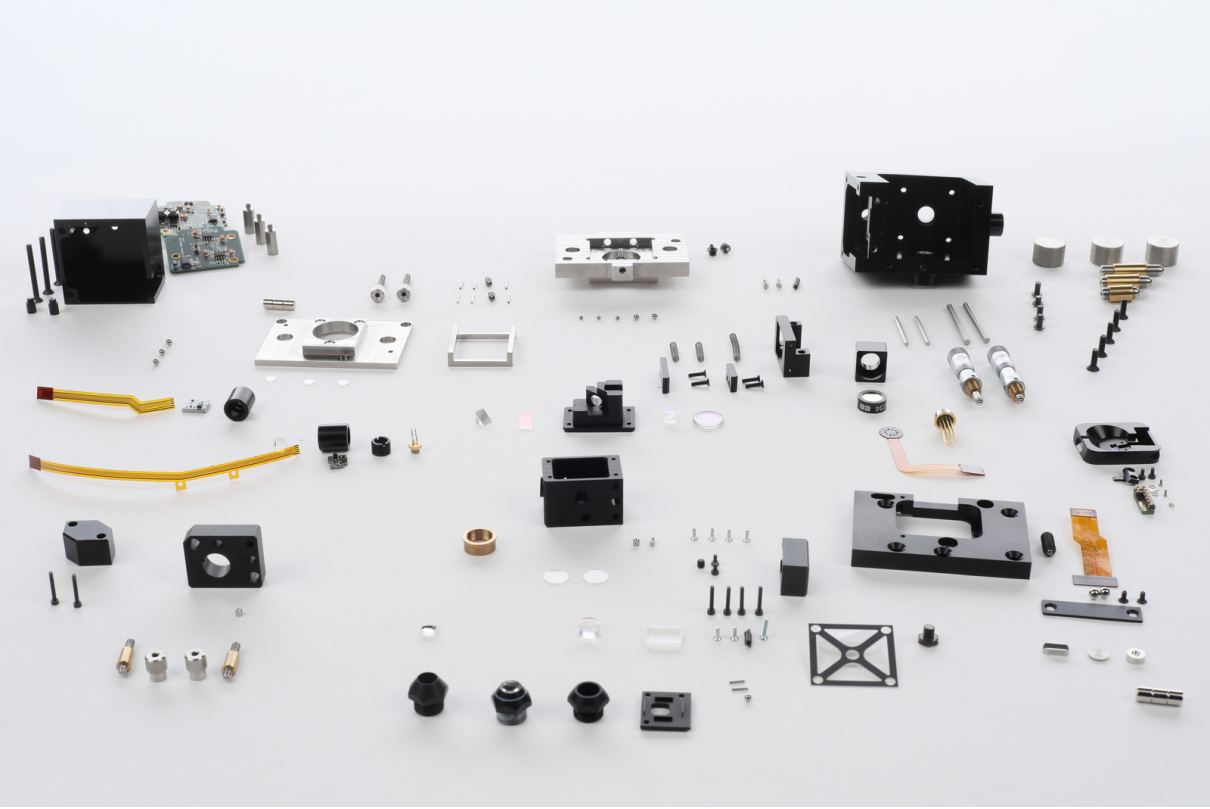
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

PHOTOTHERMAL HEAD ASSEMBLY GUIDE



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March 2018

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Chapter 1

Introduction

The Photothermal head assembling, in the version presented in this guide, has been developped at EPFL by Adrian Nievergelt, Jonathan Adams and Georg Fantner. This head offers photothermal excitation and a small spot size of 1.5μm necessary for the state of the art High-Speed Atomic Force Microscopy. This head is compatible with the widespread Multimode.

1.1 Araldite Preparation

Put gloves on (exposure to Araldite will make you allergic to it).

Mix in equal quantities the two elements of the glue on an alu foil, with a toothpick, for 1min to ensure that the proportions are respected.
Mix before each use and make fresh one when it becomes noticably less fluid - filamentous.

1.2 Oven Curing

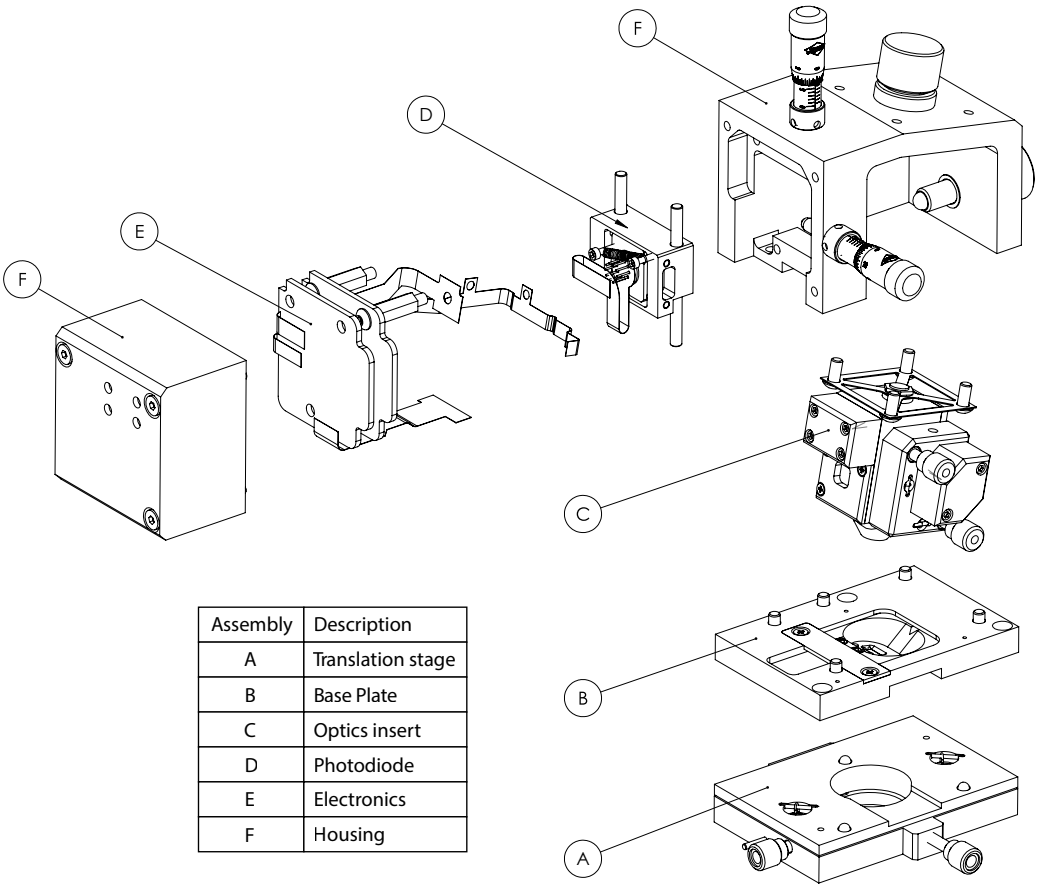
Set the temperature of your oven for 65-70°C. The curing time of the araldite is 30min.

1.3 Required materials

- Araldite standard (blue) glue
- Super glue
- Gloves
- Metric Hex keys
- Tooth picks
- Cotton swabs
- Tweezers (ESD and normal)
- Clamps and vices
- Binoculars or magnifying glasses
- Tissues
- Isopropanol (IPA)
- Soldering iron
- ESD bracelet
- Oven
- Grease (Lithium Grease with MoS2 170M)

Chapter 2

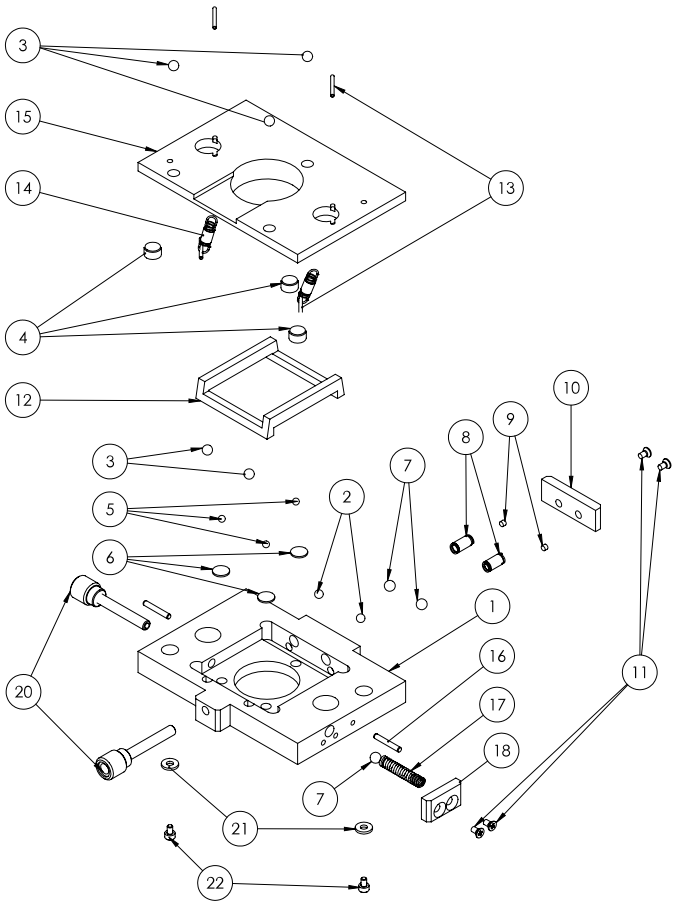
Assembly



Assembly	Description
A	Translation stage
B	Base Plate
C	Optics insert
D	Photodiode
E	Electronics
F	Housing

Figure 2.1: Exploded view of the version 2 of the Photothermal head assembly divided into 6 blocs: (A) the translation stage which moves the rest of the blocs relatively to the sample (B) the base plate which contains the cantilever holder (C) the optics insert with the laser diodes where the optical path is modified (D) the photodiode stage which slides in a guide (E) the PCBs and (F) the housing of all these components

2.1 Translation stage



BOM Table		
ITEM NO.	PART NUMBER	QTY.
1	sl_head_ts_bottom_plate_A	1
2	2.5mm_ball	2
3	3mm_ball	5
4	supermagnete_5x3_disk_magnet	3
5	2mm_ball	3
6	Swiss-Jewel_5x0.5_sapphire_plate	3
7	1-8in_ball	3
8	federnshop_compression_spring_VD-057C	2
9	socket set screw oval point_am	2
10	sl_head_ts_back_spring_stop_A	1
11	countersunk flat head cross recess screw_iso	4
12	sl_head_ts_middle_guide_A	1
13	dowel_pin_1x10_hardened_steel	4
14	federnshop_extension_spring_Z-036TI	2
15	sl_head_ts_top_plate_A_hsScanner	1
16	dowel_pin_1.5x10_unhardened_steel	2
17	federnshop_compression_spring_VD-085H	1
18	sl_head_ts_side_spring_stop_A	1
19	thorlabs_adjustment_screw_M3-0.25_F3SS25	2
21	flat washer regular_am	2
22	socket head cap screw_am	2
23	federnshop_compression_spring_simplified_D-042F-03	2

1. (Optional-v1) The components of the translation stage are required to slide over each other. You may be required to make it slide better by sanding the bottom piece. To do so, use a piece of stainless steel, wrapped with fine grain sandpaper (and brushed with oil), to sand down the appropriate face of the bottom piece.
   Wipe clean after sanding with paper and check again for the sliding ability. Wash thoroughly with detergent, then rinse and dry all three parts of the stage.

