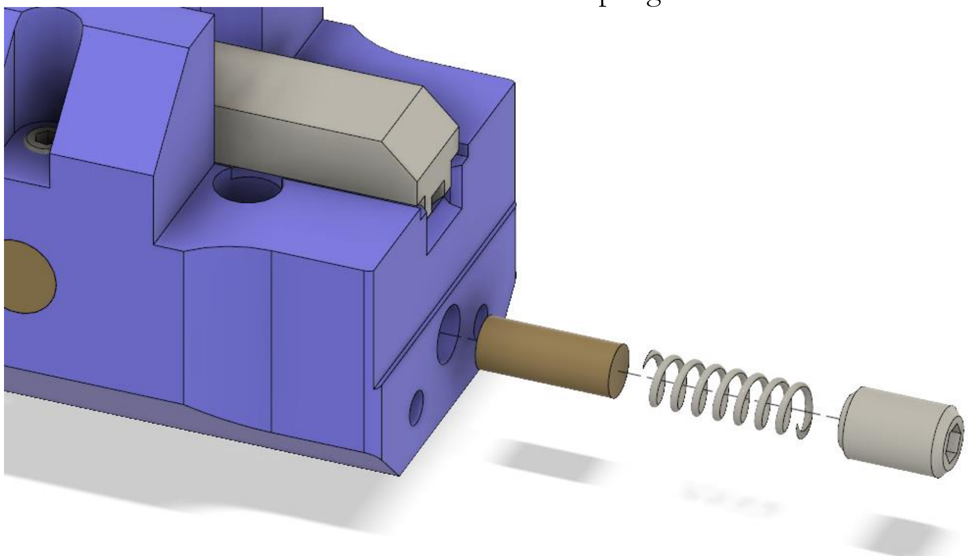
1) Unscrew and remove the screws holding on the clamping collar



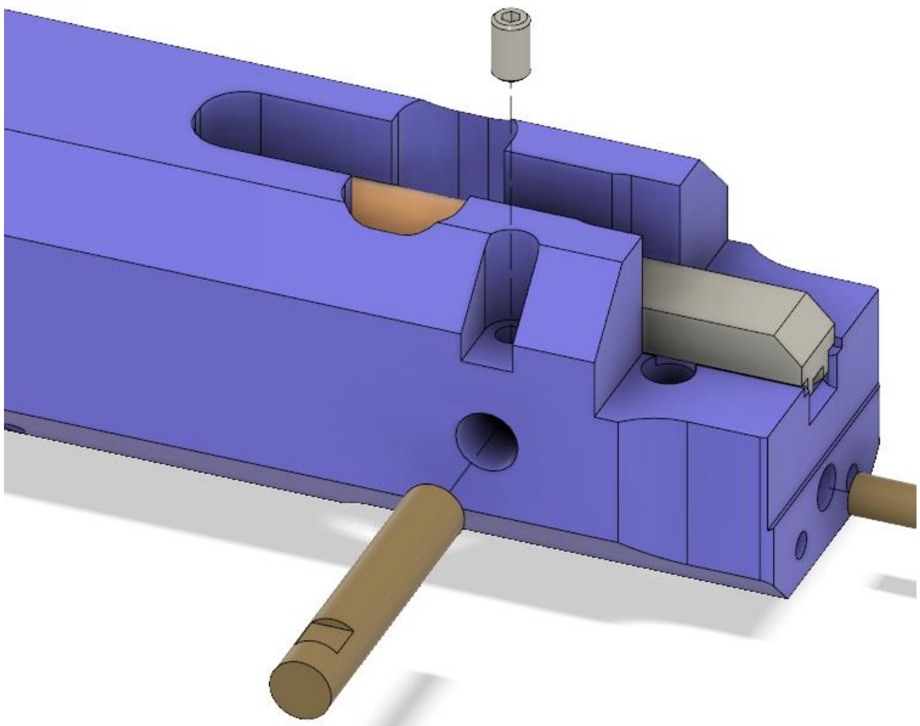
2) Remove the clamping collar



3) Unscrew the set screw in the front. Out will fall a spring and a metal extrusion.



