Photonically Integrated Cold Atom Source

Adjustable PICAS User Manual

Contents

1. Introduction

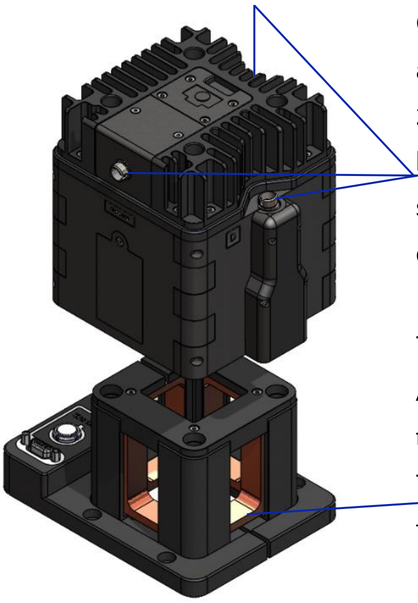


Figure 1: Adjustable PICAS overview

ColdQuanta's PICAS, Photonically Integrated Cold Atom Source, is a compact, alignment-free beam delivery package. It produces a 2D+ MOT beam configuration with three user-supplied fiber-coupled light inputs, capable of producing a cold atom flux of >10^9 atoms per second when used in conjunction with ColdQuanta's well-established CASC, Cold Atom Source Cell.

The PICAS family include two different types: adjustable and fixed. Adjustable PICAS is best suited for applications which are sensitive to external magnetic fields.
The coil structure allows you to modify and optimise the magnetic field around the ultra-cold atoms.

2. Packaging Contents

The shipment of adjustable PICAS should contain the following items:

PART	QUANTITY
ColdQuanta USB (with documentation) • Adjustable PICAS User Guide • Adjustable PICAS Test Certificate	1
PICAS optical Sub-assembly (CPxxxAM2S) • M4 x 14 mm socket head screw • Dispenser PCB connector	1 4 1
MOT Coil Sub-assembly (CAMAPA) • M4 x 14 mm socket head screw	1 4
Mount for Coil Assembly (CAAMPA/ CAAMPAD)	1
Breakout board connector – coil	2
Breakout Board connector – dispenser	1
Cable kit • Micro-D to Sub-D cable • LEMO to LEMO cable	1 2 1

Optional

Table 1: Packaging Contents List

If any of these items are missing or damaged, please contact ColdQuanta UK.

3. Specifications

	Adjustable PICAS
Minimum Laser Input Requirements	2x 20mW cooling and 0.4mW repumper for 2D MOT 1x 2mW cooling and 0.1mW repumper for Push Polarization parallel to key of fibre
Optical Input	3x FC/APC fibre Inputs
Typical Atom Flux	>10^9 pre-cooled atoms per second
Mounting	CAAMPA and CAAMPAD mounting compatibility
Viewing Aperture	7 mm square viewing aperture
Dimensions	101 x 130.70 x 113.40 mm
Weight	1.3kg
Maximum Operating Temperature	60°C