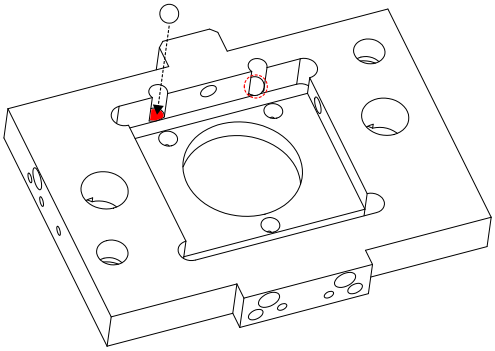
Top side of the Bottom plate : Retention balls for the middle slider

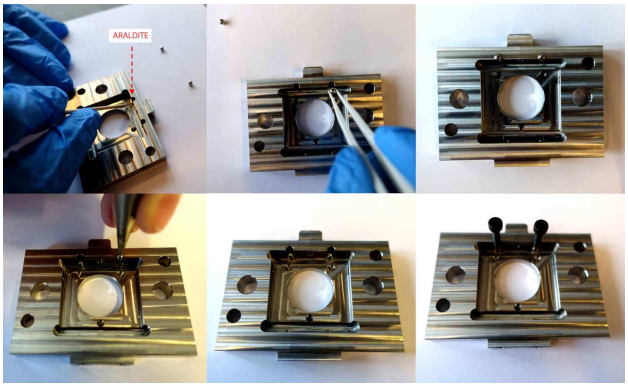
2. Add a small dollop of glue to the two depressions on the bottom surface (conical) and around the circle. Make sure not too much. Use a toothpick.

3. Add two 3 mm steel balls on top of the holes and push them to the bottom. Use a screw driver or a heavy tool.

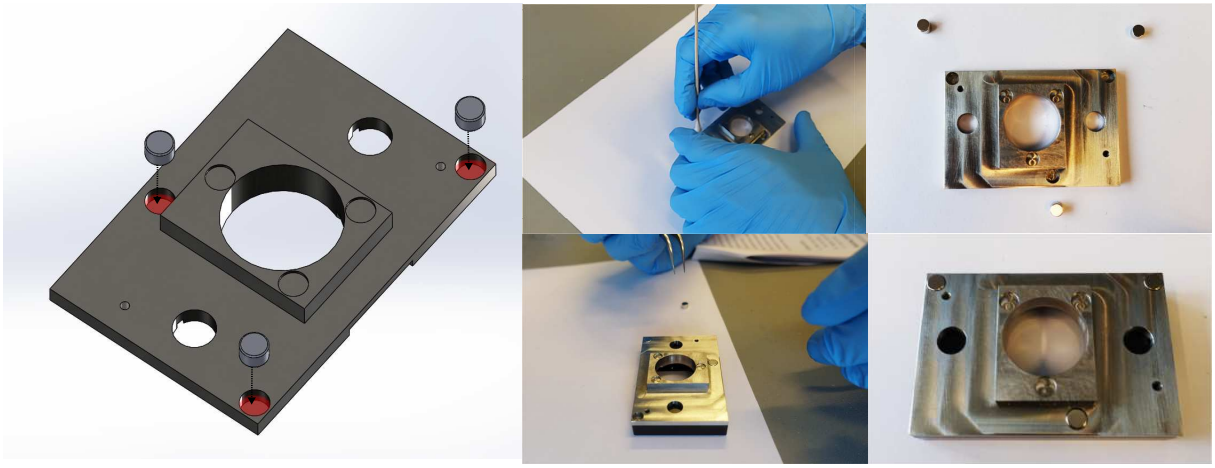
4. Add two short M3 screws on top.

5. Push down with heavy object to weigh in place and cure in oven.





Retention Magnets



6. On the bottom side of the top plate, clean the 3 holes at the corners with Loctite SF7063 using cotton swabs. Swab with a tissue before installing the magnets.
7. Put a bit of glue on the bottom and sides of the holes using a toothpick.
8. Check the orientation of the magnets by placing a base plate at the bottom of this part.
9. Insert the 3 magnets ($\varnothing 5\,\text{mm} \times 3\,\text{mm}$) in place.
10. Cure in oven with the base plate still at the bottom to pull the magnets down

Kinematic contact balls between top and bottom plate

11. Add a small dollop of glue to the holes for the 3 steel balls on the bottom plate.
12. Repeat to the thin circular depressions that will house the 3 sapphire plates on the top plate.
    Mix the dollop over the surface with a toothpick to make a thin layer.
    It usually takes less glue than you'd think!
13. Place the three2 mm steel balls in depressions (hemi-spherical) and push down.
14. Place the three sapphire plates ($\varnothing 5\,\text{mm} \times 0.5\,\text{mm}$) in depressions and push down.

15. Place parafilm between steel balls and sapphire plates and push the two pieces together ensuring that the sapphire plates match up to the steel balls.

16. Compress using clamps and cure in the oven.

Middle guide

17. Dry any surface holes thoroughly with Kimwipes and IPA. Inspect the inset runner, checking for machining stubs and file away any.

18. Apply molybdenum sulphite grease under the runner (gliding zone) in the bottom plate. Draw a line and spread out using a syringe.

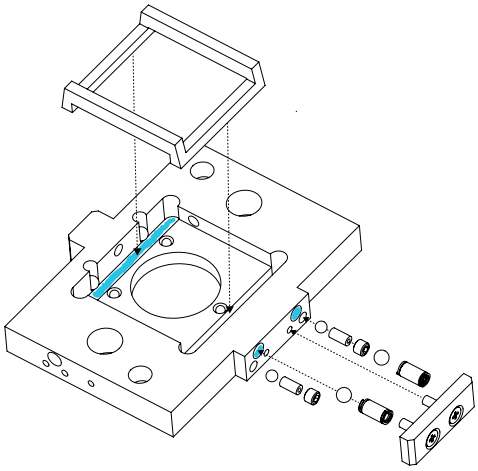
19. Insert the middle guide.

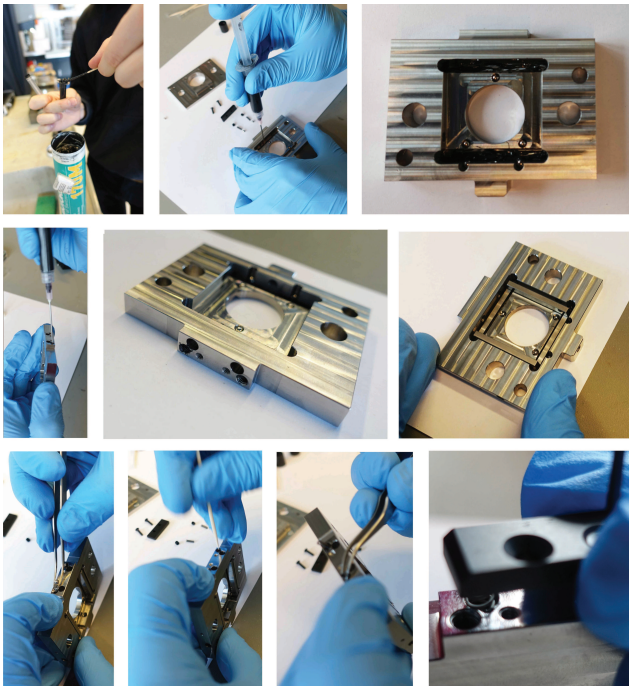
20. Grease the 2 external holes with thread on the parallel side of the guide sliding (top holes of the bigger surface).

21. Insert the two 2.5 mm balls to greased holes and push through.

22. Add the two springs D-042F to same holes.

23. Add the two M3×2 hex set screws.





24. Tighten fully the set screws followed by a full turn in the opposite direction. This helps not to have a hard contact. Make sure it is loosen enough.

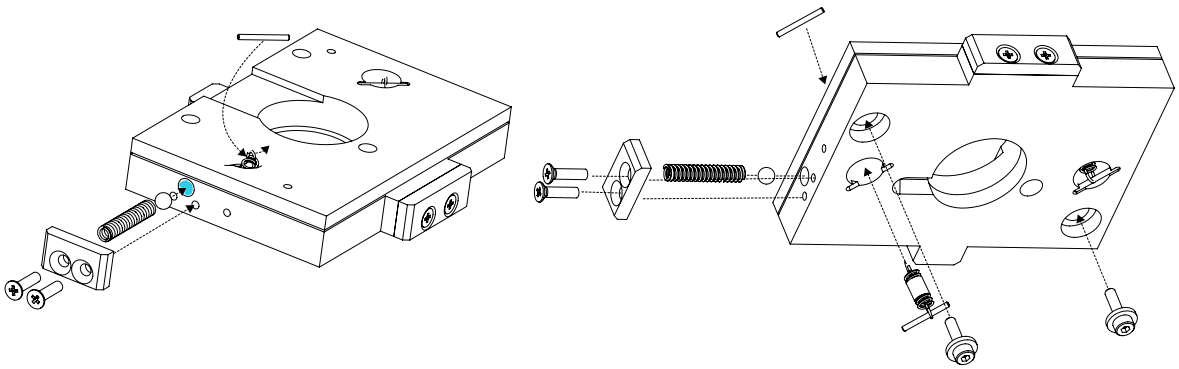
25. Insert the two 1/8 in balls in the top holes .

26. Add the two springs VD-057C on top of these balls.

27. Place the long plate (black-anodized with chamfers) which fits the surface area. Press on the spring and screw a bit in the thread one M2x8 countersunk flat head cross. Add the second screw and set into tension the springs.

Assembling Stage

28. On the top plate, apply grease where the middle guide will slide.



29. Clean the three sapphires.

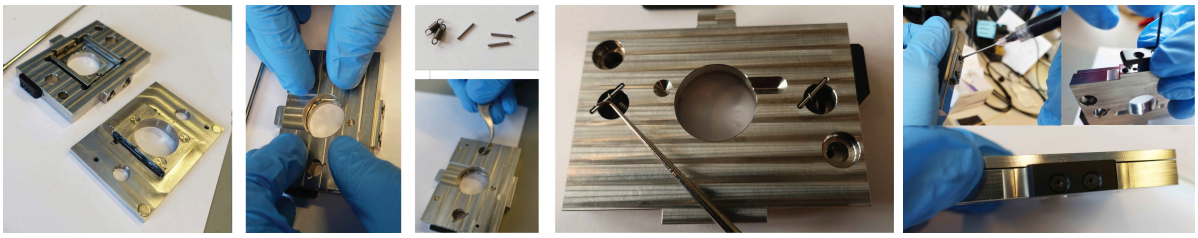
30. Place metal rod (pins) through spring and insert into hole

31. Pull through with spring hook to place the second rod through spring.

32. Repeat for the second spring.This will sit the assembly in place.

33. Grease hole on the side, and insert one 1/8 in ball followed by spring VD-085H.

34. Add side spring stop (small plate).



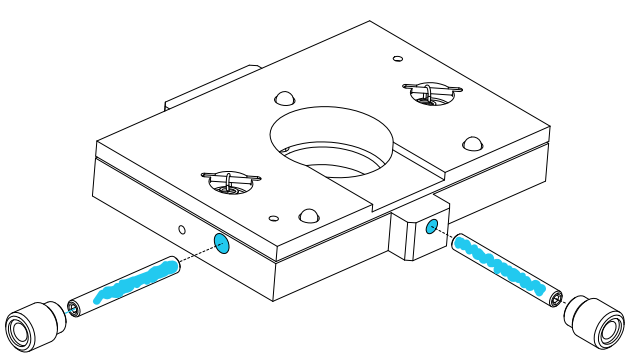
35. Screw in both M2×8 screws and tighten back plate.

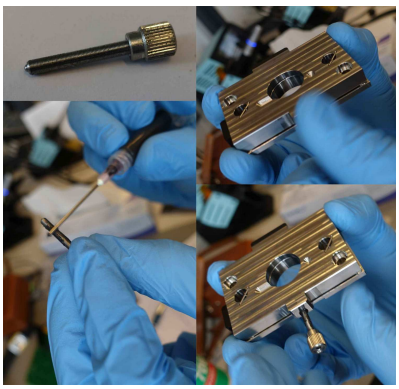
36. Screw two M2×8 socket head cap screw with 3 mm washers on the bottom side of the bottom part of the translation stage. They prevent the translation stage assembly to be unbalanced on the kinematic mount.

Translation Screw

The Thorlabs screws for the bottom plate of the translation stage may arrived already assembled.

37. Optional: Take screw part (Thorlabs F3SS25) and screw end (Thorlabs F3SSK1) and screw them into each other. Tighten with an allen key and glue the two pieces together. Cure in oven.