4) Unscrew the set screw on the top of the main body. This releases the rod about which the gripping mechanism rotates. **During reassembly ensure that the set screw screws into the flat face cut out of this rod.**



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II. Cleaning and Assembly

All parts above can be washed in acetone, so the standard cleaning procedure outline in Sec. 2.III should be followed.

To assemble, follow the disassembly process in reverse

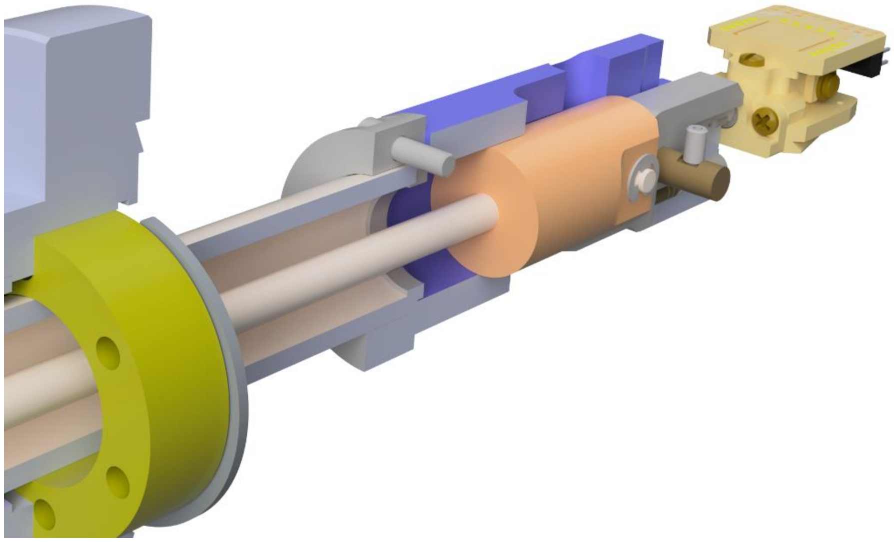
III. Troubleshooting Head Malfunctioning

Getting the manipulator head to function consistently was a recurring problem when getting the suitcase system operational. There were several parameters that were tuned to get it to work properly. These parameters are laid out below in case the head begins to malfunction. They are listed in the order that they should be adjusted.

1) **Threading the PEEK traveler**

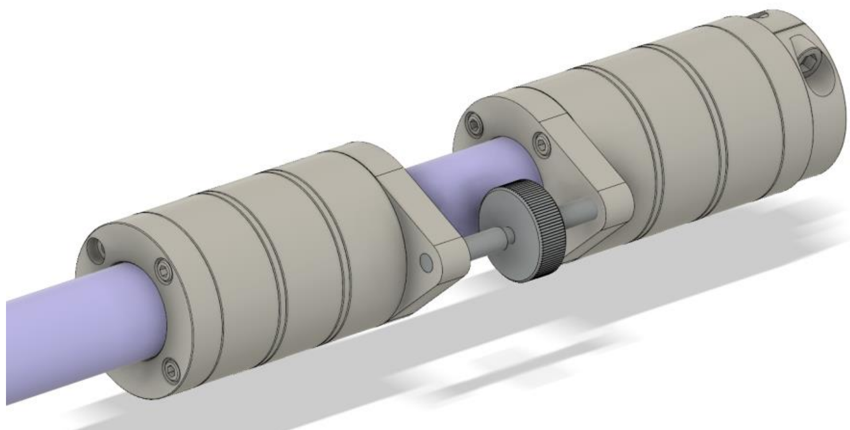
   Inside the manipulator are two rods – an outer rod which is coupled to the front handle of the manipulator, and an inner rod which is coupled to the rear handle of the manipulator.

   When attaching the manipulator head to the suitcase, the PEEK traveler is screwed onto the inner rod, and then the clamping collar fixes the rest of the manipulator head to the outer rod. It is the relative motion between these rods that moves the traveler, driving the gripping mechanism.

