COLD ATOM SOURCE CELL (CASC) USER MANUAL

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1. General Information

1.1 User Facilities Requirements

Ensure your lab or experimental setup has ample room to work around the cell for installation and laser safety. Always follow your institutional guidelines concerning a safe work environment.

1.2 Package Contents

Upon receiving the cold atom source cell, inspect the packaging for damage. If the packaging shows signs of damage, excessive shock or if the shock watch is red, notify the shipping company and then contact Infleqtion.

When unpacking the CASC, be particularly careful to avoid dropping it or knocking it against anything, as it is a glass cell and could easily break. The cell is shipped in a cloth lens pouch. Carefully remove the cell and inspect for any damage. Please contact Infleqtion if there are signs of damage to the cell. **Keep all original packing materials.**

The shipment should contain the following items:

Item	Quantity
Cold Atom Source Cell (CASC)	1
High-temperature wires with terminal pins	4
Additional terminal pins	8
Copper Gasket	3
Socket Head Cap Screws 8-32	12
Washers	12

If any of these items are missing, please contact Infleqtion to obtain replacements.

If the CASC will be exposed to atmosphere for an extended period of time, store in a dry environment with desiccant. The dispensers and getters will absorb water if left in a humid environment, potentially causing the CASC to not function as intended.

2. Safety

2.1 Definitions, Labels and Symbols

	Caution! – Risk of electric shock
	Caution! – Risk of damage to equipment

2.2 Warnings

FUSES – Always use a fuse to prevent over-driving of the atom dispensers inside the cold-atom source cell. Over-driving a dispenser can prematurely deplete the atom source, rendering the device non-functional.

TORQUE SPECIFICATIONS – When attaching the source cell to a vacuum system, use a calibrated torque wrench to ensure proper vacuum sealing of the ConFlat flange. This precaution will ensure a proper UHV seal and minimize stress that can cause fractures and cracks.

KNIFE-EDGE PROTECTION – When handling the cold atom source cell, protect the knife-edge on the ConFlat flange. The knife-edge can be damaged by contact with other hard surfaces, such as metal tools. A damaged knife-edge will prevent the source cell from being properly sealed to a vacuum system.

GROUNDING – The atom dispensers in the source cell must be connected to a power supply that uses a three-wire power cord with a protective ground contact. Always use a three-prong outlet that is properly grounded. Do not operate the device with a power supply that uses a two-conductor outlet or extension cord. If using an extension cord, use a three-conductor version.

MAXIMUM OPERATING CURRENT – Never drive the dispenser with a current exceeding the maximum specified. Over-driving the dispenser can release excessive quantities of material, depleting the dispenser and likely rendering the device non-functional. Over-driving the dispenser can also coat the cell walls with alkali metal, making the surfaces opaque to laser beams.

REUSE – Infleqtion does not guarantee performance of the source cell if it is exposed to air after the dispensers have been activated. Both dispenser activation and baking should be performed after the source cell has been affixed in its final position on the target vacuum system. Consider activating only one of the dispensers, leaving the other as either a backup or for a future experiment.

2.3 Physical Safety

This cell is made of glass. Handle with care, as the glass can break and cause a hazard. The cap of the CASC will become hot when in use as the dispensers will heat up when current is applied. Be careful not to touch the cap as it may cause burns.

2.4 Electrical Safety

This product requires the use of a power supply to drive current through the dispensers. As with any electrical product there is always a risk of electrical shock. The power supply must use a three-prong wire that is properly grounded, and if used with an extension cord, it must be a three-conductor version.

2.5 Laser Safety

Disclaimer	This is not a laser product. This is for reference only. Please refer to the manufacturer manual and safety information for each laser system that you will use with this product. Please follow your institutional guidelines concerning laser safety.
DANGER!	If the equipment is used in a manner not specified by the manufacturer, then the protection provided by the equipment may be impaired.

This cell has specular surfaces, is intended to be used with laser power, and reflections of the laser may occur. Laser safety glasses should be worn when using this product with a laser. Please follow your institutional guidelines concerning laser safety.

3. Specifications

Infleqtion's cold atom source cell is a compact vacuum component that simplifies the production of high-flux beams of laser-cooled atoms. Fluxes of several billion atoms-per-second can be achieved for rubidium and cesium.