Table 2: Adjustable PICAS specifications

4. Installation

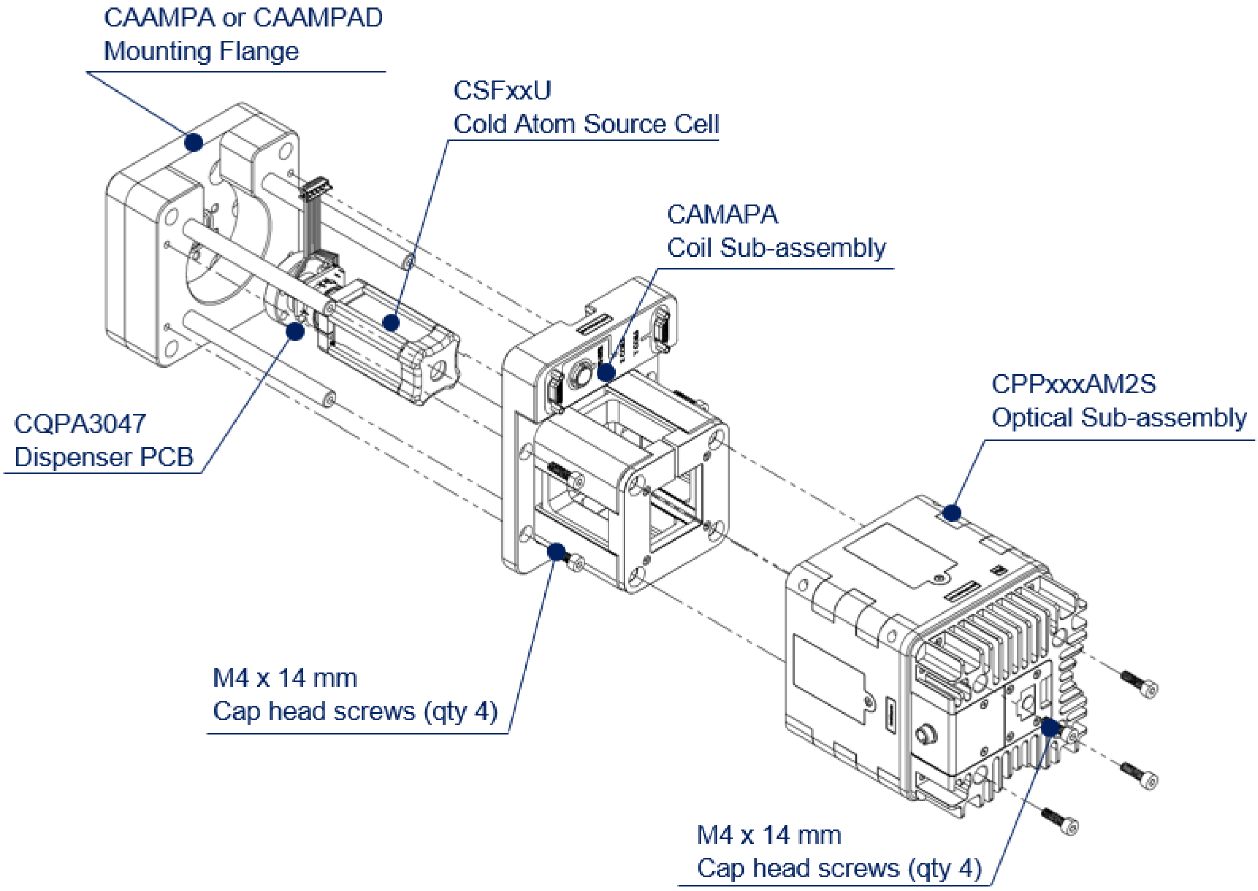


Figure 2: Installation Overview

4.1 Required Parts

Part number	Description
CPxxxAM2S	Optics Sub-assembly
CAMAPA	Coil Sub-assembly
CSFxxUU	Cold Atom Source Cell
CAAMPA or CAAMPAD	Adjustable PICAS Assembly Mount

Table 3: Required parts for installation

NB: CAMAPA Coil Assembly and CPPxxxAM2S Optics Assembly must not be included in any bake-out process.

4.2 Installation Process

1. Carefully locate the coil sub-assembly (CAMAPA) onto the guide rails and place it over the source cell (CSFxxUU). Secure the coil sub-assembly in place using four M4x14mm cap head screws into the mounting flange (CAAMPA or CAAMPAD). The Dispenser PCB can then be connected onto the cell and the coil sub-assembly.

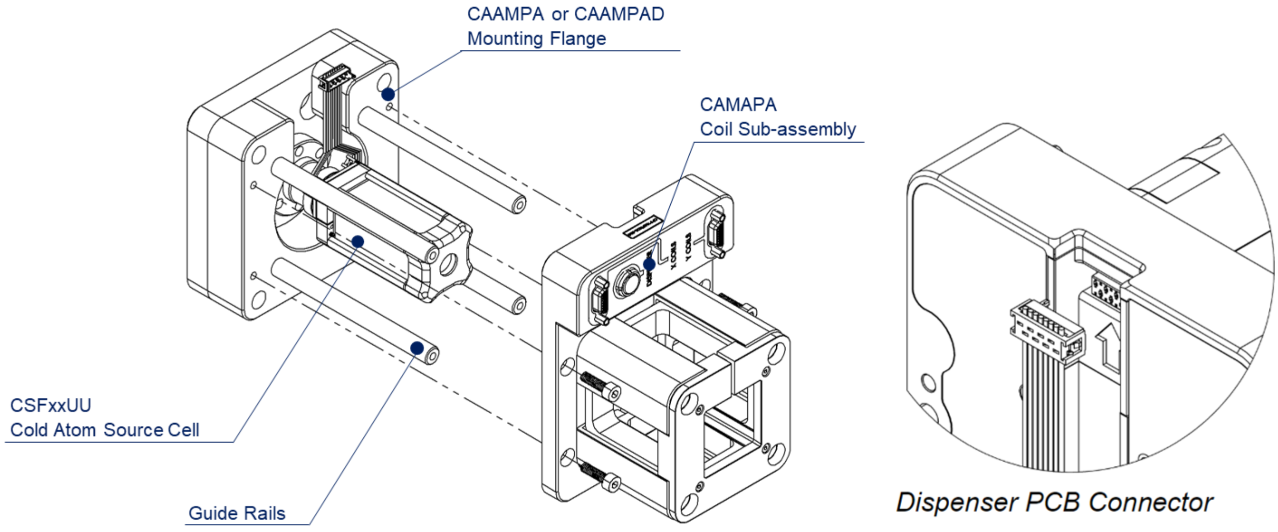


Figure 3: Installing the coil sub-assembly (CAMAPA)

2. Carefully locate the optical sub-assembly (CPxxxAM2S) onto the guide rails and place it over the coil sub-assembly. Secure in place with four M4x14mm socket head screws.