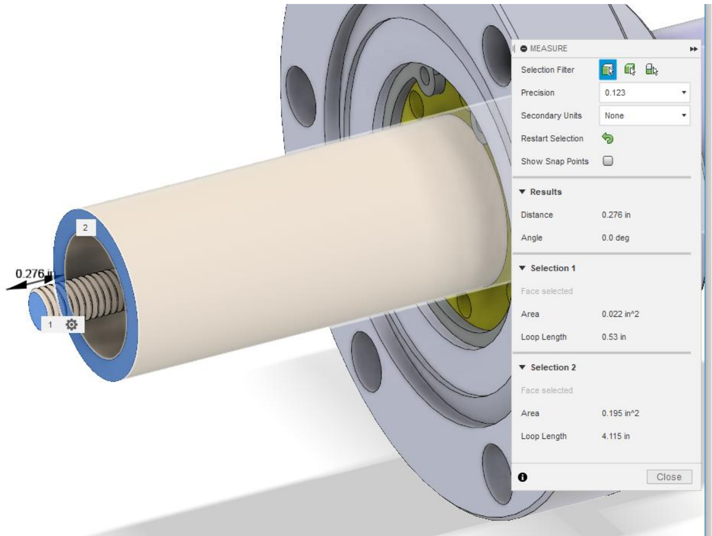


The traveler requires .400 in. to operate. The thumbscrew of allows for .700 in. Therefore, it is important to place that .400 operational stroke in the middle of the .700 manipulator stroke. To do this, follow the following procedure:

a. Turn the thumbscrew until the ends of it are flush with the threaded plates of the manipulator handles

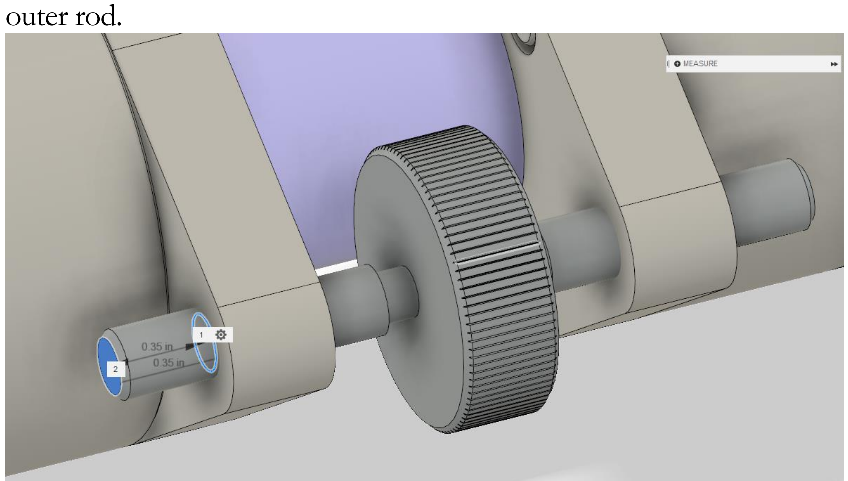


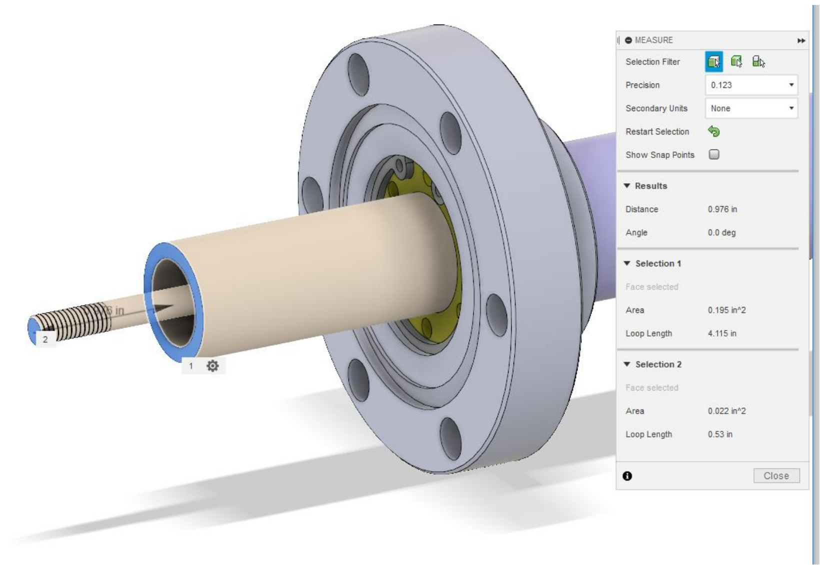
b. At this point the inner rod should protrude about .28" from the outer rod