PRODUCT SPECIFICATIONS	
Overall Dimensions	30 mm x 30 mm x 94 mm 1.2 in x 1.2 in x 3.7 in
Clear Aperture	40 mm x 16 mm side walls, Ø10 mm end cap
Atom Sources	Up to two pre-installed sources: Rb, Cs or both
Vacuum Connection	DN16 (1.33") CF (2.75" adapter plate available)
Glass Thickness	1.5 mm
Vacuum Aperture	0.75mm Ø
Vacuum Conductance	0.05 l/s
Electrical Conductance	4 PCB pin connections (2 per source)
Maximum Bake Out Temperature	225 °C
Ramp Up/Down Temperature	1 °C/min
Typical Atom Flux*	$1\text{x}10^9$ atoms per second
Typical Atom Velocity*^	10 m/s – 20 m/s
Recommended operating conditions for optimal performance	
Amperage	2.7 – 3.5 A
Pressure/Vacuum Level	10^{-7} - 10^{-6} Torr

*Output condition depends on 2D MOT laser parameters

^Longitudinal velocity

4. Regular Product Maintenance

4.1 Handling

Take care when handling the glass cell, as the fragile assembly can be easily chipped or cracked. Always move slowly around the lab and ask for assistance when installing the cell. Do not touch the glass cell with ungloved hands.

4.2 Cleaning

Infleqtion recommends cleaning the cell in a typical optics manner.

- Appropriate cleaners include IPA, methanol, acetone, or deionized water.
- Use a fresh section of wipe each time to avoid glass chips dragging across the coated surface.

5. Installation

5.1 Mounting the Source Cell to a Vacuum Chamber

The cold atom source cell is mounted to a standard 1.33” (DN16) ConFlat vacuum flange. Using a calibrated torque wrench, the connection should be made using a standard OFHC copper gasket (included) and screws that are compatible with your vacuum system. Figure 1 shows the vacuum flanges and knife-edges on the adapter plate.

WARNING!

KNIFE-EDGE PROTECTION – The knife-edge can be damaged by contact with other hard surfaces, such as metal tools. A damaged knife- edge will prevent the source cell from being properly sealed to a vacuum system.

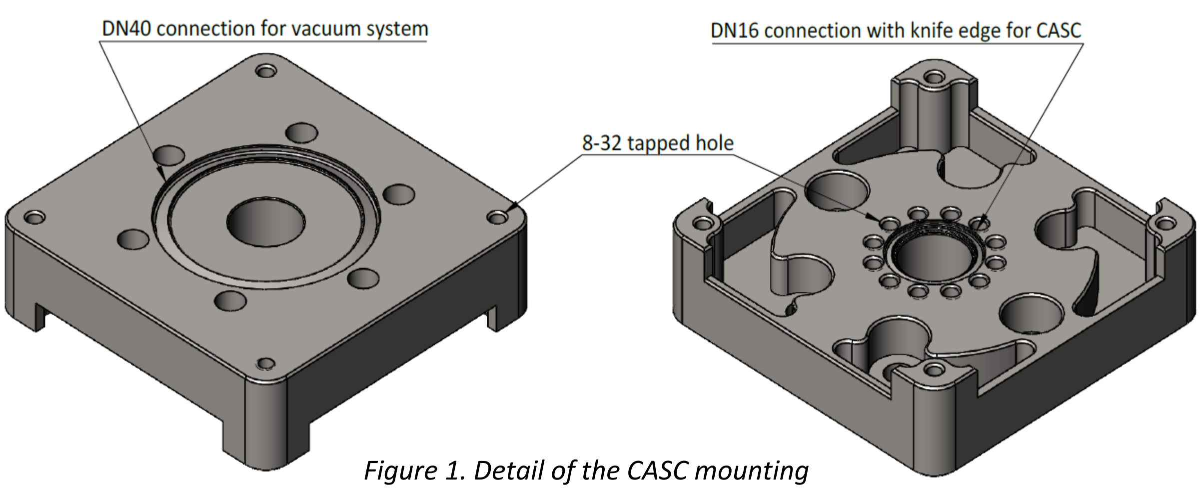


Figure 1. Detail of the CASC mounting plate (CAAPC1) showing the connections for both the DN40 and DN16 flanges.

The screws should be tightened in a star-like 1-4-2-5-3-6 pattern, as shown in Figure 2. Only a calibrated torque wrench should be used to tighten the screws. Ensure that the torque wrench does not touch the cell, as this can damage the glass. The screws should be first torqued to 30 in·lbs (3.4 N·m), followed by two rounds at 50 in·lbs (5.6 N·m).

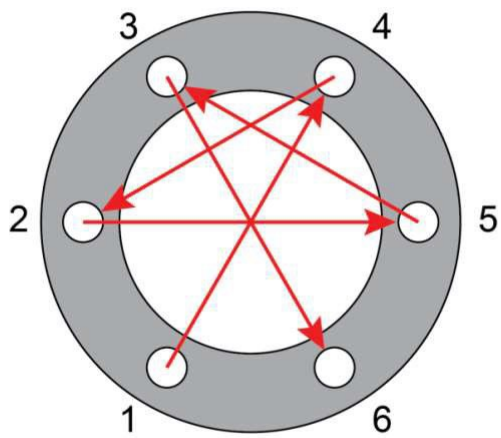


Figure 2: When attaching the science cell to a vacuum system, use the appropriate screws that are compatible with your vacuum system. The screws should be tightened in a star-like 1-4-2-5-3-6 pattern.