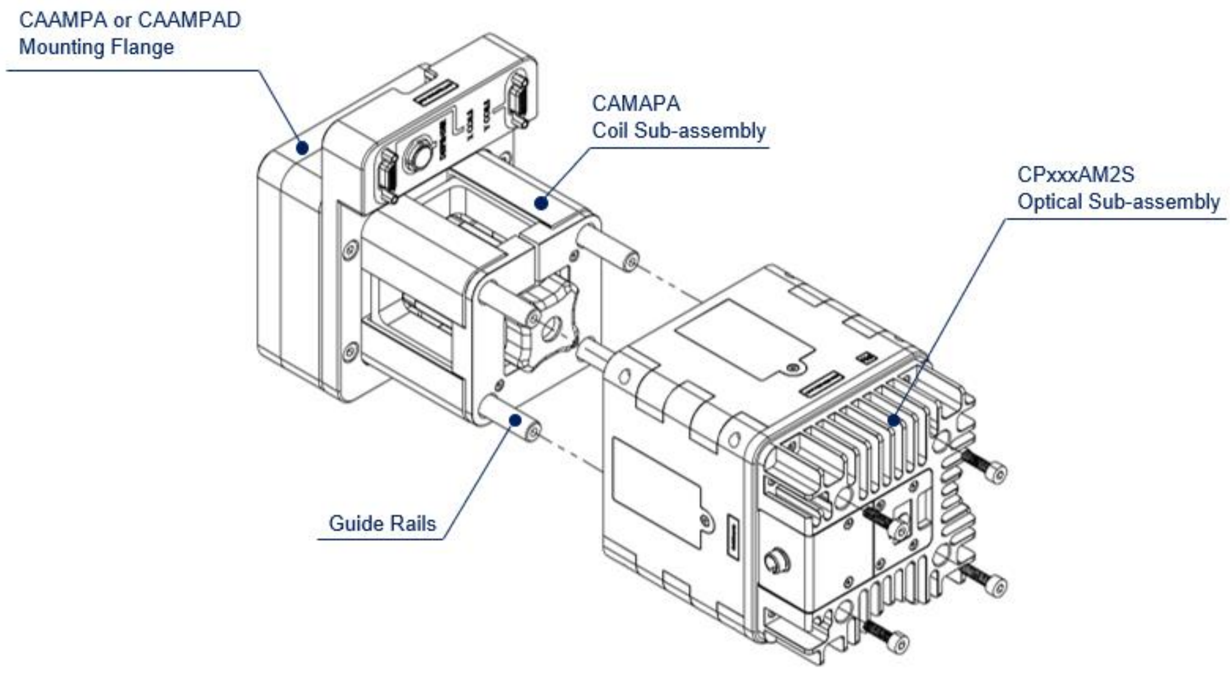


Figure 4: Installing the optical sub-assembly (CPxxxAM2S)

3. To image the 2D MOT, remove the imaging plate. **Do not remove the imaging plate whilst the push fiber is connected, as reflections can leak through the cube.**

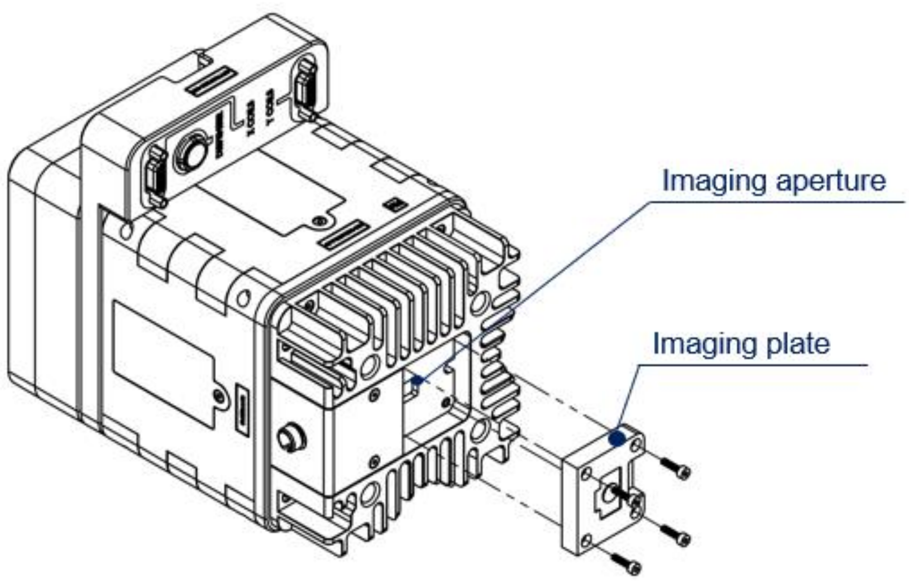


Figure 5: Removal of the imaging plate

4. Connect to the appropriate breakout connector using the adapter cables provided.

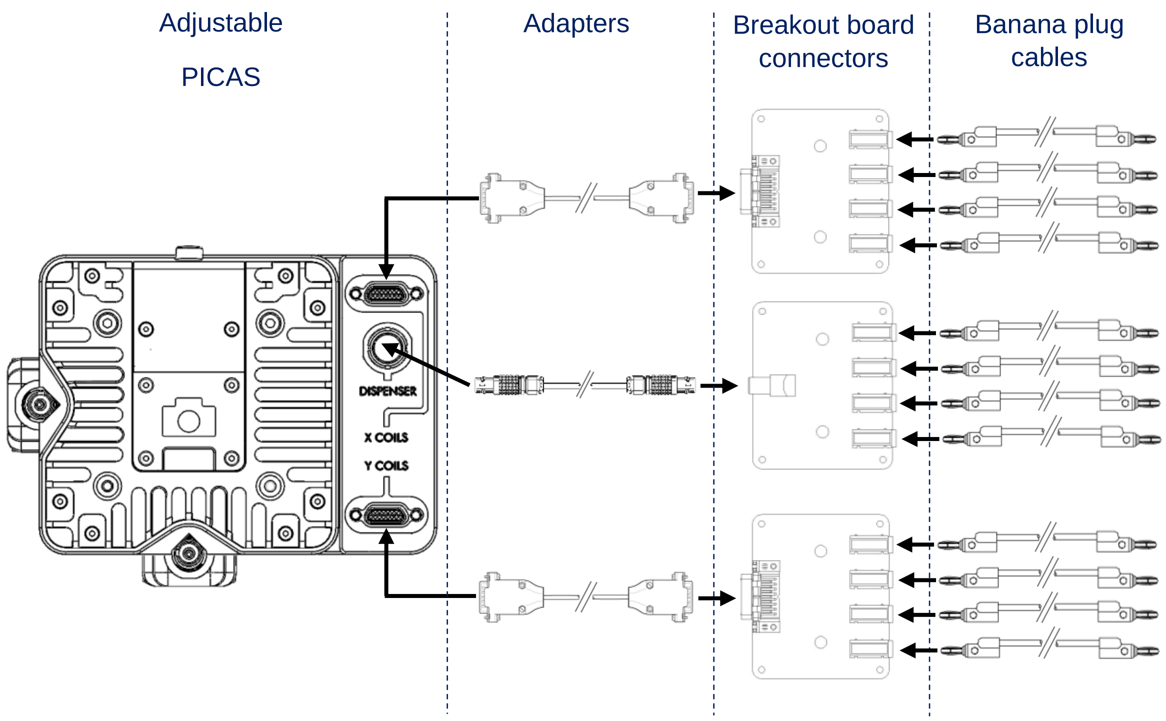


Figure 6: Connections Overview

5. Operating Instructions

5.1 Initial Requirements

Before creating a 2D+ MOT with the PICAS system, the CASC dispensers need to be activated and successfully dispensing such that fluorescence is observable. The typical operation of the dispensers is detailed below (quoted from: Cold Atom Source Cell Manual CASCII Rev 8.pdf):