38. Grease front and side threaded holes for the screws, opposite to the black plates.

39. Grease the micrometric screws and screw them in to hole.

40. Bottom plate should move in 2 directions by moving micrometer screws.

Pins for the mounting of the Translation stage

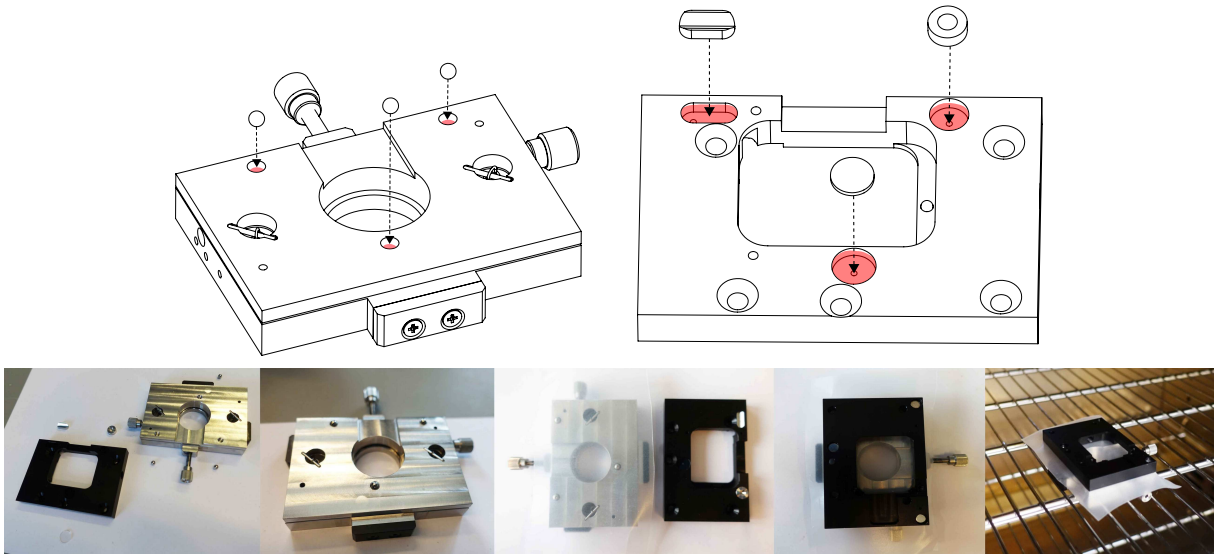
41. Glue the two dowel pins ⌀1.5 mm × 10 mm on the remaining holes and cure in oven. They are used to fix the head on the scanner.

- Translation stage is complete.

2.2 Baseplate

Kinematic positioning

One face of the stage contains magnets in three corners, the other side has a steel disk, a conical recession and a slotted recession. This is the basis of the 3-part kinematic mount for the steel balls.



1. Glue in the three 3 mm steel balls (as described earlier) on the top side of the top part of the translation stage.

2. Glue the 3-part kinematic mount elements.

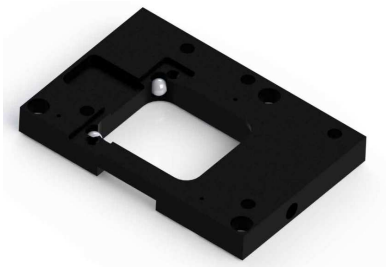
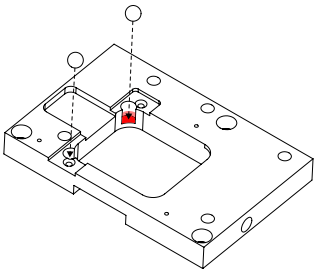
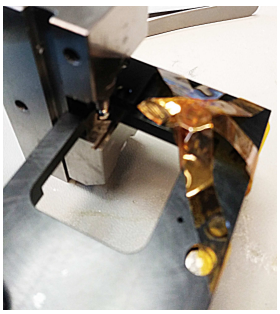
3. Place parafilm between the two parts to avoid gluing the steel balls to the kinematic parts.

Rentention magnets

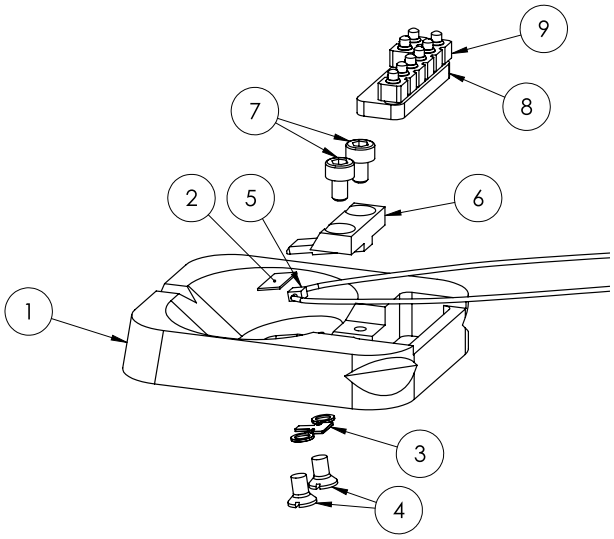
4. Glue in the three ⌀5 mm × 5 mm magnets, on the top side of the base plate. You can also use ⌀5 mm × 4 mm or ⌀5 mm × 3 mm for less retention force. PUT A PICTURE

Balls for Cantilever Holder kinematic mount

5. Put plenty of glue in the pockets at the corner of the main opening, on the top side of the base plate (magnets already in place).
6. Glue in the two 4 mm steel balls.
7. Push hard with the smallest M4 screws.
8. Clamp: make a cross with kapton or use a small vice and cure in oven.

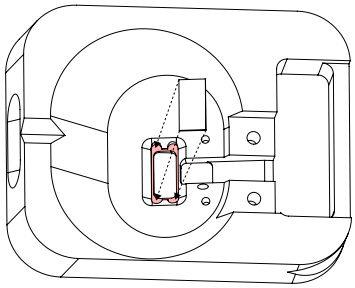
2.3 Cantilever holder



Glass window

There is a small piece of anti-reflective glass in the window in the cantilever holder. It has to be glued to insure the sealing of optics and electrical connections against liquid on the other side.

1. Add a very small amount of glue around the bevelled edge of the window - tiny groove of the slanted zone. Working under the binocular is recommended.
   The glue should be homogeneous, little but all accross so that it is sealed.

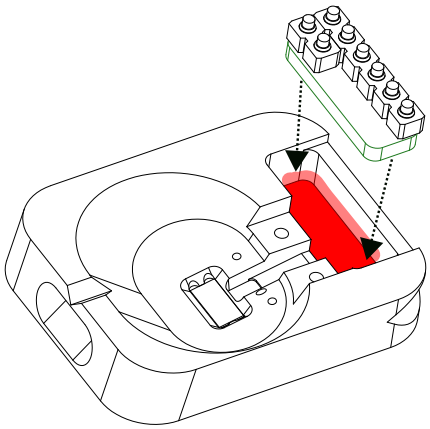


2. Place glass in to the window with tweezers, holding the sides.

3. Push down on the very edge of the glass with tweezers, to avoid any damage in the path of the lasers in the center. If the central part of the glass window has glue, clean the parts (window and holder) with acetone and repeat the steps or use a new window.

4. Cure in oven.

Board inset



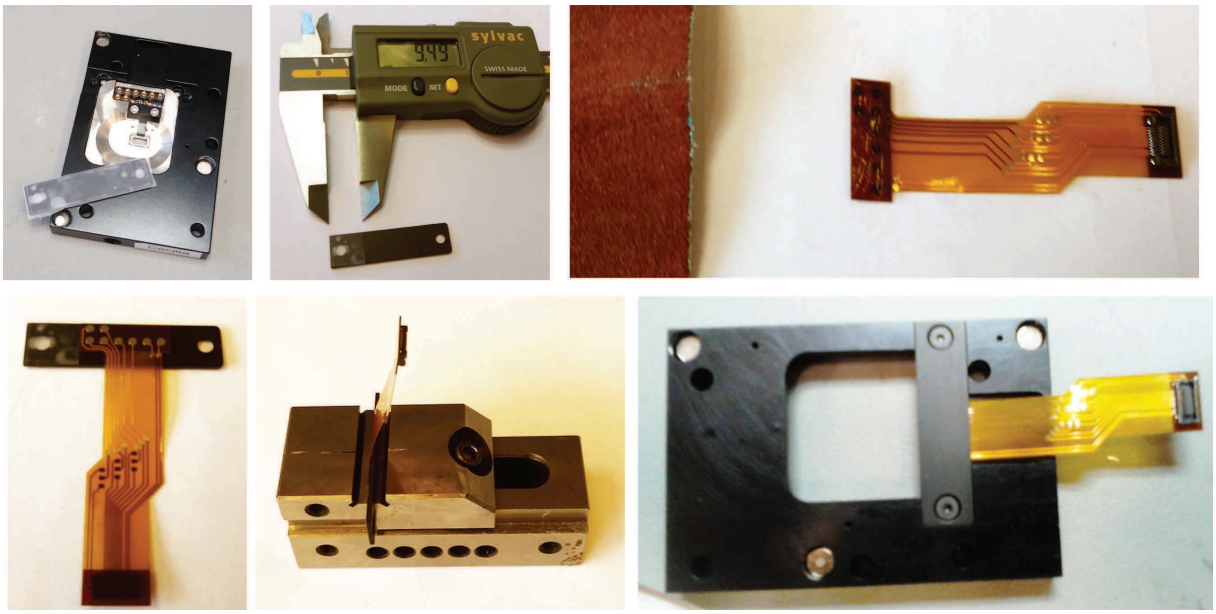
1. With the relevant stencil, deposit solder paste on the contacts of the elongated green board. Deposit and align the black PCB components on top.
   Place in reflow oven to solder.
   Note: The alignment doesn't have to be perfect: the reflow curing will center the pins anyway.

2. Once soldered, isolate the PCB by cutting off the holder and grind off remaining stub on PCB.

3. Apply a thick layer of epoxy in the rectangular hole of the cantilever holder. Press the finished cantilever inset in to the hole. Cure in oven.

Base Plate Flex PCB Clamp on the Cantilever holder: Contacts for the fluid cell

The straight PCB cover is used to hold the flex PCB against the cantilever holder, later connected to the readout board. This cover should have the countersink of the screw away from the baseplate to fit the screws. The Flex PCB should stick out away from the baseplate and the contacts should be under the cover. As the corners of the clamp are different on both sides, it is good to check again on the baseplate before gluing.



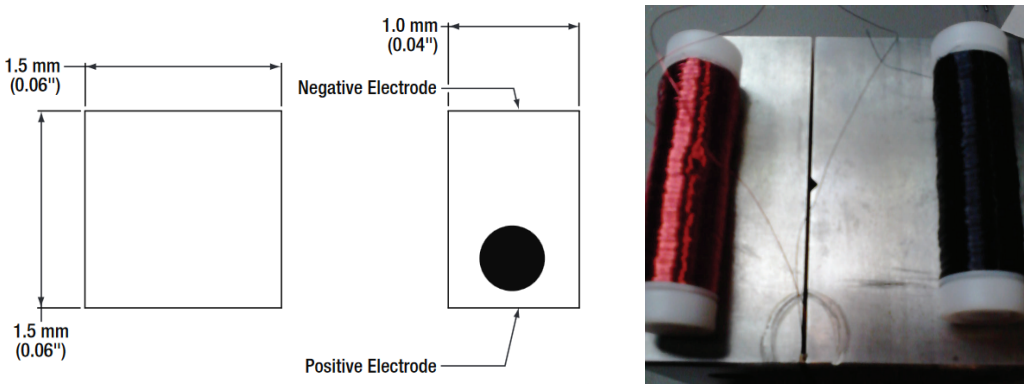
1. Use tape as an alignment mark to glue the flex PCB on the cover: Put 2 layers of scotch tape on the non-countersunk side of the cover. The tape should surround the part.
2. Trim the extra tape with scissors, so that it fits the shape of the part.
3. The part has 2 type of corners: rounded and squared ones. From the squared ones, measure 9.5mm long, cut the tape with a scalpel and remove the inside piece of the tape. A short length of tape should stay on the side of the squared corners, no tape on the side of the rounded ones.
4. Lightly sand the kapton stiffner of the flex PCB for a better adhesion of the glue.
5. Add a layer of glue on the flex PCB, on the stiffer side, opposite to the electrodes. Keep the electrodes away from the glue.
6. Align the flex PCB with the tape at a few hundred of μm from the border of the cover. The Flex PCB has its electrodes up, at the right of the alignment tape.
7. Clamp carefully and cure in oven.