WARNING!

TORQUE SPECIFICATIONS – When attaching the science cell to a vacuum system, use a calibrated torque wrench to ensure proper vacuum sealing of the Con-Flat flange. This precaution will ensure a proper UHV seal and minimize stresses that can cause fractures and cracks.

5.2 Electrical Connections

To make electrical connections to the atom dispensers, use the terminal pins shipped with the unit. To connect a pin, gently press it into the socket on the bottom side of the cell while gently applying equal pressure on the far side of the cell (see Figure 3).

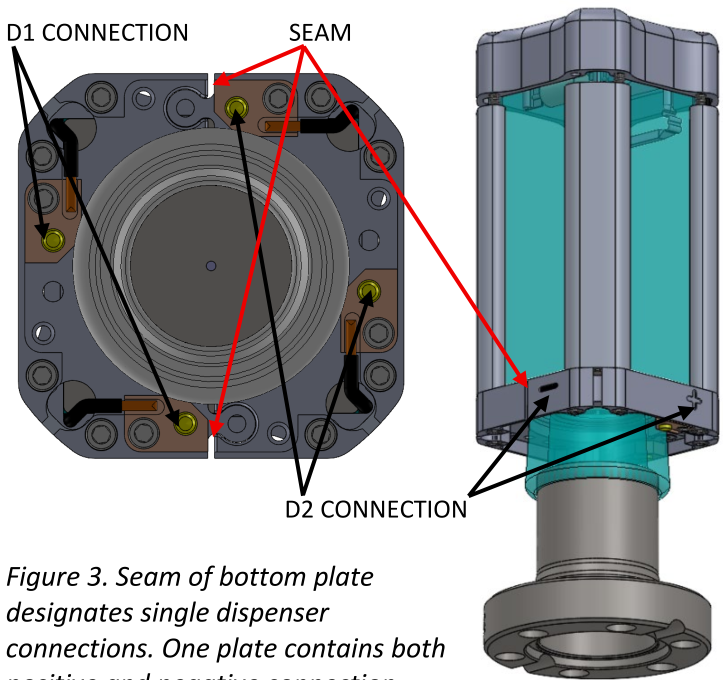


Figure 3. Seam of bottom plate designates single dispenser connections. One plate contains both positive and negative connection points for a single dispenser. D1 is the first dispenser, D2 is the second dispenser. Shown on the CASC where the user would attach the pins.

For dispenser activation during bakeout, use the pins attached to the high-temperature wire shipped with the unit. The two atom dispensers should always remain electrically isolated. The dispenser electrical connections on the CASC are not sensitive to electrical polarity. As long as each dispenser lead is connected to a (+) and (-) voltage, the CASC will work. **Each half of the**

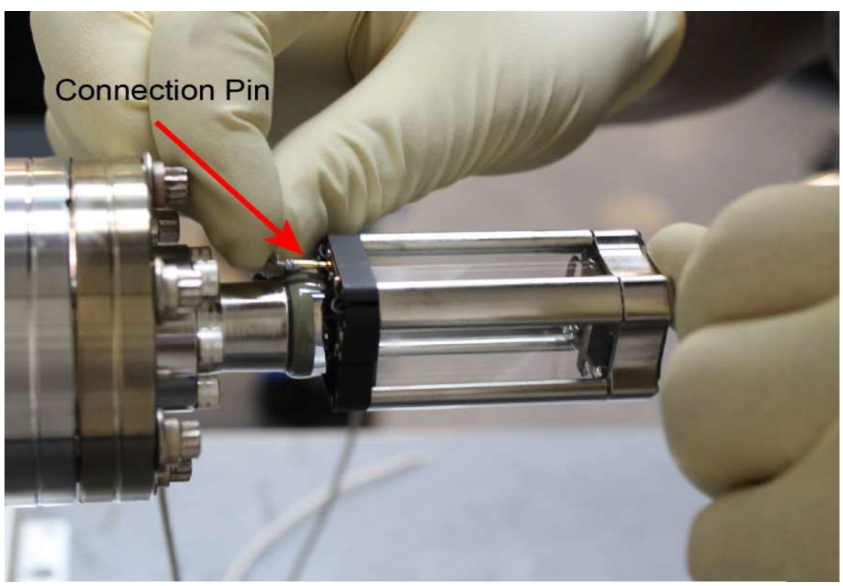


Figure 4: Making electrical connections to the source cell.

plug plate corresponds to one dispenser. Be mindful of this when you affix your CASC to your vacuum system, as you will need to have access to a (+) and (-) terminal pin. See Figure 4 below.