4.4 NORMAL OPERATION OF THE SOURCE CELL   ***WARNING! 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.*   ***WARNING! 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 rending the device non-functional. Over-driving the dispenser can also coat the cell walls with alkali metal, making the surfaces opaque to laser beams.*   ***WARNING! 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.*   *For normal operation, drive the dispenser with a constant current between 3.0 and 3.7 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 the next section 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 optimum dispenser current may vary between different dispensers. To identifying the ideal dispenser current, start with the lowest current of 3.0 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 3.7 A, contact ColdQuanta.*   *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.*   *The two atom dispensers should always be electrically isolated from each other.*

Table 4: Section 4.4 extraction from CASC II Rev 8 manual

Once fluorescence in the CASC chamber has been observed, the next step is to ensure the laser parameters are correct for 2D+ MOT operation. We recommend the following laser parameters:

	Recommended parameters
2D MOT fibre	>20mW cooling per arm, >2mW repumper per arm
Push fibre	>2mW cooling, >0.2mW repumper
Cooling Detuning*	-3Γ (Γ=2π x 6.065MHz for Rubidium) -3Γ (Γ=2π x 5.222 MHz for Cesium)

Table 5: Recommended laser parameters

**This is the nominal detuning – depending upon the available power of the laser, the optimal atomic flux should be achievable with a scan range of ~20MHz around the recommended cooling detuning. To achieve peak atomic flux, we recommend using a laser locking scheme that allows the frequency to be fine-tuned over this range.*

Each coil can be individually controlled. The coils should be connected to reproduce the field lines in the diagram relative to the B and D orientations (see section 5.3 Coil Connections to determine how to connect the coils). A good starting average current is 1.7A (later optimisation can be done). Using the imaging method detailed in section 5.2 Imaging, it is possible to observe and move the 2D MOT position by changing the current in one coil (e.g. changing the current in the X1 coil will move the 2D MOT in the X-axis). Change the currents in the coils to centre the 2D MOT on the pinhole of the CASC, whilst trying to maintain an average current of ~1.7A. Atomic flux should be present once the 2D MOT is centred and the push beam connected. Further optimisation of the flux can then be done.

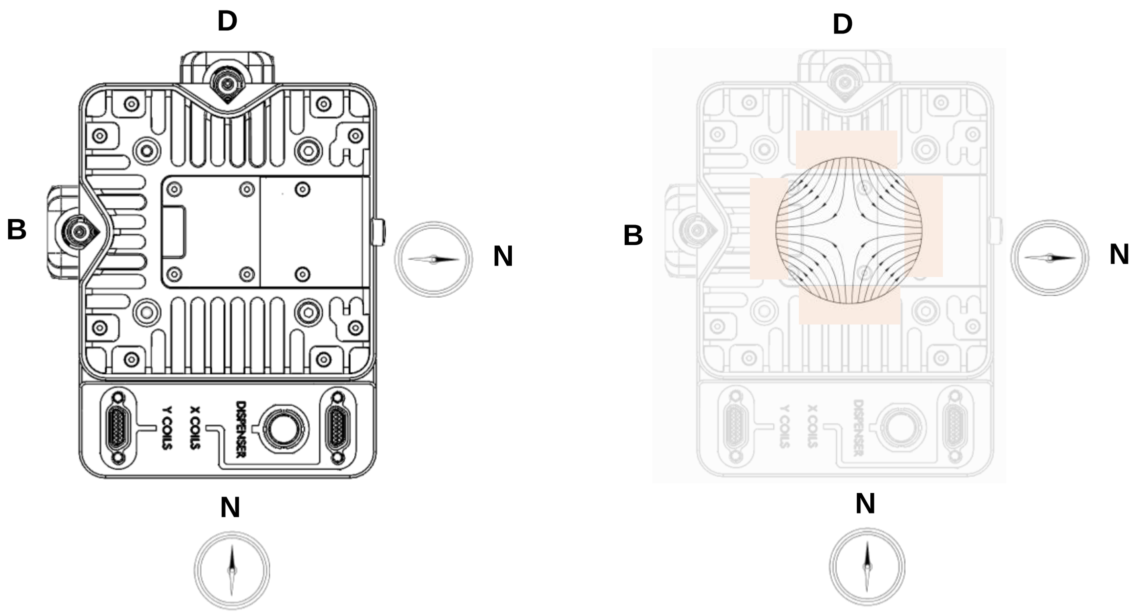


Figure 7: Left, simplified magnetic field orientation shown with respect to the fibre optic inputs. Right, complete magnetic field lines overlayed

If the above requirements are met, a 2D+ MOT should be created when the dispensers are operating at nominal current.

5.2 Imaging

The easiest way to image the 2D MOT with the PICAS system is to remove the imaging plate by unscrewing the four M2 screws (as shown in Figure 5). Make sure the push fibre is removed before doing this. With the imaging plate removed, a camera can be used to view the 2D MOT through the imaging aperture.

If the 2D MOT is aligned visually to the CASC pinhole, as shown in Figure , a large portion of the cooled atomic beam should pass through.