Soldering the Piezo

The piezo stack (1.5mm $\times$ 1.5mm) has two coated faces. The black dot shows the positive polarity (+), is on a uncoated side. Close to the small dot, there are two sides: a small side

which is the positive electrode (+) and a big side which is not conductive and is the side normal to the motion.

1. Clamp the piezo



2. The soldering is done with enameled copper wires. Expose the enamel of the wire ending to hot solder ($350°C$). The solder tweezers are very adequate for this operation.
Pre-tin the wire ending.

3. Put flux on both electrodes of the piezo.

4. Using $220°C$ solder to avoid depolarizing the piezo, solder with a very small soldering point the red wire on +, the black wire on -.

5. Check capacitance with the multimeter: it should be in the tens of nF. Check the resistance between RED and BLACK wire: it should be some MΩ if no short circuit.

6. Fix the piezo in the inset with a tiny drop of superglue.
Warning: Pay attention to the membrane under the cantilever. Don't press on it too much, it is extremely thin and can break.

7. Solder ($350°C$) the other extremities of the wires to the straight PCB in the cantilever holder: RED wire connected to the Piezo (+) square pad (on the edge), BLACK on the Piezo (-) pad (next to the Piezo +). The wires should be a bit longer than the distance between the piezo and the board to hide them under the clamp.

8. *Optional*: Add a thermistor to the cantilever holder. The thermistor is inserted in the small hole which has its ending close to the glass window on the side of the cantilever chip. If no thermistor is glued in the hole, it is better to add a tiny drop of epoxy in this opening to avoid that a liquid can go up in the cantilever holder close to the optics or electronics.

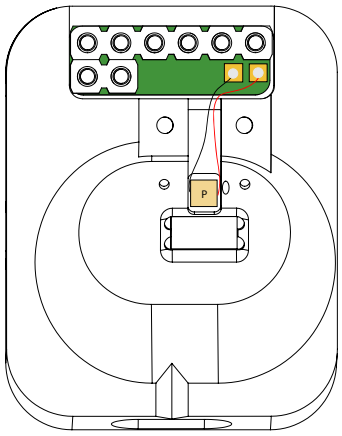
9. Make a small hole with a file in the piezo clamp, on the side of the piezo pad, in the middle of the tongue of the clamp. Glue the thermistor with epoxy into the hole next to the piezo and fix it with scotch tape to cure.

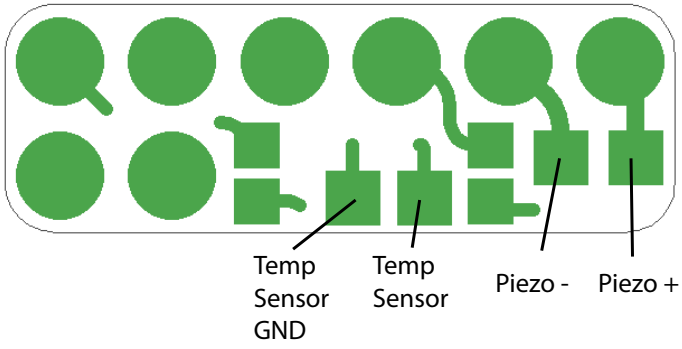
10. Very gently separate the 2 fragile wires of the thermistor, remove the polyamide coating with a fresh scalpel. Work with tweezers under the binocular. Solder them to the corresponding pads. There is no polarity.

11. Pot the inset (wires and piezo) with epoxy to protect from any liquid or salts during the experiments or the cleaning of the cantilever holder. Make sure not to cover the PCB.

12. Screw the piezo clamp on top and cure in oven.

13. Connect a UMCC cable to the drive board to read the thermistor values.





Cantilever holder Assembly

Cantilever Spring Clip Chamfering

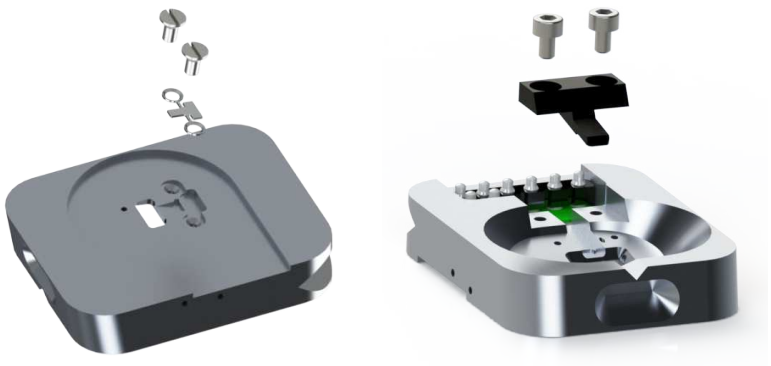
Add a chamfer in the holes of the spring clip to avoid the screws sticking out.

1. Install the clip in the dedicated holder so that it doesn't move.

2. Use a chamfer tool and set the drill speed to 140rpm. Very gently push down a bit. The thickness of the clip around the holes should become quite thin. Check under the optical microscope.

3. Add a chamfer to the font part of the spring clip, where the cantilever is clipped, for the same reason than before. Sand a little bit forward and backward.

Spring Clip Screwing

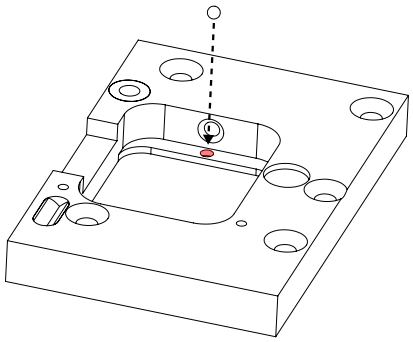


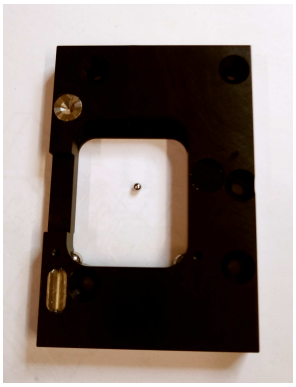
4. Screw in two M1×3 slotted countersunk flat head screws: one screw pushes the spring clip on the cantilever holder, the other screw deforms the flexure due to its own friction.
5. When tightening the lefthand screw (cantilever facing upwards), push with tweezers against the flexure beam to keep it from bending downwards.

Piezo Clamp

6. Place piezo clamp on piezo.
7. Grind down two stainless steel socket cap screws M1.6×3 until they fit (non-standard length of 2.5mm.)
8. Finger tight the screws: use the longest part of the hex key to apply less force on the screw and on the membrane under the piezo.

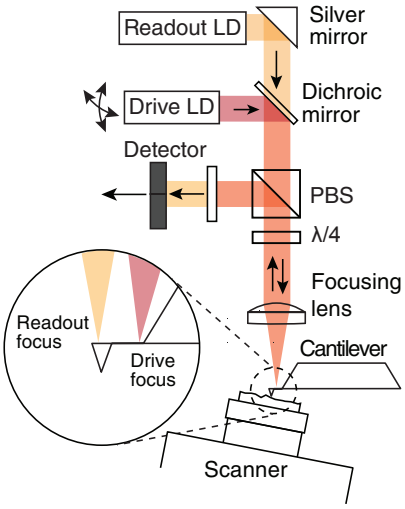
Cantilever Holder in Base plate

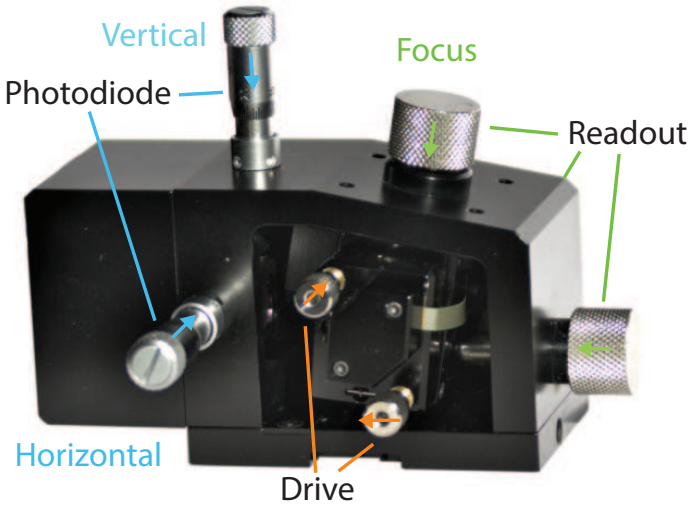




1. Glue in the final 2 mm steel ball in the cantilever holder pocket of the baseplate.
2. Place parafilm on top of the ball.
3. Place the cantilever holder on top of the ball.
4. Grease the nearest hole to the ball and screw in a M5×10 ball–tipped set screw in.
   This mechanism locks the cantilever holder in the base plate and is the technique to exchange the cantilever during the experiments.
5. Cure in oven.

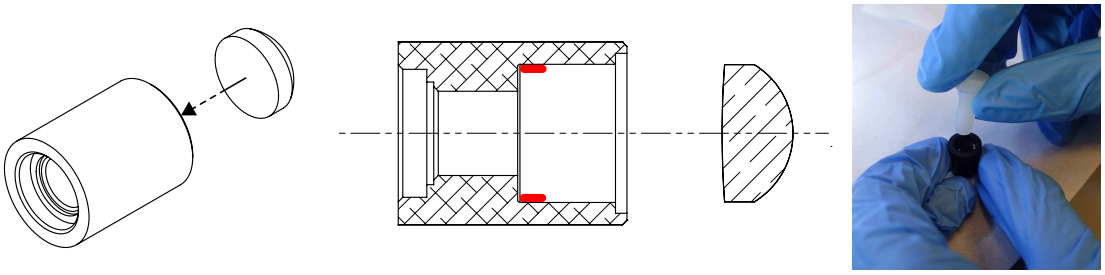
2.4 Lasers





Collimation Lens

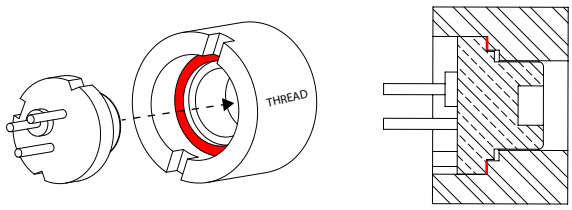
1. Take the lens for collimation 355110.
2. The part which holds this lens has 2 opening sides: one side has an internal thread, the other one is smooth.



3. Put a small amount of glue inside the smooth side, only in the very bottom before the shoulder (see figure) and spread it in a ring.
4. Insert the lens, with the rounded side toward the outside of the part (up), then push down with a plastic screw.

Laser diode mounting

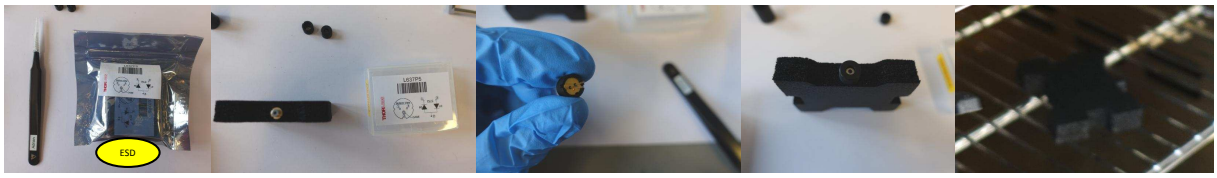
Note: Always manipulate the diodes (laser and photodiode) with ESD tweezers and bracelet. The devices are extremely sensitive to handling.
Two laser diodes are used in the optical assembly. The readout diode ($\lambda = 635\,\text{nm}$) is the one monitored on the photodiode. The drive laser ($\lambda = 675\,\text{nm}$) excites the cantilever and is filtered before the photodiode.
To avoid mixing them, put them in their original boxes at any step of the assembly.



1. Put a little bit of glue inside the shoulder of the threaded laser diode mount.
   Don't overcoat bottom or glue will squeeze out. No need to coat to very top. Any problems, take out and place in Acetone.
   Check the bottom of the cylinder for glue leakage.

2. Open the drive diode box (HL675MG) with an ESD bracelet.

3. With ESD tweezers, take the diode in the foam inside the box and revert it to place it in the laser mount.



4. Repeat the steps for the readout diode (L637P5) and cure in oven in their respective packages.

Collimation

This procedure aims to collimate the laser beams of the two diodes, by adjusting the distance between the diode and the collimating lens.