5.3 Vacuum Bakeout and Dispenser Activation

To achieve UHV-level pressures, the source cell must be baked out. The source cell can be baked up to a maximum temperature of 225 °C. The cell should be heated and cooled no faster than 1°C/minute.

The bake-out procedure for a single dispenser is:

1. Ensure that one dispenser (two connections) is connected to a power supply using the provided high-temperature wire and terminal pins. The power supply should be programmed in constant current mode, with a voltage limit set to 5 V.To monitor the temperature of the bakeout, affix a thermocouple to the metal neck connected to the ConFlat flange (see Figure 5). Secure the thermocouple in place using both Kapton tape and a thin metal wire.

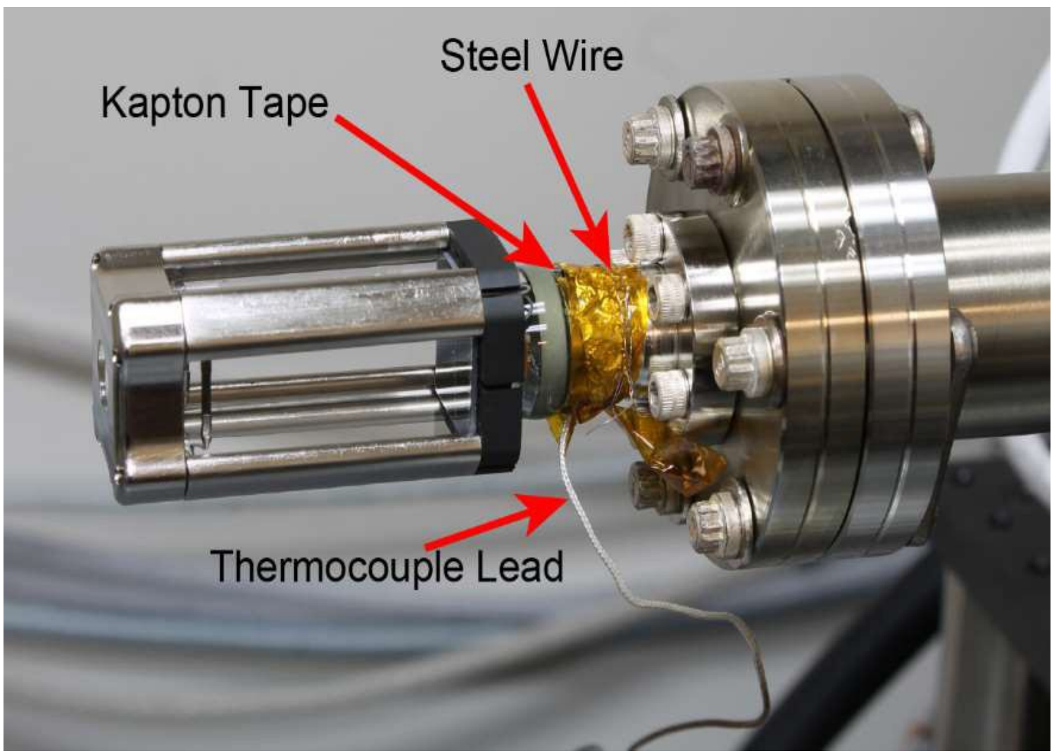


Figure 5: Affix a thermocouple to the metal neck of the source cell using Kapton tape and steel wire.

2. Heat the cell to no higher than 225°C at a rate of 1°C/min.
3. After the cell has reached the target temperature, pump on the source cell until pressure has reached a steady-state level (i.e. slope less than 10^{-8} Torr/hour).
4. Turn on the power supply to 3 A. The pressure in the chamber will rise.

5. After the pressure has stabilized, activate the dispensers by repeating the following three times:

a. Record the pressure in the UHV side of the vacuum system

b. Record the voltage across the dispenser

c. Apply 5.5 A for 1 minute, recording the maximum pressure

d. Lower the current to 3 A and record the pressure and voltage

e. Wait 15 minutes

Use the table below to record these values.

6. After the dispenser is activated, set the current to 0 A and continue to bake the system until the pressure has reached a steady-state value.
7. Cool the cell at a rate of 1°C/min.
8. After the cell has cooled,
   a. remove the thermocouple,
   b. replace the high-temperature wires with ones that are more compliant, and
   c. If purchased, install the Picas assembly around the cell according to the specified user manual.

Dispenser #1					
Activation #	Initial Pressure	Initial Dispenser Voltage	Max Pressure	Final Pressure	Final Dispenser Voltage
1					
2					
3					
Dispenser #2					
1					
2					
3					

6. Operation

6.1 Normal Operation of the Source Cell

For normal operation, drive the dispenser with a constant current between 2.7 and 3.3 A. It may take up to 20 minutes for the dispenser to thermally stabilize once current has been applied. To ensure proper dispensing, look for atomic fluorescence induced by a resonant or near-resonant laser beam passing through the cell. The camera setup described in Section 10 can be used to observe this fluorescence.