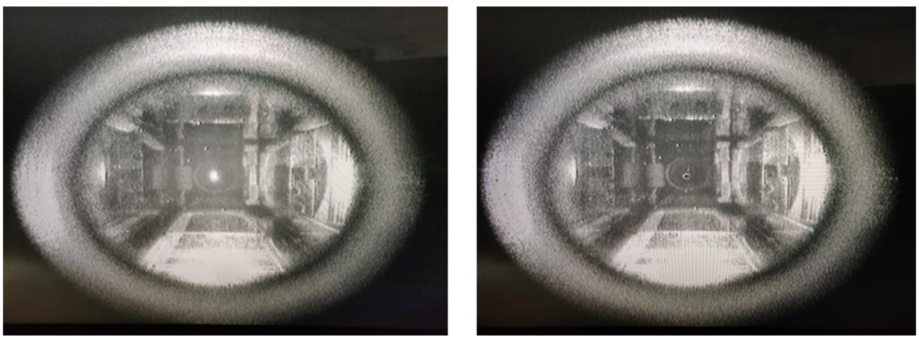


Figure 8: 2D MOT (left) and absence of 2D MOT (right) where the CASC pinhole is visible

5.3 Coil Connections

The connectors for the coils are provided through two 15-pin micro-D sub miniature connectors. The coil specifications can be found in Table 6 below.

Coil Parameters	5 x 15 turns of 0.8 mm wire
Resistance per coil	0.4Ω
Nominal current	1.5A per coil
Maximum current	2.8A per coil

Table 6: Coil Specification

The positioning of the coils and their associated pins can be found in Figure and Table 7.

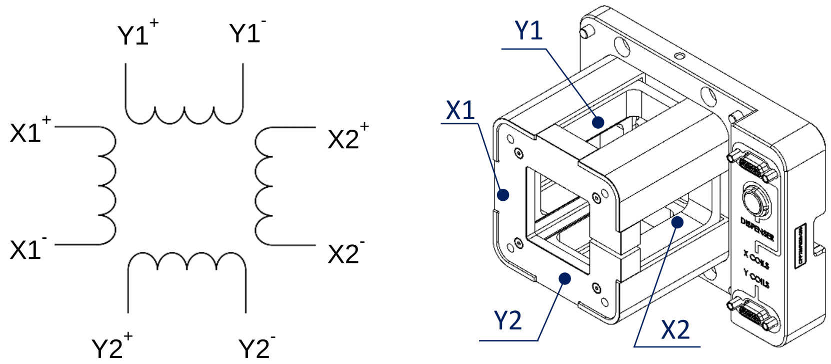


Figure 9: Coil configuration

X		Y	
Connection	**Pin**	**Connection**	**Pin**
$X1^+$	1, 9, 2, 10	$Y1^+$	1, 9, 2, 10
$X1^-$	3, 11, 4, 12	$Y1^-$	3, 11, 4, 12
$X2^+$	5, 13, 6, 14	$Y2^+$	5, 13, 6, 14
$X2^-$	7, 15, 8	$Y2^-$	7, 15, 8

Table 7: Coil pin-out table

5.4 Dispenser Connectors

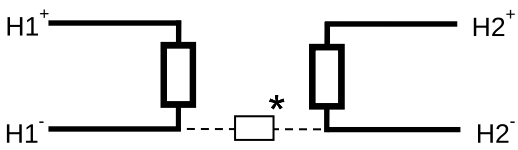


*Figure 7**0**: Dispenser connectors schematic*

*There is a non-evaporable getter connected between $H1^-$ and $H2^-$ with an impedance <1 Ω. No current should be allowed to flow through this path.

Connections are made through a single 4-pin LEMO socket: ECG:0B:304

Connection	Pin
$H1^+$	1
$H1^-$	2
$H2^+$	3
$H2^-$	4
Resistance is < 1 Ω per dispenser Nominal Current is: 3A Max: 3.7A	

Table 8: Dispenser specifications and pin out

6. Troubleshooting

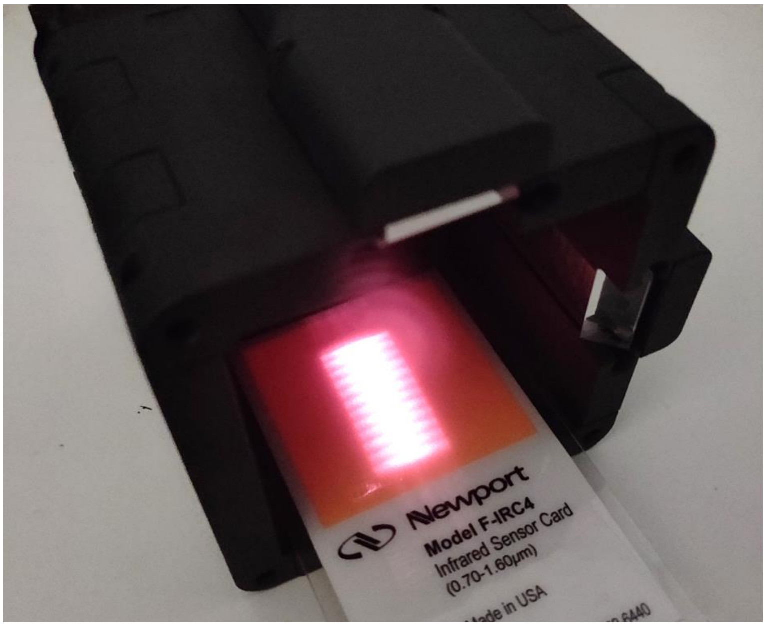
Fault	Possible Solution
The optics assembly does not sit flush or square against the flat face of the coil assembly	We recommend using the dowel pins included to help located the optics assembly (CPxxxAM2S) onto the coil assembly (CAMAPA).
I do not see fluorescence	1. Check that the CASC is dispensing. See the “Cold Atom Source Cell User’s Manual” that is given in the operating instructions part of the manual for details on how to operate the CASC dispensers. 2. Check laser frequency and polarisation. If dispenser operation is nominal, then check that the laser system is locked to the correct frequency for 2D MOT operation as described in this manual. Confirm that the light output from the fibres is polarised parallel to the fibre key axis, as if this is not correct very little light will be present within the 2D MOT chamber. 3. Check beam profiles. If dispensers and laser frequency are correct, but fluorescence is still not visible, then check that the light from optics assembly (CPxxxAM2S) is reaching the atoms. This can be achieved by blocking/unblocking the light from the user’s laser system and observing a change in background scattered light on the edges of the CASC. This can also be checked by removing the optics assembly (CPxxxAM2S) and carefully using a small thin sensor card to view the beam profiles (as shown in Figure 8)  *Figure 81: PICAS beam profile observed with sensor card*