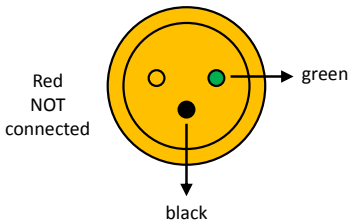
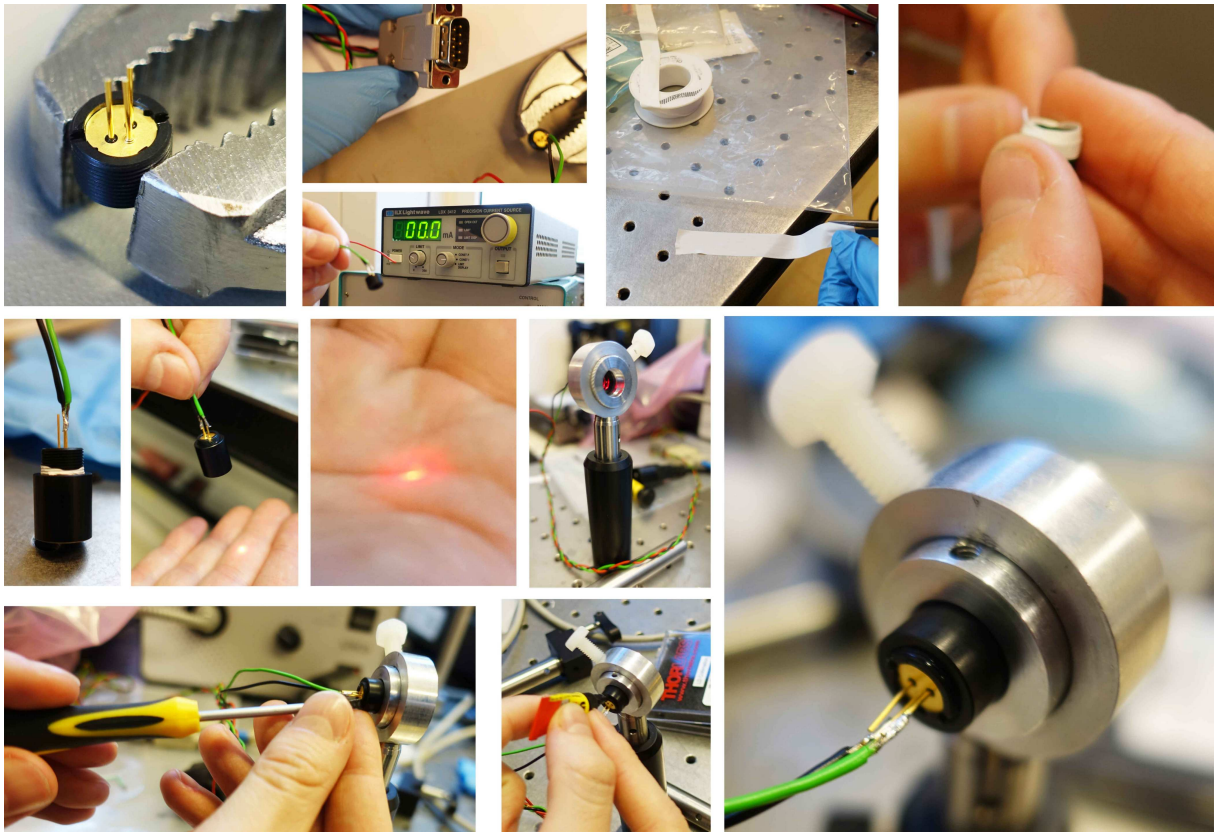


Figure 2.2: Soldering of the Diode pins to the light source

5. Take out diode and solder the green and black wires of the cable of a sub-D 25pins to the pins of the laser diode, according to figure 2.2.

6. Connect to diode driver (1LX Light wave) and turn current to 0 mA.

7. Turn on the source and increase the current until the lasing treshold.
   The readout diode lasing threshold is around 13 mA. DO NOT go over 18 mA.



The drive diode lasing treshold is around $32mA$.
Compare to the readout diode, it looks less bright but the power, measured with a power meter, makes it a class IIIb laser: 50mW.

8. Cut a very small sliver of Teflon tape (2 mm × 60 mm).

9. Wrap Teflon tape around thread on diode, at the front, in the direction that it does not wrap when the lens will be screwed on top of it. This step stabilizes the thread and seal the optics from the super glue.

10. Cut tape after 2 full revolutions.

11. Twist the diode in to lens holder until the laser spot is approximately collimated. *Note*: a collimated beam will have the same diameter over a large distance, check this by measuring the diameter near the diode and far away from it.

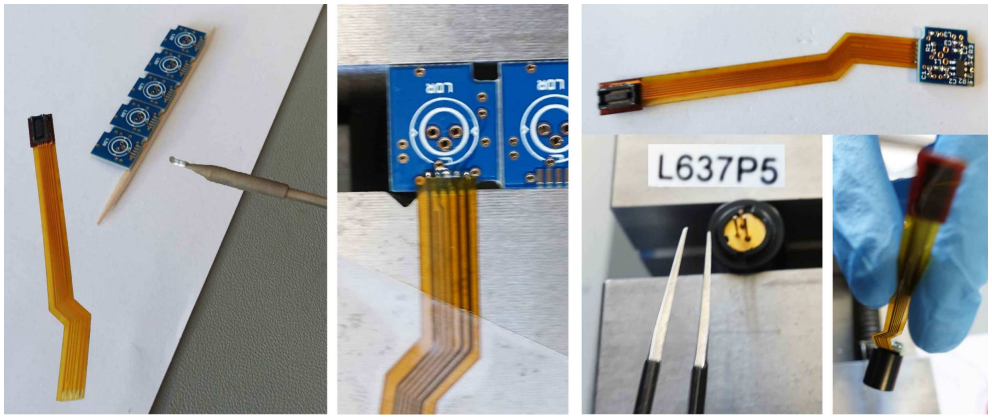
12. Place the collimated diode in optics mount.

13. Use screwdriver to change alignment of diode with lens along a long projection distance.

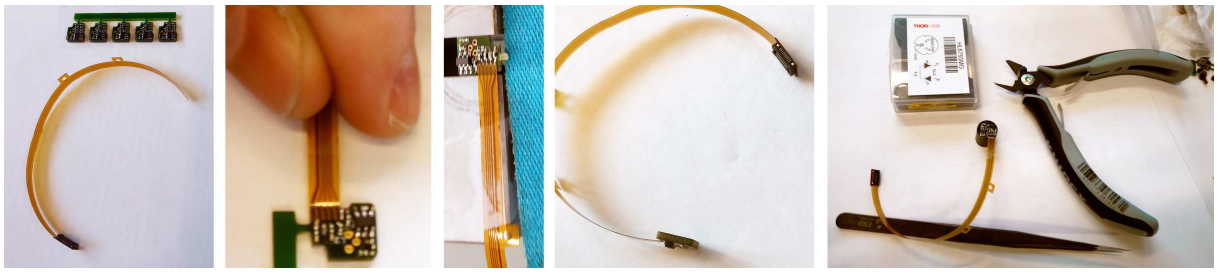
14. Drop tiny drop of superglue into thread of laser, the capillary effect will wick this up. **Do not** touch the diode.

Attaching modulator boards to Laser Diodes

1. Flux the small blue board to remove oxides and add solder to the end of the board. Reflux the solder.

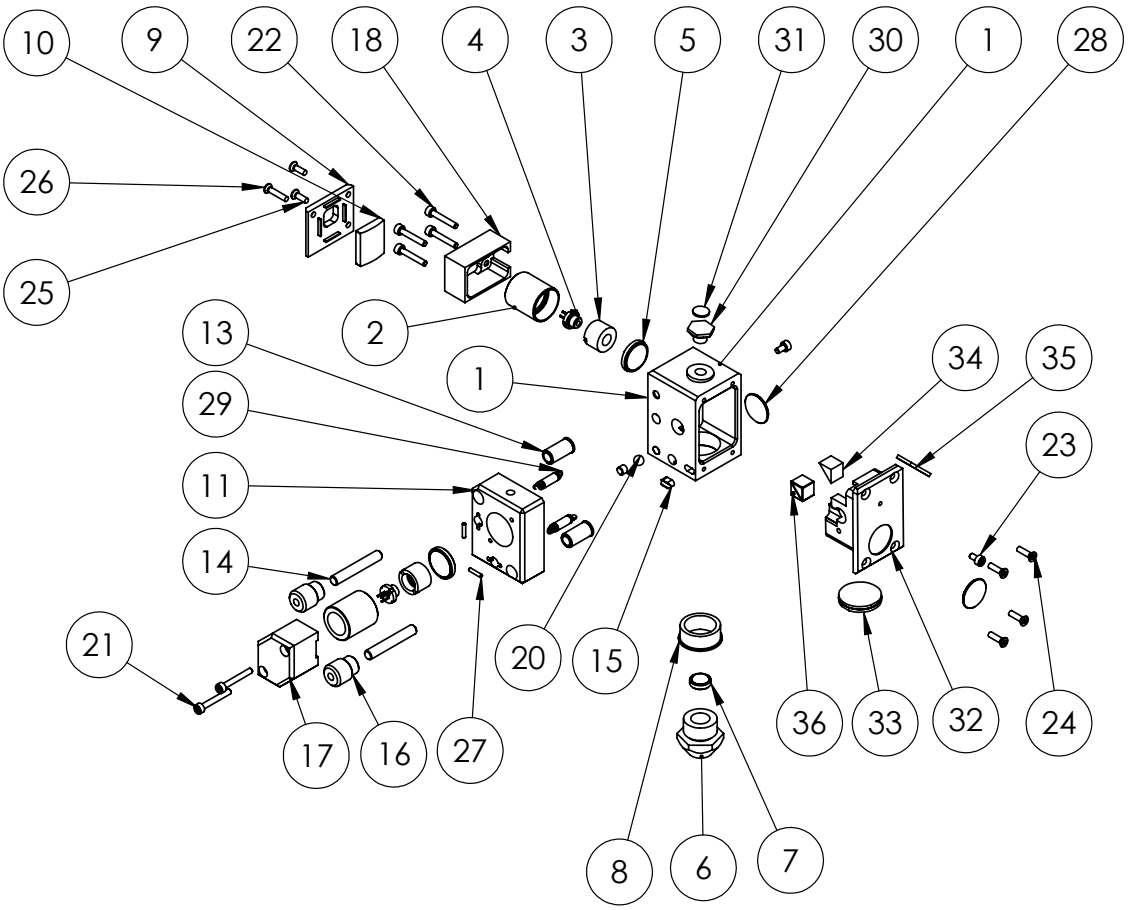


2. Trim the kapton at the end of the flex PCB.
3. Put solder on the lines of the flex PCB (use flux before).
4. Align the lines of the flex PCB with the modulator board in a vice.
5. Apply sticky-tape to the cable to hold it in place with respect to the clamped board.
6. Leave a small gap to the edge of the pins to allow soldering iron access.
7. Apply flux and run solder along the four pins. Another way is to solder on top of the Flex PCB.
8. Check connections.
9. Wash board to remove flux if connections are okay (may need flux remover)
10. Optional: Epoxy the connection to prevent stress fractures.
11. Put on the ESD bracelet and take the ESD tweezers to install the mounted readout diode in a vice.
12. Insert the pins of the diode in the holes of the blue board: wiggle a bit the pins.
13. Solder the 3 pins using flux.
14. Cut with precision pliers the legs of the diode.