Always drive the dispenser with a power supply programmed in constant current mode with a voltage limit. The voltage limit will prevent thermal runaway of the dispenser that can prematurely deplete the atom source.

Due to variations in atom sources, the optimal dispenser current may vary between dispensers. To identify the ideal dispenser current, start with the lowest current of 2.7 A and look for laser-induced fluorescence after 20 minutes. If no fluorescence is observed, increase the current by 0.1 A, wait 20 minutes, and look again for fluorescence. Repeat this process until fluorescence is observed. If no fluorescence is observed at 3.3 A, contact Infleqtion.

To increase atom flux in the output beam, it may be desired to drive the dispenser at a higher current than the minimum needed to observe fluorescence. Typically, loading rates into a 3D MOT are used to determine a more optimal dispenser current. Note that higher dispenser currents will shorten the lifespan of the dispenser and may impact the vacuum quality in the rest of the system.

To observe the 2D MOT, Infleqtion recommends the layout shown in Figure 6. Here, a polarized beamsplitter cube (PBS) allows the push beam to pass into the source cell while simultaneously providing optical access for a camera. For MOTs operating at red and near-infrared wavelengths, Infleqtion recommends black-and-white “bullet”-style cameras (e.g. KT&C Co. KPC-S190S with 16 mm lens). When using the camera to look into the cell, the push beam should be blocked (e.g. with an iris) to reduce scattered light from the PBS.

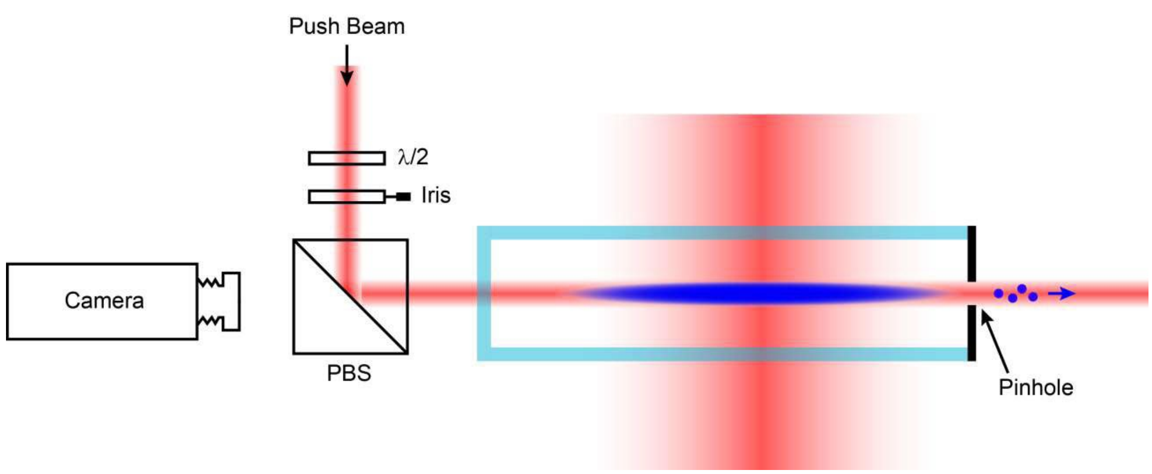


Figure 6: Using a polarized beamsplitter cube (PBS), a camera can be used to observe a 2D MOT along the cell axis.

7. Troubleshooting

Description	Solution
No fluorescence is visible	• Ensure that the atom dispenser is properly connected to a power supply, and that the fuse on the supply wires has not blown • Ensure that the two dispensers are electrically isolated • Check that the power supply is driving the correct current to the dispenser, and has not switched to constant-voltage mode • Check that laser light is passing through the cell • Check that the frequency of the laser light is correct and locked. • If the above doesn't work, contact Inflegtion
Fluorescence is visible, but no MOT	• Check that the magnetic fields are correct • Check that the laser beams are circularly polarized with the correct handedness • Check that the frequencies of BOTH cooling and repumping lasers are set correctly and locked • If the above doesn't work, contact Inflegtion
The resistance of the atom dispenser is greater than 1 Ω	• Ensure good electrical connections between the power supply and dispenser. • Ensure that the two dispensers are electrically isolated • If the above doesn't work, contact Inflegtion

FAQs

Where are the dispensers located?

Dispensers are in the cap of the CASC, opposite the flange. As a sanity check, if the cap becomes hot (be careful!), then current is flowing through the dispensers.

Can I create a 2D+ MOT?

Yes, the CASC is designed to create a 2D and 2D+ MOT. See Figure 6 in Section 6.1 for further explanation.

Does the atomic flux have both radial and axial velocity?