Table 9: Troubleshooting (part 1)

Fault	Possible Solution
I do not see a 2D MOT	1. Check for fluorescence. Check that fluorescence is observed as described in the "I do not see fluorescence section". 2. Check image focusing. Make sure that the view of the 2D MOT region is similar to that of Figure . The pinhole should be observable and approximately in focus. If the fluorescence is too strong then your camera may be saturated with light and the pinhole and 2D MOT will not be visible. To avoid this, reduce the dispenser current until the pinhole at the far side of CASC is visible, and adjust the camera such that this aperture is in focus. 3. Check laser frequency and power levels. If the camera is focused correctly and the fluorescence light is at a reasonable level, but a 2D MOT is still not observed, check that the user's laser system are at the correct frequencies and power levels for both cooling and repumper (typical 2D MOT parameters are shown in "Operating Instructions"). Adjust the cooling laser frequency in MHz steps around the typical 2D MOT parameters (laser frequency adjustment is essential for optimal 2D MOT operation and a method of changing the frequency should be implemented in the user's laser system, typically with an AOM or an offset lock scheme). A full scan range of ~20MHz around the typical 2D MOT cooling frequency should be enough to observe a 2D MOT. 4. Check the polarity of the adjustable PICAS unit. The polarity of the coils can be adjusted. This can be done by placing a compass near the coils when in operation. The compass should point in the same directions as that in Figure 8. If they do not, or you are unsure if they do, flip the polarity of the coils by flipping the banana plug cables in the break out board and retest for a 2D MOT. 5. Check beam profiles. If a 2D MOT is still not visible, remove the PICAS assembly and use a thin/cut-down sensor card to view inside the PICAS assembly and check the beam profiles. If the beam profiles do not look similar to that of Figure 8, contact ColdQuanta UK.
The exposed optics have become dirty	If dust or hair has appeared on an optical surface of PICAS, a clean-air duster (compressed and filtered air or nitrogen) can be used to spray the dust off. For other forms of dirt such as grease or fingerprints, cleaning of the optical surface is required. If performed correctly this process can usually remove contaminants, however we recommend that you do not undertake this stage lightly and damage due to improper cleaning is not covered by our warranty. Gloves, lint-free optical grade cleaning tissues, optical grade cotton applicators and cleaning solvents are required for this task. Cleaning solvents we recommend are acetone, isopropanol, or methanol (always refer to safety manuals and procedures when using solvents). Always use lens tissue and cotton applicators with cleaning solvents i.e. do not use a dry lens tissue or cotton applicator. First, blow the dirty region with a clean-air duster to remove any loose particulates that may scratch the optic if wiped. Then attempt to clean the dirt off with a small amount of cleaning solvent applied to an optical grade cotton swab, where a single, slow, gentle wipe of the optical surface is used. Do not rub the optical surface back and forth with the same swab. Replace the cotton swab with a fresh one after wiping. If the dirt cannot be reached with an optical grade cotton swab, then the PICAS segment with the dirty optic should be unscrewed via the four M2 screws. With the segment unscrewed, it should be possible to access the dirt using either a cotton swab or some lint-free cleaning tissue. A similar method of single, slow, gentle wipes of the optical surface should be used with the lint-free tissues as well, where a small amount of cleaning solvent is applied to the tissue. The tissue can be held by hand using gloves, or via forceps.

Table 10: Troubleshooting (part 2)

7. Frequently Asked Questions (FAQs)

1. Are the fibre keys always aligned in the same position?
   Yes, the fibre keys are always aligned facing right (3 o'clock) when viewed from the back.

2. Where is the serial number located?
   Each adjustable PICAS optics assembly, coils assembly and mounting flange have a unique serial number. This is located on a label on the external face.

3. What material is the unit made from?
   The adjustable PICAS optics assembly is made from carbon reinforced nylon. It is additively manufactured using SLS technology. The coil assembly is made from aluminium. The mounting flange is made from stainless steel.

4. What grade of screws are used in the PICAS assembly?
   We use A4 Grade, 316 Stainless Steel screws in the production of all PICAS models.