15. Repeat for drive diode (long flex).

2.5 Optics block



Lens Holders

There are three objective lenses and one cylindrical lenses:

- Short Focus lens for air (small spot)
- Short Focus lens for liquid (small spot). Painted in blue at the beginning with nail polish, in order to not mix them up.
- Long working distance Focus lens for cantilevers $>1.5\,\mu m$ in width (spot $\approx 4\,\mu m$)

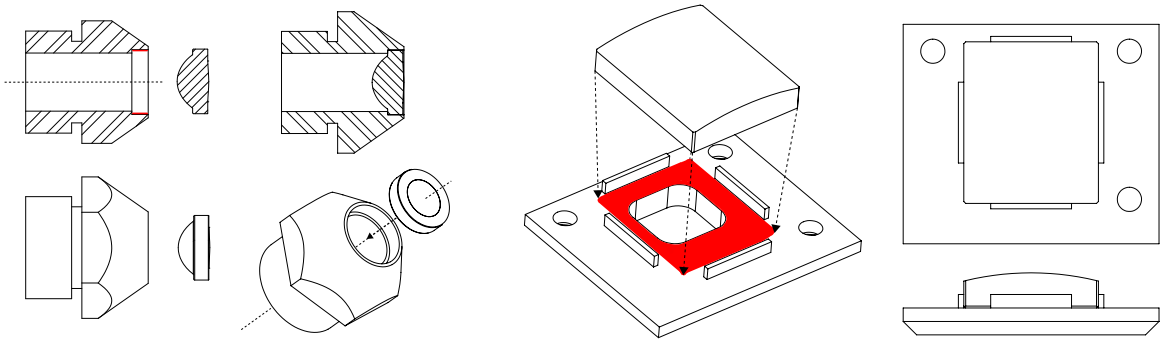
Another lens is also glue to its holder, but will stay permanently in the optics block

- Horizontal Focus lens LJ1402L1-A

The two lens holders for the air and liquid lenses are the same, however the holder for the long-focus lens is recessed.

1. Glue a very thin layer around the edge of the holder (not too much at the bottom).

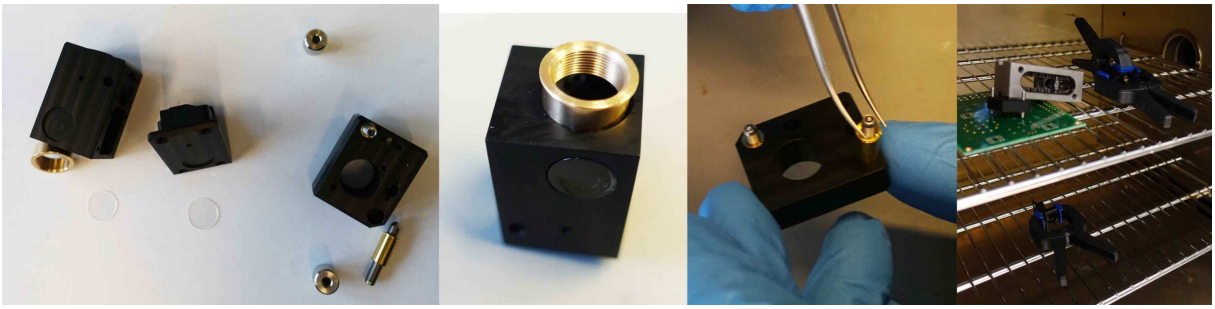
2. Hold the lens at edges with tweezers - flat side should be up, curve side directed towards the holder.
3. Drop in lens – The air and water lenses will sit flush.
4. VERY GENTLY push the long-focus lens in to the holder using a plastic screw.
5. Cure in oven.



6. For the Horizontal Focus lens, place glue in corners of the uprights (small amount to avoid leakage)
7. Place lens in flat face down and push in with plastic tool
8. Place in oven to cure

Optics housing

9. Glue the sapphire disk ($\varnothing 9.5\,\text{mm} \times 0.5\,\text{mm}$) into corresponding hole.
10. Place parafilm over the sapphire disk and clamp to cure.



11. Place glue around the edge of the hole at the bottom of the optics housing.
12. Push gold bushing in with the flange facing out.
13. Clamp and cure in oven.
14. Glue in the kinematic elements ($\varnothing 2.5\,\text{mm} \times 0.5\,\text{mm}$ sapphire disk, cone insert and slot insert).
15. Clamp and cure in oven.

Optics insert

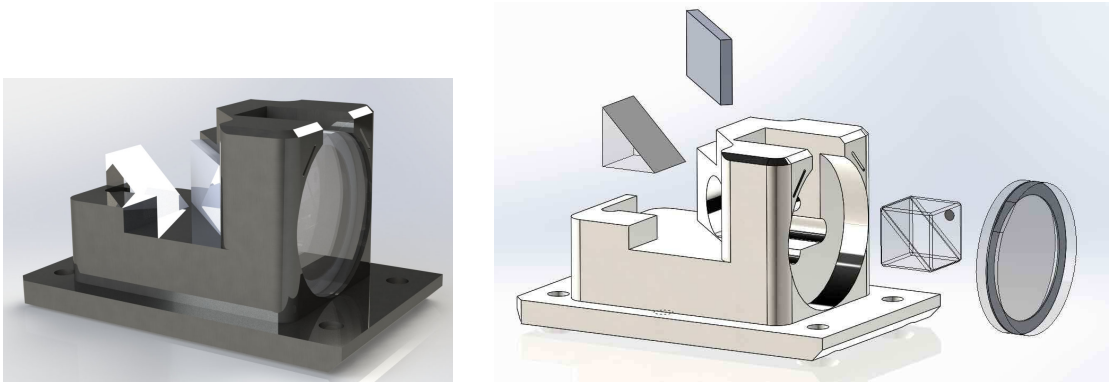


Figure 2.3: Exploded view of the Optics Insert

Dichroic Mirror

The dichroic mirror has active and passive sides. Hold it up to the light and look very parallel to the glass. The active side will have a uniform color all over (red or blue, depending on the angle of the light), you will not clearly see the furthest edge of the bottom through the glass. Through the passive side, you can see the edges of the other side **??**. Put the non coated side of the mirror up. Double check if you see the coating through, by reverting several time the mirror.

1. Place inset in the vice at 45 degree so that the dichroic mirror lies flat.
2. Put a thin layer of glue on the flat side of the plastic (avoid the edges).

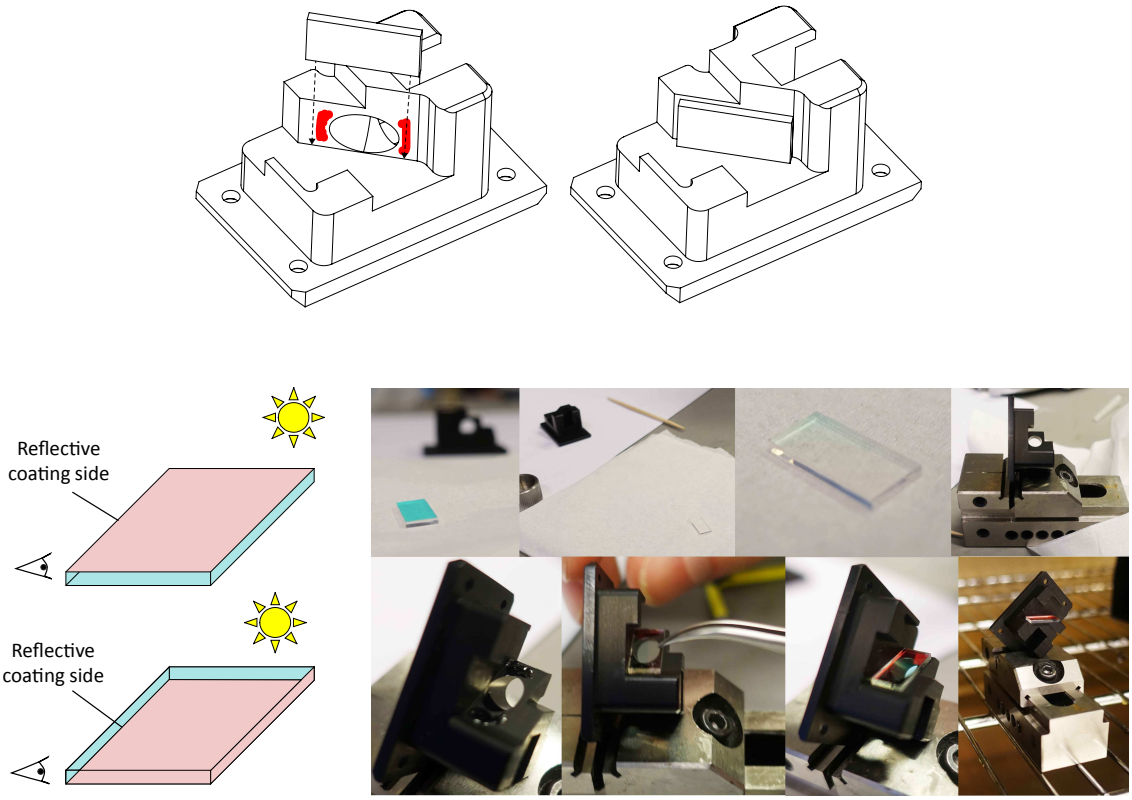


Figure 2.4: Dichroic Mirror

3. Drop the mirror on, the coated side of the mirror goes against the part.

4. Place the mirror carefully on the flat and slide slightly towards the bevel.

5. Push down on all four corners with a plastic tool to ensure good glue connection. Push the mirror a little bit in the direction of the curvature of the holder.

6. Cure in oven in vice. DO NOT clamp the mirror.

Right Angle Mirror

7. Put glue on flat and sidewall. DO NOT put glue on the dichroic. The flat surface towards the table, the active surface up. DO NOT touch the slanted surface.

Polarizing Beam Splitter

8. There is a dot on one side. Hold the beam splitter by the non reflective sides. Put glue on the side and bottom of the square opening of the insert. Align the dot according to Figure 2.3.

Quarter-wave Plate

At this point, the Polarizing Beam Splitter should be cured in place in the holder.

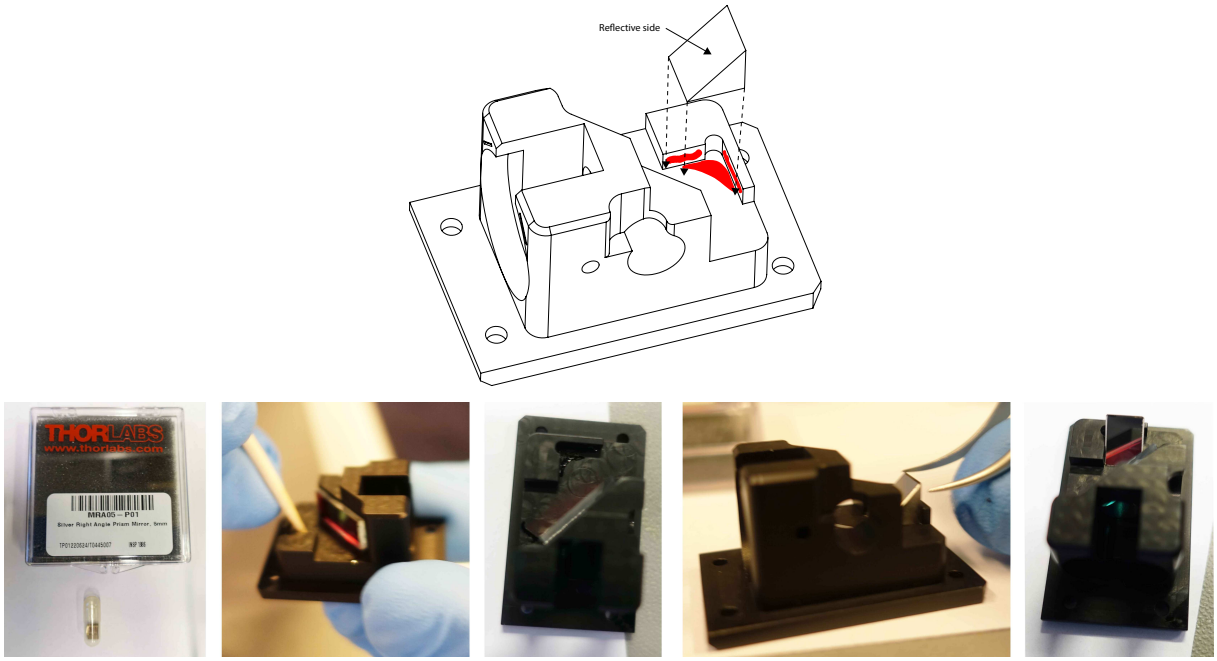


Figure 2.5: Right Angle Mirror

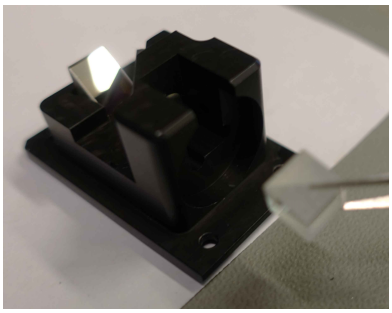


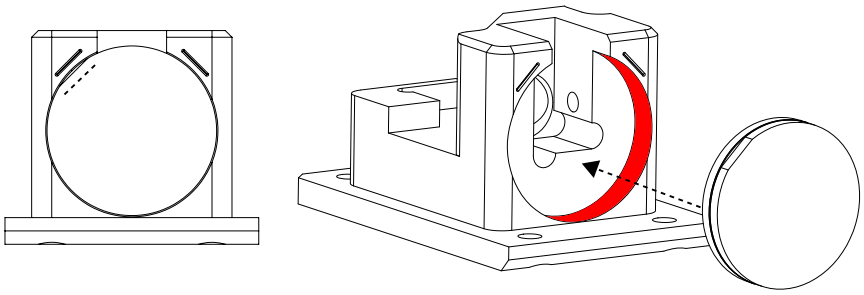
Figure 2.6: The orientation of the polarizing Beam Splitter in the insert is given by the dot position.