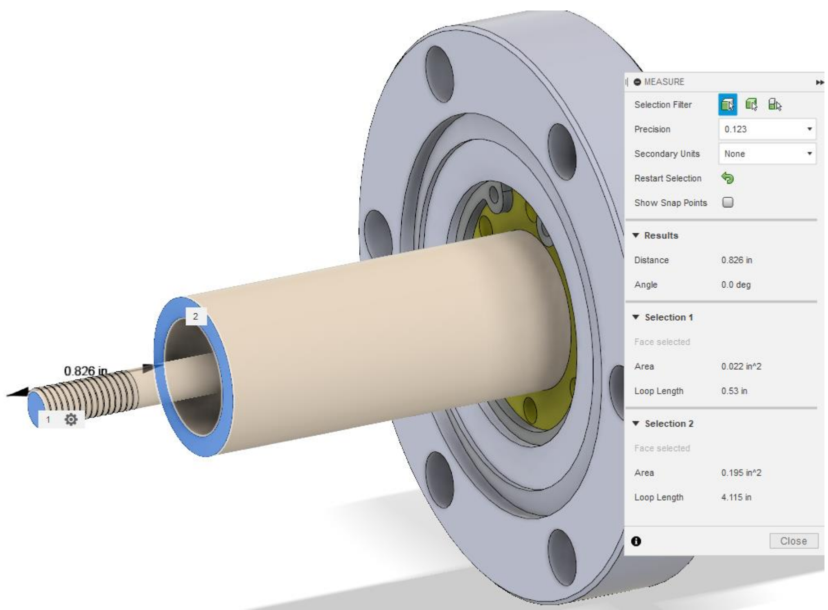
If it does not, the handles are decoupled from the rods. Remove the thumbscrew and move the handles until the rods snap into place.

c. Advance the thumbscrew. The inner rod will begin to protrude more and more from the outer rod. Once the inner rod **stops moving,** the end of the operational range of the thumbscrew has been reached. Note that **the thumbscrew will not have advanced the all the way down its threading when the inner rod stop moving.** If the thumbscrew is advanced too far beyond this point the magnets may decouple. The point at which the inner rod stops moving even if the thumbscrew is still advanced corresponds to the inner rod protruding about .976" from the outer rod.





d. Advance the thumbscrew in the direction which retracts the inner rod into the outer rod **.150”**. The .700” operational thumbscrew stroke minus the .400” head stroke leaves a .300” buffer. This is then cut in half so that the buffer is equal on both sides of the head stroke, placing the head stroke in now middle of the operational thumbscrew stroke.