The atomic flux has radial velocity.

Are the detuning parameters the same for Rb and Cs?

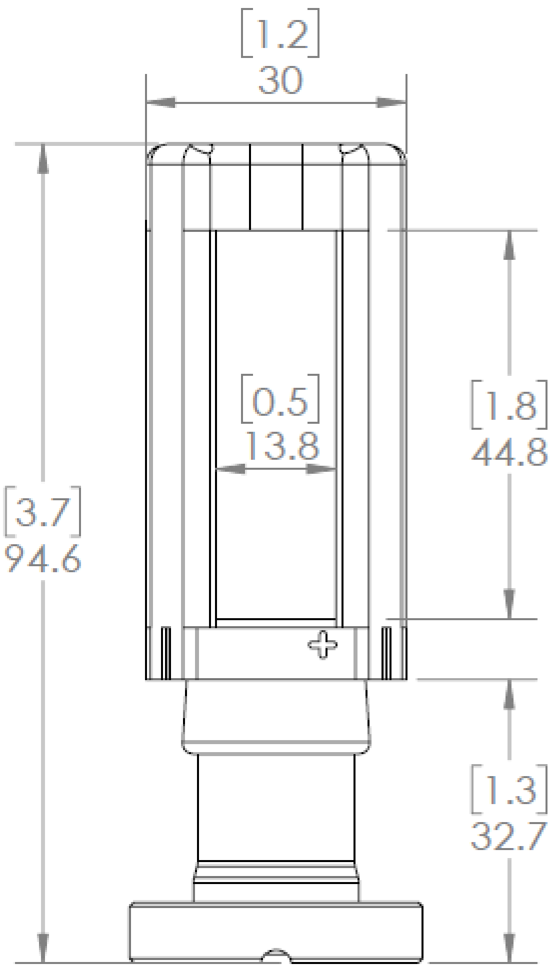
Yes, they are in the same ballpark. Cooling detunings should be -2 to -3 linewidths detuning. Repumper detunings should be similar (on resonance, 0 linewidths detuning).

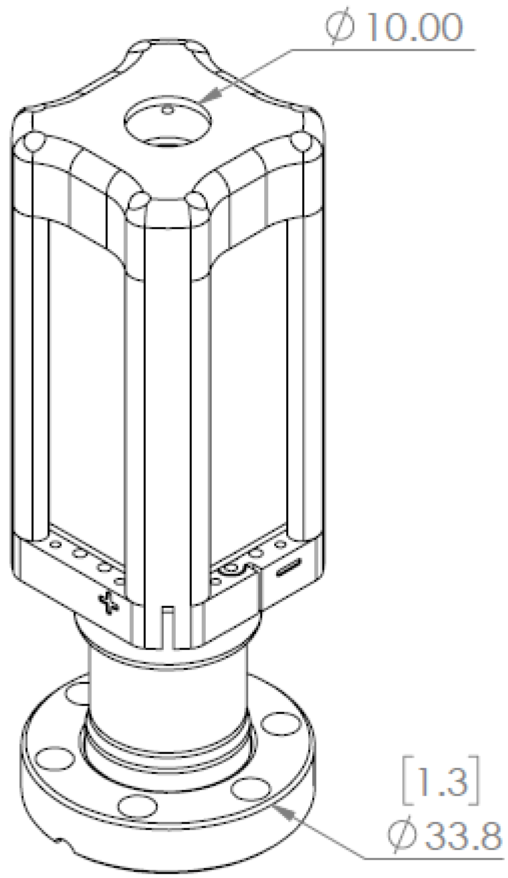
8. Warranty

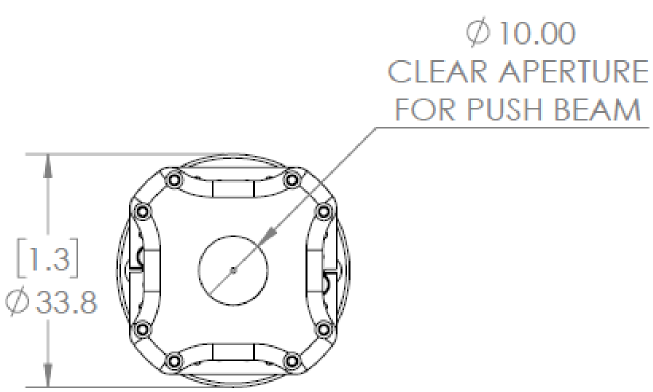
Infleqtion's Terms and Conditions, including the warranty, can be found at: https://infleqtion.com/terms