9. Remove quarter wave plate from its mount (unscrew with key): turn with the Thorlabs tool the black ring to free the quarter wave plate. Then reverse the part in the bigger ring. Release by pressing the glass on the sides gently.

10. Tip out quarter wave plate into lens/wax paper (the quarter wave plate will look like slightly yellow glass in a metal washer).

11. Check if quarter wave plate fits in the housing before gluing! The two glasses are glued together and the assembly may be a bit misaligned. If not, sand it down using 240 metal

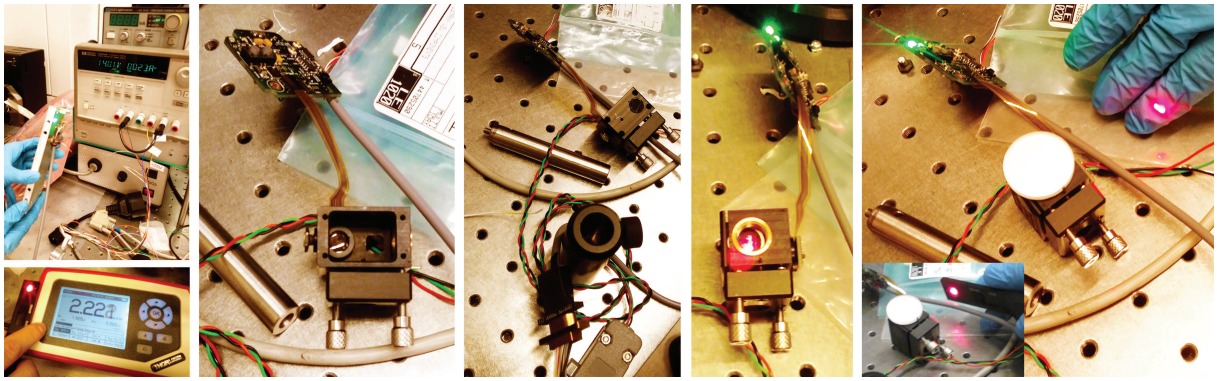
sandpaper. Place magic tape over both sides of lens and scalpel off edges of tape. Sand down by keeping paper still on a hard surface and move the quarter wave plate over it in a smooth bending motion.



Second Step: Check the alignment and power.
Depending on the version of the head, there may be alignement marks machined on the optics insert for the Quarter Wave Plate.

12. Check the size of the quarter wave plate again. If it fits, remove tape carefully with sharp tweezers.

13. The way-up of the quarter wave plate is not important but it is critically important that it is in the right rotational orientation! The quarter wave plate has a line/flat on it marked on the side and visible from the top. Match the line up with the line on the optical housing if it exists – they must be parallel, not lined up.



14. Insert quarter wave plate in to hole with (flat) aligned parallel to the mark (as above). Drop the optics insert into the optics assembly. You will see if there are losses, complete disappearance of the spot on the photodiode.

15. Insert readout laser attached to readout circuit in the correct direction, fix with a M3 screw, and turn on the laser.

16. Check power out. You should expect about a 20% loss through the nine interfaces until the beam exits the optics housing.

17. Place a silver mirror at output to imitate a cantilever.

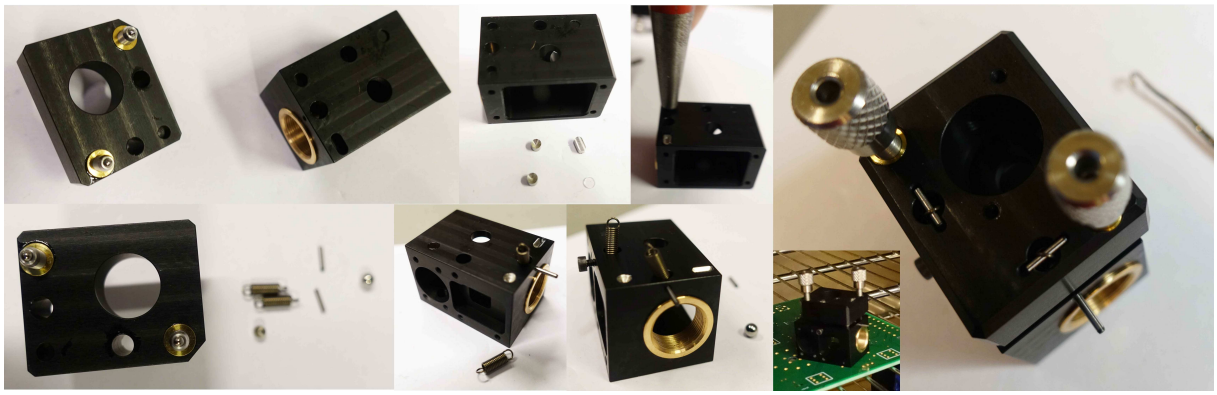
18. Check power at the output of the cylindrical lens with the power meter: the loss should be less than 10%. If more loss, rotate the quarter wave plate and repeat the measurement.

19. To glue the quarter wave plate, remove the optics insert from the housing. Wiggle the Quarter wave plate to disassemble.

20. Apply epoxy to the pocket for the quarter wave plate and reinsert the quarter wave plate like it was for the test.

21. Replace optics insert in housing and recheck the power. Reminder: Insert the optics insert in the bloc with the drive board connected to the small green PCB by the flex cable.

Kinematic drive mount



1. Glue in the cone insert of the kinematic mount. You may need to push in hard with a metal part. If any glue overspills wipe off with a tissue. If necessary, clamp for curing.

2. Put a thin layer of glue on the gold bushing of the two micrometer screws and insert them in the part and cure in oven.

Assembling the optics block

1. The optics insert is put into the optics housing and fixed with two countersunk M1.6×6 screws.

2. The third screw–hole has a perpendicular bore that fits the extension spring. When screwing in this screw, use it to fix the extension spring (Z-024AAX).

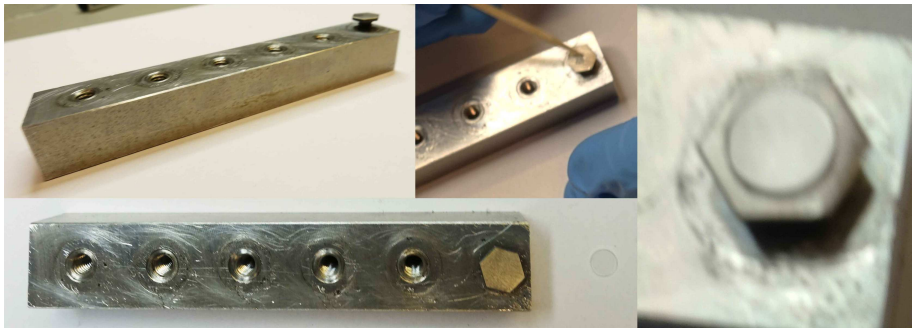
3. Fix the second spring of the same type with a ⌀1 mm × 6 mm dowel pin.

4. Put a dollop of superglue on the dowel pin to hold it in place.

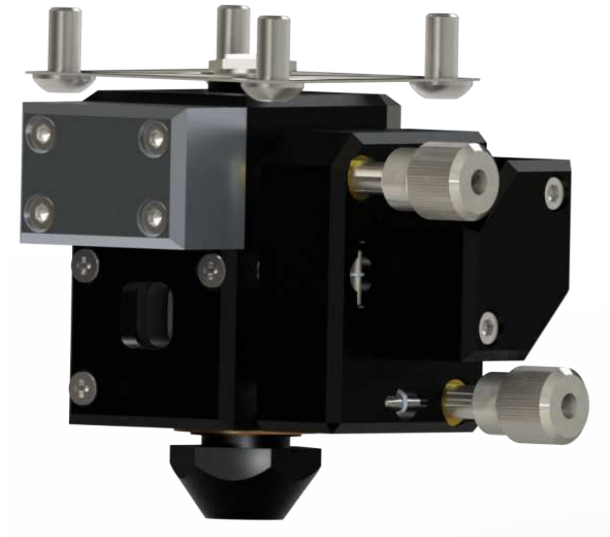
5. Use a spring hook to attach the kinematic drive mount to the optics housing by fixing the other end of the extension springs with ⌀1 mm × 6 mm to the kinematic drive mount.

6. Place a 3 mm ball between the conical insets of the optics housing and the kinematic drive mount.

   The flexure of the optical assembly is fixed with a screw that haS to be shorten.



7. Mill down a hexagonal M4 screw with carbide tool inside alu holder. Tighten.
8. Add glue on top of the screw (don't be afraid to put more).
9. Put a sapphire plate (5mm × 0.5mm) on top. This sapphire will push against the micrometre screw that controls coarse z-position of the assembly.
10. Clamp and cure in oven.
11. Attach the flexure with the newly made screw to the top of the optics housing, making sure that the walls of the housing are parallel to the sides of the flexure.
12. Place the drive and readout lasers into their respective bores and tighten the respective set screws. Ensure the flexes come out of the flex holes.
13. The drive housing is placed on top. Screw in on top with two screws. Ensure that the flex comes out of small slot in housing

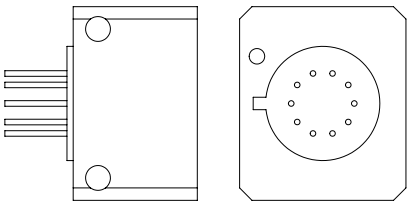


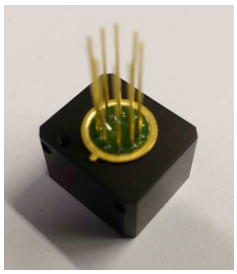
14. Use two M1.6×2 screws to secure long flex in place around the optics housing.
15. Place the housing on the readout.
16. Screw in four M1.6×10 screws.

2.6 Photodiode assembly

Photodiode Mount

1. Mount the 4-quadrant photodiode in the small cube.
   The orientation needs to be correct so that the reverse bias is on the right pin.
   The bigger hole of the cube should be up, and a small hole close to it should be on the top left corner.
   The photodiode has a small tongue. Orientate it so that it is on the left of the part, under the small hole of the cube.

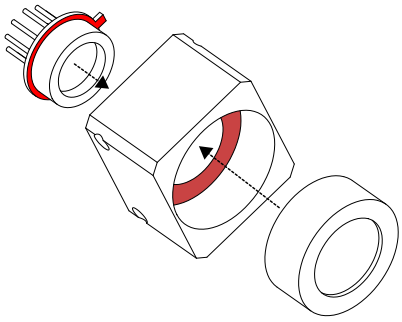


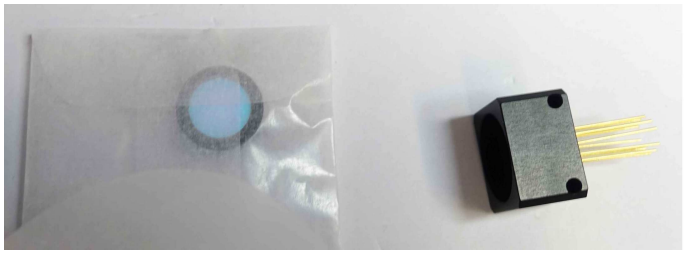


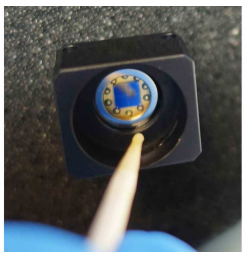
2. Add glue on the external golden ring, on the side of the diode aperture. Insert and press against the cube. Cure in oven.