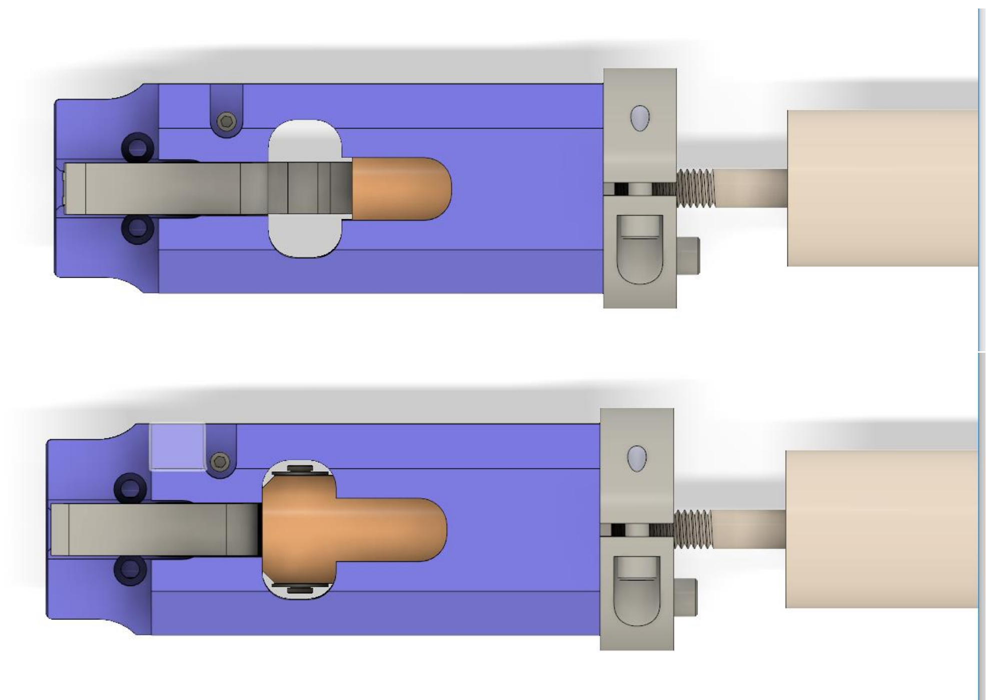


In the picture above, the inner rod protrudes .826”. The .276” starting positon plus .700” yields .976”. Subtracting.150” off of this yields .826”, which corresponds to the relative positon between the rods that should leave the head fully closed. Alternatively, this can be viewed as taking the original .276”, adding .150” of buffer, and then adding the .400” of thumbscrew operational stroke to yield .826”, leaving another .150” of buffer before reaching the maximum extension of the inner rod at .976”

It is best to measure how far the inner rod protrudes from the other rod in order to take this measurement. Alternatively, calipers may be used to measure how far the thumbscrew has advanced in the threaded plates on the handles. This .150" should be cut in half because the thumbscrew is threaded through the plates of both handles, so each side of the thumbscrew should protrude .075" from the outside face of the threaded plates.

e. The inner rod is now in the positon which should correspond to the PEEK traveler being fully advanced and the head being closed. Screw the manipulator head onto the inner rod.

The easiest method for this is to use a sterile Allen key to push the PEEK traveler into its retracted positon so that the head is open and then turn the entire head around the axis of the inner rod to screw it onto the inner rod.



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f. **The traveler is not screwed on until its threading bottoms out**. To determine how far to screw it on, screw the head on partially and then try to push it onto the outer rod. When this happens the PEEK traveler will be pushed forward, closing the head. When the traveler is fully pushed forward, the clamping collar should then just barely fit fully onto the outer rod.

Redacted Image

If the head has not been screwed on enough, when the traveler bottoms out into the positon which closes the head, the clamping collar will not quite reach the outer rod.

Redacted Image

If the head has been screwed on too much, the clamping collar will reach the outer rod before the PEEK traveler has bottomed out.

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This step is absolutely crucial. Just a $1/8^{th}$ turn can be the difference between the head being operational and the head malfunctioning.

g. When the clamping collar *just* fits fully on the end of the outer rod as the PEEK traveler hits its bottomed out position, the traveler has been threaded properly.

h. Secure the clamping collar with an Allen key

2) Adjusting the set screw

There is a set screw on the front face of the manipulator head which parameterizes the clamping strength of the manipulator head. The further advanced into the body of the manipulator head the screw is the greater the clamping force. It is better to err on the side of caution (with higher gripping force) and risk breaking a titanium lead screw than accidentally dropping a sample holder in the magnet (with lower gripping force).

IV. Magnetic Handle Decoupling

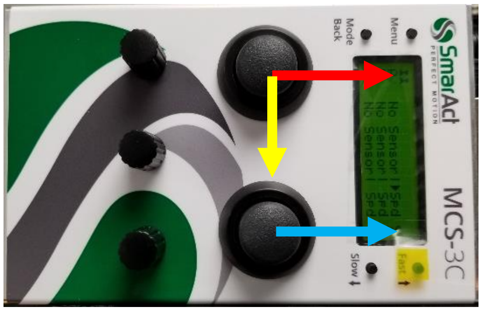
The manipulator handles of the BVS may become decoupled during operation. It is almost always the rear handle and is usually caused by the thumbscrew being advanced too far, allowing the handles to come too close together