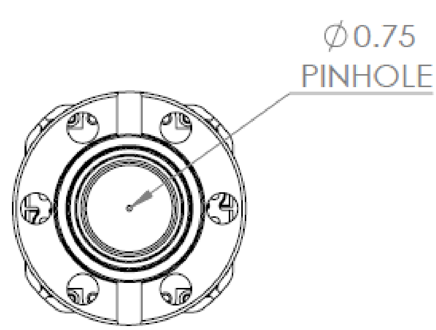
9. Technical Drawings and Dimensions

Uncontrolled sales drawings for reference only. All dimensions in mm and [inches]









10. Appendix: Principles of Operation

In conjunction with an external magnetic field gradient and laser beams, the cold atom source cell can be used to produce a two-dimensional (2D) magneto-optical trap (MOT) from an alkali metal vapor. The vapor is created by Joule heating one of the dispensers with an electrical current. To increase the flux of the atomic beam, a “push” laser beam can be directed along the cell axis, creating a 2D+ MOT. An aperture in the metal cover at the top of the source cell provides optical axis for a push beam.

The cold atom source cell can be integrated into an existing vacuum system with a standard 1.33” ConFlat flange. Infleqtion offers an adapter plate for connecting the source cell to a 2.75” ConFlat flange. Other adapters can be used to connect the source cell to a ConFlat flange of a different size. Quick flange (QF/KF) connections are not recommended, as the elastomeric o-ring used for sealing cannot withstand the high temperatures needed for baking the source cell.

The cold atom source cell is shipped with two alkali metal dispensers. Each dispenser is electrically connected to two vacuum feedthroughs. The dispensers must be properly activated to generate vapor inside the cell. Section 5.2 describes the procedure for attaching electrical wires to the vacuum feedthroughs. Section 0 describes the procedure for vacuum bakeout and activating the dispensers. Note that Infleqtion does not guarantee performance of the source cell if it is exposed to air after the dispensers have been activated. Note that activation of the dispenser should be performed during baking so that contaminants released during activation are pumped away. Since activated dispensers should not be exposed to air, both dispenser activation and baking should be performed after the source cell has been affixed in its final position on the target vacuum system.

To simplify the production of a 2D MOT, Infleqtion offers an assembly that uses permanent magnets to create the necessary magnetic fields for generating a 2D MOT. Section 6.1 contains more information about using the cold atom source cell to create 2D+ MOTs.

One of the most common techniques to produce high-flux beams of laser-cooled atoms is the *two-dimensional-plus* (2D+) *magneto-optical trap* (MOT). Figure 7 shows the layout of this approach. Here, two pairs of counterpropagating laser beams passing transversely through an atomic vapor produce an elongated 2D MOT. A magnetic quadrupole field is applied along these two transverse directions. The laser beams are circularly polarized, with the members of a single pair having opposite helicities (i.e. a σ^+- σ^- configuration). The lasers are typically detuned 2 or 3Γ to the red of a closed two-level transition (e.g. the $|F = 2, m_F = +2\rangle \rightarrow |F' = 3, m_{F'} = +3\rangle$ transition in ^{87}Rb), Here, Γ is the natural linewidth of the transition.

In the longitudinal direction, atoms in the 2D MOT are pushed by a laser beam that is directed along the MOT axis. The force imparted by this “push” laser beam is unbalanced, resulting in a net flow of cold atoms toward, and then through, a pinhole. In the cold atom source cell, the pinhole has a diameter of 0.75 mm and is created in a piece of silicon. For the red and near-infrared wavelengths typically used for laser cooling alkali metal species, a finite percentage of the push beam will reflect off the silicon in the doughnut-shaped region surrounding the pinhole. This retroreflected light provides additional molasses cooling, but without trapping, along the third dimension, giving rise to the name “2D+” MOT.

Another key role of the pinhole is to establish differential pumping between the source cell and the rest of the vacuum system. With this differential pumping, a higher vapor pressure can be maintained inside the source cell while having minimal impact on the background pressure outside the cell. Up to a point, a higher vapor pressure yields a higher atom flux. For alkali metals, the highest fluxes are typically obtained with pressures between 10^{-7} and 10^{-6} Torr. At higher pressures, the collision rate with background atoms increases, which in turn increases losses from the MOT.