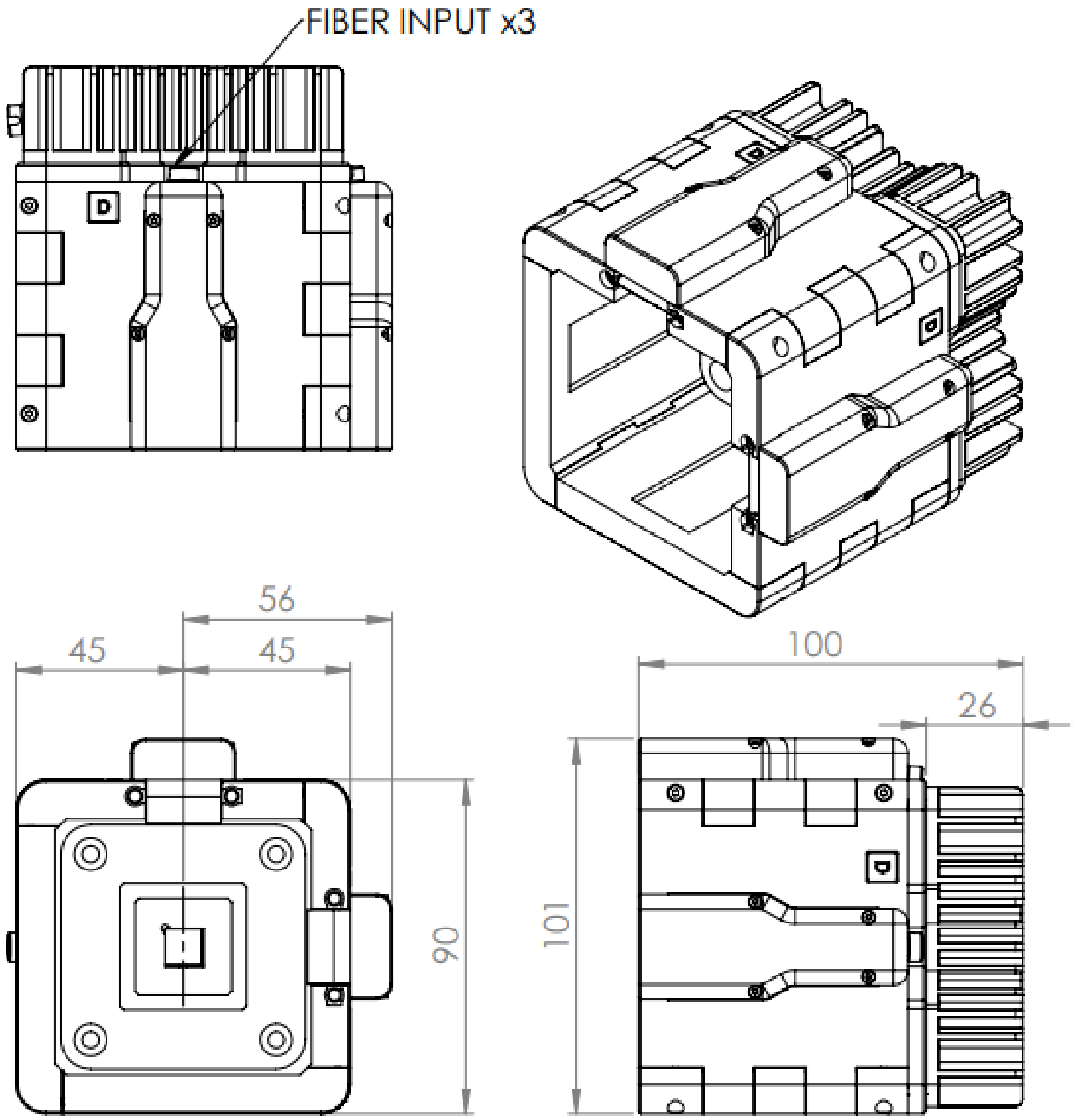
5. What grade of rods are used in the Adjustable PICAS assembly?
   We use A4 Grade, 316 Stainless Steel, 4x 8mm diameter rods in the production of all Adjustable PICAS models.

8. List of Acronyms

2D MOT	Two-Dimensional Magneto-Optical Trap
2D+ MOT	Two-Dimensional Plus Magneto-Optical Trap
AOM	Acousto-Optic Modulator
CAAMPA	Mounting flange for Adjustable PICAS
CAAMPAD	Mounting flange for Adjustable PICAS compatible with the ColdQuanta DoubleMOT
CAMAPA	Coil assembly for Adjustable PICAS
CASC	Cold Atom Source Cell
FC/APC	Ferrule Connector Angled Physical Contact
PICAS	Photonically Integrated Cold Atom Source
PM	Polarisation Maintaining
SLS	Selective Laser Sintering