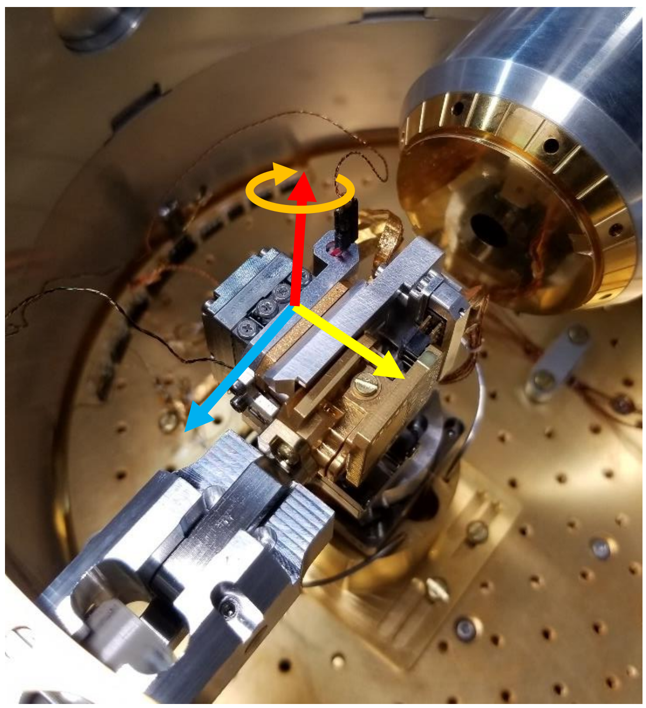
If decoupling occurs, first try advancing the thumbscrew to push the handles as far apart as they can go. If this works, a force can be felt on the handle as it is recoupled to its complementary rod inside the manipulator body.

If this does not work, then try removing the thumbscrew and sliding the handle up and down the shaft. Again, it will be felt re-coupling when this works.

Either of these procedures may affect the head operating properly. If the head is not working consistently, remove it and re-attach it according to Appendix I.III.1 (Sec. 7.I.III.1).