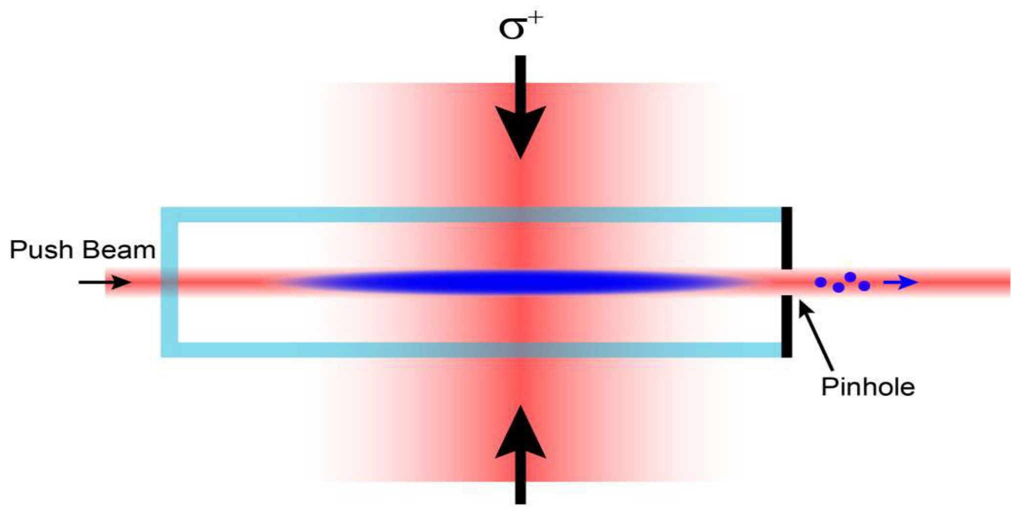


Figure 7: In a 2D+ MOT, two pairs of counterpropagating laser beams help create a 2D MOT from a background vapor. An additional push beam drives atoms through a pinhole and into the rest of the vacuum system. Only the vertical MOT laser beams are shown; a second pair of laser beams is aligned perpendicular to the page.

The cold-atom flux depends on several factors, including power and detuning/frequency length of the 2D MOT in the longitudinal direction use of repumping power and polarization of the push beam sizes and angles of the laser beams size of the magnetic field gradient the size of the pinhole background vapor pressure alignment of the magnetic field and laser beams.

Since atom flux increases with the length of the 2D MOT, the transverse laser beams should be elliptically shaped so that they fill the usable clear aperture on the four sides of the cell. A beam profile of 25 x 15 mm is recommended.

The cold atom source cell is based on the 2D+ MOT design in Inflegtion's RuBECi® two-chamber vacuum system. In a RuBECi, the performance of the 2D+ MOT cold-atom beam is characterized by loading atoms into a 3D MOT. Typical operating parameters for ^{87}Rb are shown in the table below. With these values, 3D MOT loading rates up to 4 x 10^9 atoms/s can be achieved. At higher laser powers, an atom flux as high as 84 x 10^9 atoms/s has been reported (Jöllenbeck 2011).

2D+ MOT Parameter for ^{87}Rb	Value
Total Cooling Laser Power (MOT plus push beams)	65 mW
Cooling Laser Detuning from the $5^2S1/2 \rightarrow 5^2P3/2$ Transition	-2.5Γ (Γ = 2π ⍰ 6.066 MHz)
Total Repumping Laser Power (MOT plus push beams)	7 mW
MOT Laser Beam Profile (1/e^2 diameter)	25 x 15 mm
Magnetic Field Gradient	37 G/cm
Push Beam Laser Power	~1 mW
Push Beam Laser Polarization	Linear
Push Beam Profile (1/e^2 diameter)	5 mm circular

Figure 8 shows an on-axis image of a 2D MOT. The MOT itself appears as a small bright white spot. The fainter white circle surrounding the MOT is fluorescence produced by the hot background vapor.

The references in Section 10 contain detailed information about several 2D+ MOT cold-atom beams. Many of these set-ups use creative laser beam geometries to simplify the number and arrangement of optics, improve efficiency (i.e., atom flux per watt of laser power), or to manage the stray push beam that copropagates with the atom beam through the pinhole. Most of these references utilize ^{87}Rb, although some utilize ^{133}Cs. The list is certainly not exhaustive and is meant to serve as a starting place for finding more information about 2D+ MOTs.

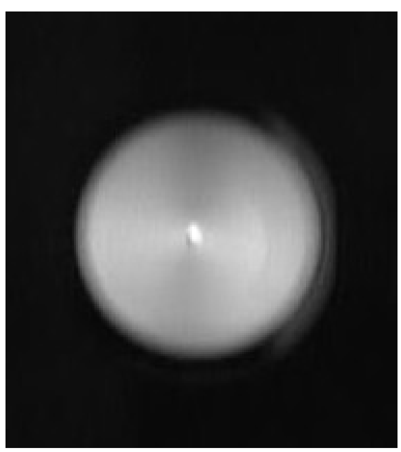


Figure 8: Photograph of a 2D MOT taken with a "bullet"-style camera aligned along the axis of the source cell.

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REVISION CONTROL

When any part of this procedure requires amendment, the document shall be re-issued in its entirety; requests for change shall be addressed to the document owner.

Revision	Date	Change Description	ECO	Originator(s)
Previous	August 2022	Document Creation		E. Salim
1.0	September 2025	• New format and new Infleqtion branding • Technical drawings updated • More emphasis on direction of use of product • Specific emphasis on location of dispenser connections relative to seam	S1025	C. Ward C. Williams