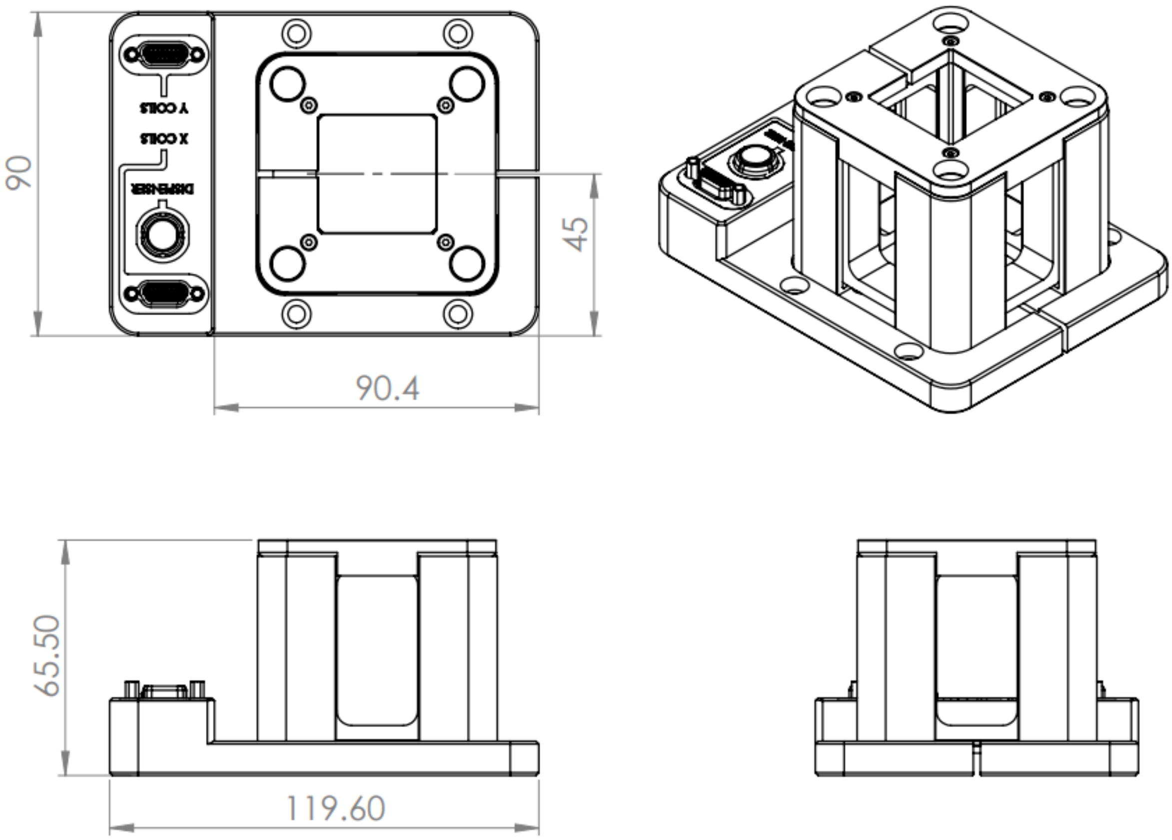
9. Technical Drawings

9.1 CPPxxxAM2S - Optical Sub-assembly



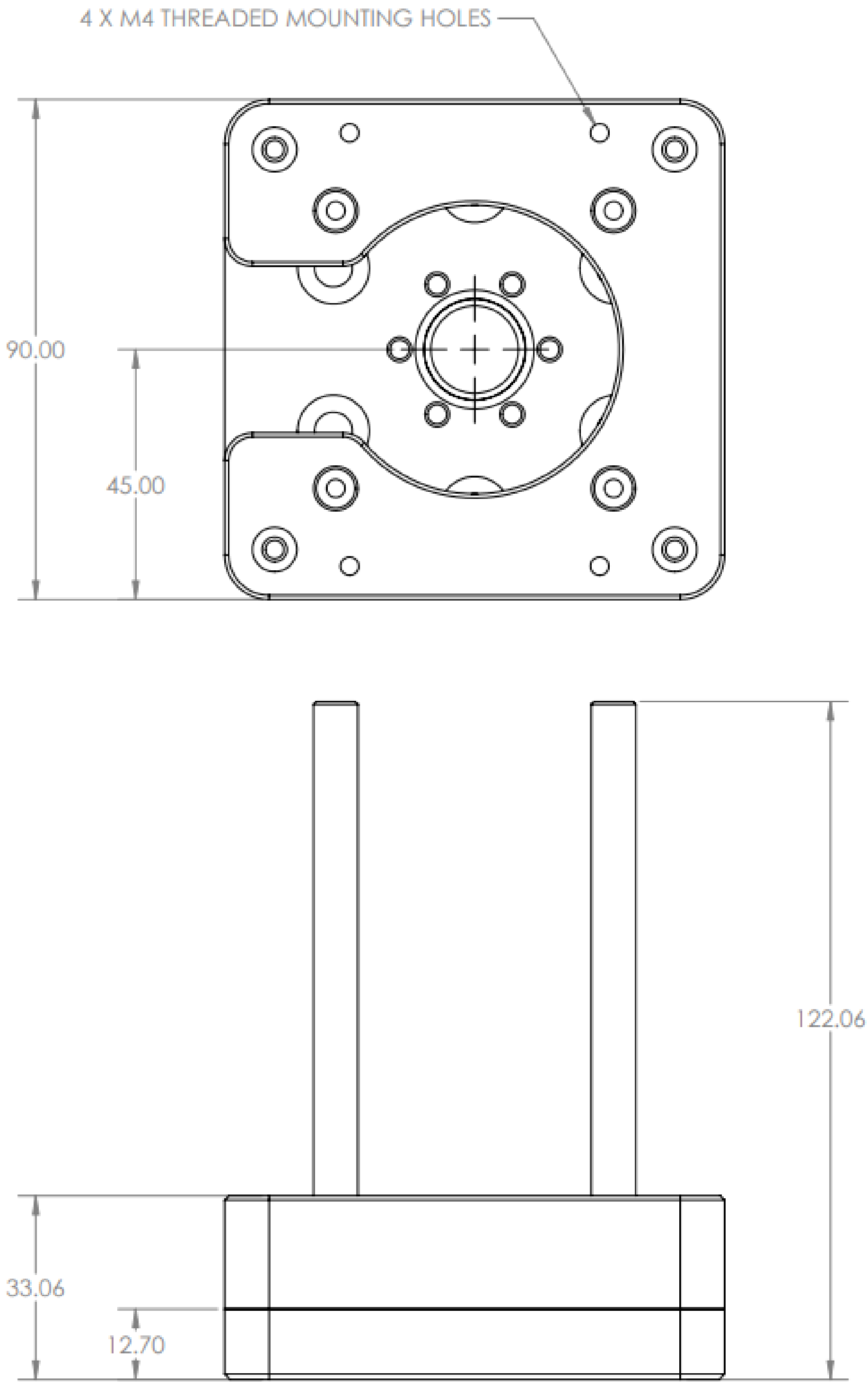
Dimensions in mm **NOT TO SCALE**

9.2 CAMAPA – Coil Sub-assembly



Dimensions in mm **NOT TO SCALE**

9.3 CAAMPA Mounting Flange



Dimensions in mm **NOT TO SCALE**

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