II. Montana Piezo Stage Operation



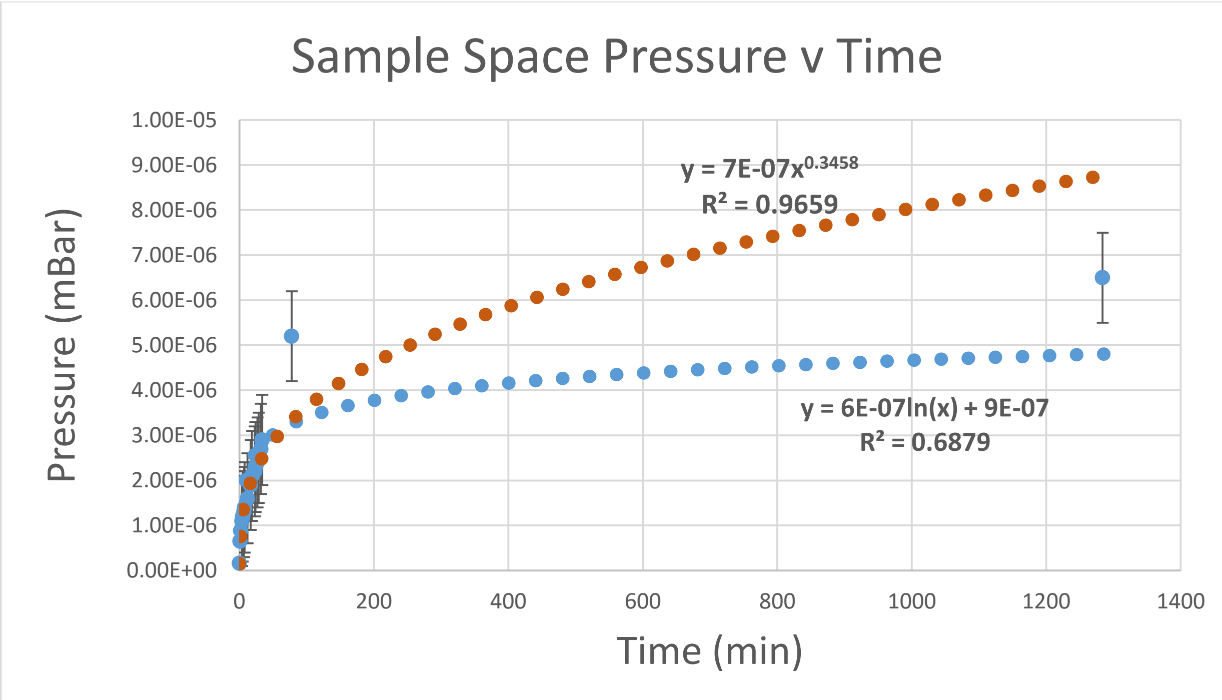


III. Vacuum Degradation

Currently, the BVS does not have dedicated pumps on the suitcase sample space. CF4.5 ports have been left to accommodate ion and/or getter pumps in the future if necessary. Since there is also no gauge on this space, monitoring the vacuum when the sample space **Valve A** is closed is impossible. Therefore, a test was done in order to monitor the vacuum degradation over time.

The sample space was brought under vacuum without bakeout, and then **Valve A** was closed so that the sample space had a blank on one CF 4.5, a gauge on the other (via CF 4.5 to 2.75 zero length reducer), the manipulator on one CF 2.75 port, and the closed valve on the other. Then the vacuum was then checked intermittently and recorded.

The data can be found in the Google Drive folder for this manual, (Sample Space Pressure v Time.xlsx) and some additional graphs can be found below



Chapter 8

Glossary

Brass Boss	The threaded boss on the Montana sample holder into which the Titanium Lead Screw threads
Breakout Box	A metal box which "breaks out" a composite wire into its constituents so that each wire may be electrically probed individually
BVS	Burch Vacuum Suitcase
Cleanroom-in-a-Glovebox	Alternate name for Glovebox
Conflat (CF)	A vacuum standard used for UHV (up to 10^{-11} mBar) and bakeable. Connections are made with sexless flanges cutting into a copper gasket.
Glovebox	Fabrication chamber for LASE
Intermediate Chamber	The chamber attached to the back of the glovebox that is used to transfer into the glovebox. Implemented so BVS and (more so) ZVS sample spaces see nothing but vacuum.
Kwik-Flange (KF)	An alternate name for Quik-Flange (QF)
Lead Screw	Another term for *Titanium Lead Screw* (lead as in "to lead", not the metal)

Manipulator	A mechanism used to move something in vacuum
Manipulator Head	The head of the BVS manipulator which is responsible for holding sample holders in vacuum during transfer and transportation
MARTI	Alternate name for magnet
Montana	As a noun, refers to the Cryostation designed by Montana Instruments As an adjective, used to describe any component designed by them to work with the Cryostation.
Quik-Flange (QF)	A vacuum standard used for low vacuum levels (up to 10^{-6} mBar)
Sample Block	Blocks attached to the intermediate chamber manipulator that receive a specific type of sample holder. Each sample holder has its own sample block.
Sample Holder	An object to which a sample to be measured is mounted. Usually contains a circuit board to which a sample can be wired and sufficient thermal conductivity for cooling if required
Sample Holder Receiver	An object to which a sample holder is mounted in order to secure it into a measurement apparatus
Sample Receiver	An alternate name for sample holder receiver
Sample Space	The part of a vacuum suitcase where the sample sits during transportation. IPN: WHAT for the BVS
Titanium Lead Screw	The screw on the Montana sample holder which is held by the BVS manipulator (lead as in "to lead", not the metal)
Titanium Screw	Another term for *Titanium Lead Screw*

Transfer Tee	The part of a vacuum suitcase which sits between the sample space and system to be transferred into, separated from each by valves. It is pressurized to atmosphere during transportation and vacuumed out during transfer
Valve A	The valve between the sample space and transfer tee of the BVS
Valve B	The valve to which the BVS/ZVS transfer tees attach on the glovebox intermediate chamber
Valve C	The valve on the argon line of the intermediate chamber
Valve D	The valve between the intermediate chamber and glovebox
Valve E	The valve on the Montana to which the BVS attaches
Valve F	The valve on the magnet to which the BVS attaches
ZVS	Zeljkovic Vacuum Suitcase