Photodiode Filter

The filter prevents the ambient light or the drive laser light to go on to the photodiode (625nm). It also seals the photodiode. The filter has a directionality, indicated by the arrow on the side of the package.





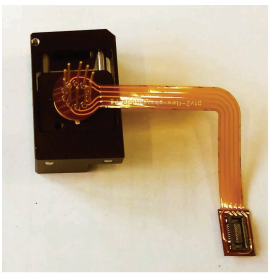
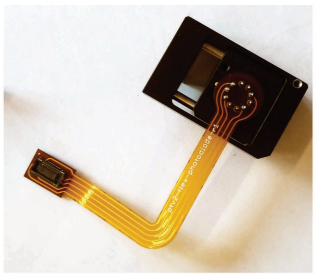
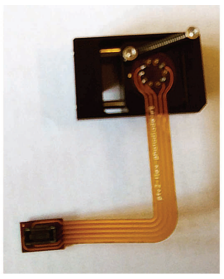
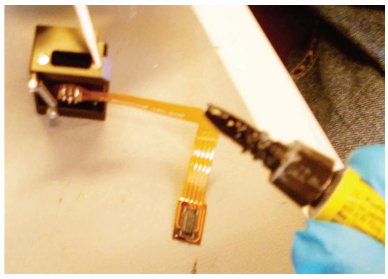


1. Mount the Photodiode on a foam.

2. Clean with Nitrogen flow before enclose.
3. Put some epoxy around the inside hole of the black insert.
4. Insert the filter with the arrow towards the photodiode, in the photodiode mount and cure in oven.

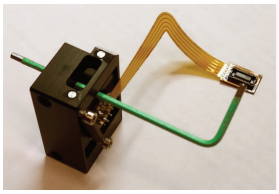
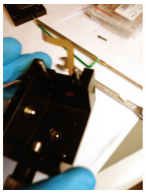
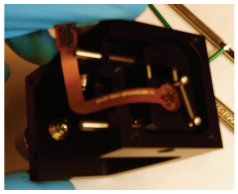
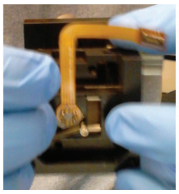
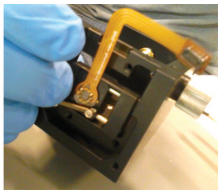
Soldering the Photodiode Flex Cable

1. Grip the main housing in a vice with the photodiode legs facing up

2. Place the flex cable on the photodiode legs. The flex is oriented away from the small tapped hole beside the photodiode.
3. Flux around all pins and solder each pin in separately.
4. Once each pin is soldered, clip all pins.
5. Gently fold flex cable up and across. DO NOT cause nicks in the cable; fold it gently.
6. Gently dab pins with deionised water, followed by flux remover.
7. Dry the cleaned pins.

Assembling the carriage

1. Grease the two rods
2. Glue sapphire square 7cm $\times$ 3cm on to the side of the photodiode assembly (thin layer underneath)
3. Clamp with a stick pressing (spring load it)
4. Glue the ends of the rods in place by placing glue around the edges of the rod. The photodiode should glide easily on the rails!

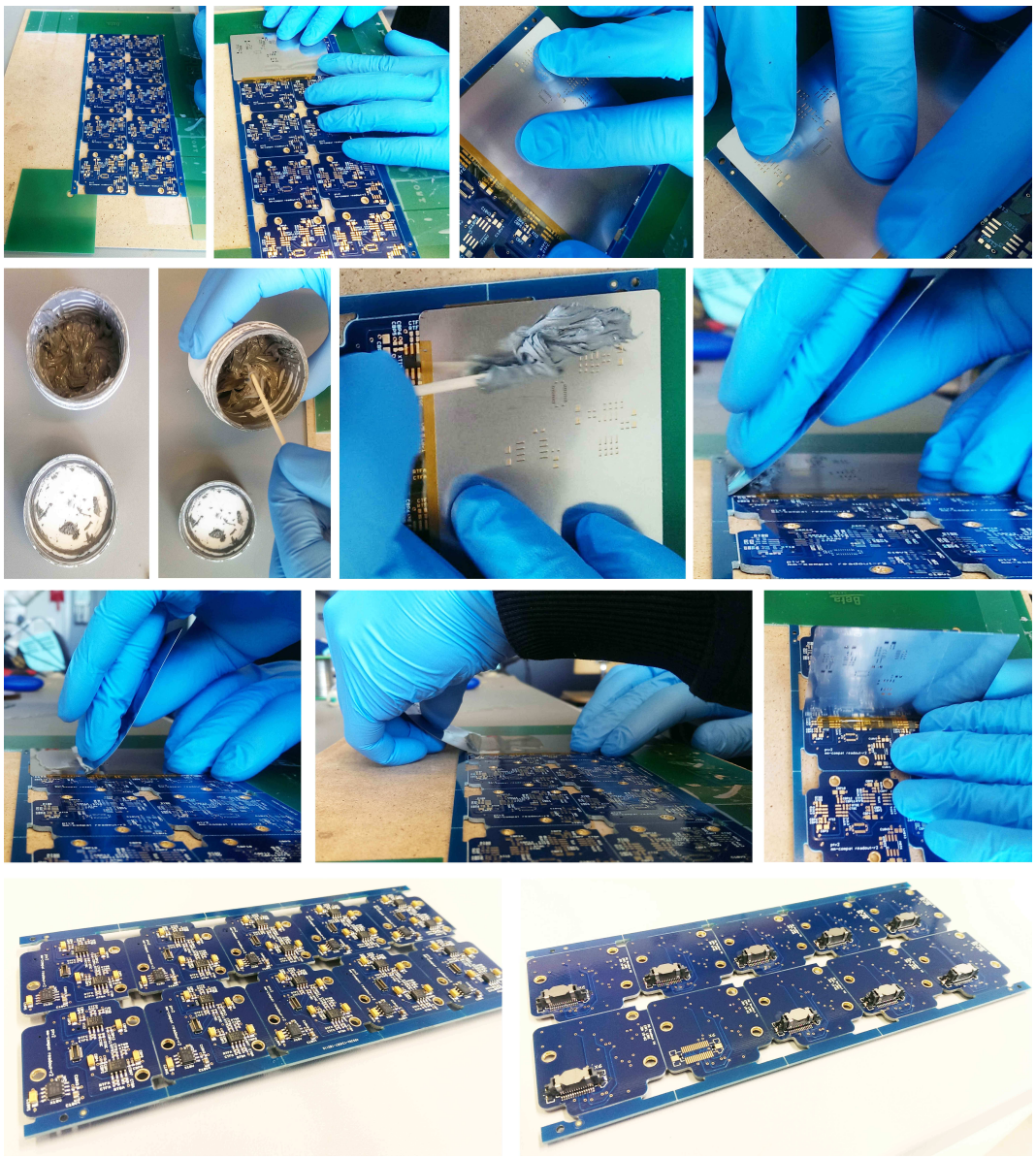
2.7 Electronics

Notes: There are four rigid PCBs: two large and two small ones.
Blue: photodectector readout circuit (4 trans-impedance amps, voltage reference)
Green: drive circuit (2 laser drivers, power regulation, switching).
Three Flex cables: two to connect the diodes to PCBs, the third to connect the cantilever holder elements (piezo, temperature sensor, tip bias).

Preparing the PCBs

If you want to learn how to prepare the PCB before putting the components...

1. Tighten the PCB in between other PCBs of the exact same height, on a flat surface: the stencil cardboards are a perfect support for that purpose.

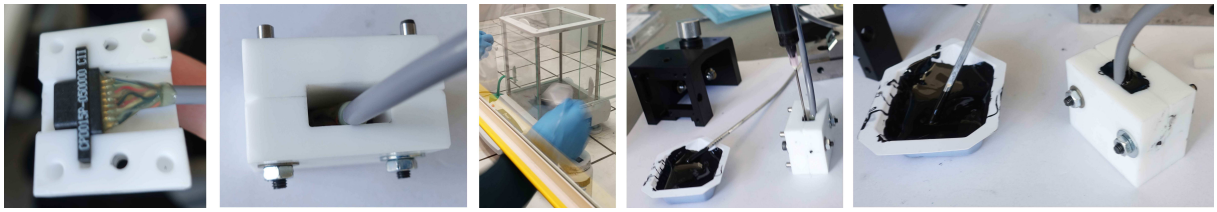


2. Place the stencil on top and align the pattern at the edges. When the mask is precisely align, tape the side of the stencils, limiting the surface of tape on it.

3. Mix the solder paste with a toothpick in the pot and deposit a sufficient amount of paste on a side of the stencil.
4. The quantity to prepare should be enough to cover the whole mask in one step, but sufficiently low so that the paste in the holes stays very thin and that there is not a lot of waste.
5. Put the trash PCB or stencil before the paste and slide it over the stencil completely from one edge to the other, with a small angle to avoid having too much or little paste in the holes. Depending on the size of your trash stencil, you may have to repeat this step to cover the whole stencil.
6. DO NOT repeat this movement on a zone where there is already paste. You may put too much.
7. If some zones are not covered, put a tiny bit of paste next to the zone and pass once adapting your movement to the zone to cover.
8. When the paste covers all the zones, detach carefully the stencil without moving it laterally.
9. Put your components on the boards with tweezers following the board file. As always in electronics, it is relevant to multiplex by preparig several PCB at a time, for example.
10. Release the PCB and cure it with a reflow recipe corresponding to the used paste.

Preparing the cable connecting the head to the base

The received cables are connected to micro sub-D. Melted silicone is used for isolation between the wires. This isolation is not mechanically good enough. To help handling the cables, we cure black epoxy in a mold around the silicone.



1. Mix thermally conductive black epoxy part A - black resist - and part B - hardener - on a scale (1×1): 35g $\times 2$. Make sure than the quantities are respected. Mix well (in the corners also). Put in dessicator to degass.
2. Clean the mold and the cable. Tighten the cable in the mold and close with the screws and rods.
3. Fill the mold from bottom with a syringe to prevent the bubbles. The fluid may be hard to push in the syringe. In this case, simply pour the epoxy from the bottom with a rod (the fluid is very viscous) and once it is filled, use a dessicator to remove the bubbles again. Refill if necessary after this step.
4. Cure for more than 4 hours in the oven. If less, the epoxy will be too soft to remove the mould. The epoxy cures at room temperature in more than 24h.

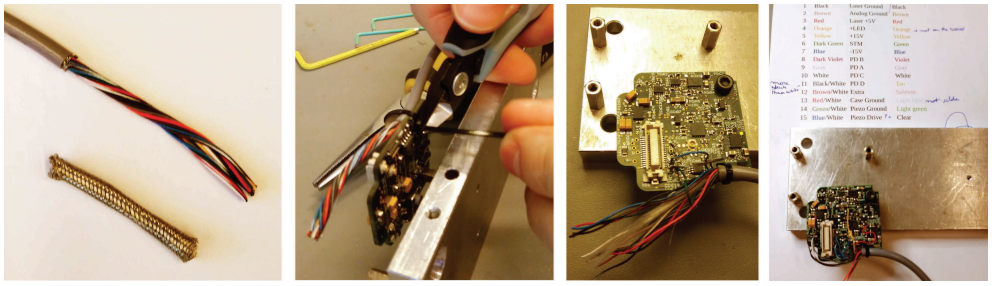
Soldering the Head connector cable

1. Take drive board (green, ptv2-drive-r3) and place in vice.

2. Trim grey connector cable to length (380 - 450cm).

3. Strip the final 40mm of grey insulation off the cable.

4. Remove grey casing mesh by trimming gently around circumference with sharp wire cutters and pulling the casing off to expose the wire. Make sure there is no rest of mesh which can contact the PCB (vias).



5. Place two cable ties around cable through board holes by pushing the flat end through the hole and securing underneath. Ensure that the stripped cables do not touch components. They should start 3-5mm after the cable tie.

6. Tighten cable ties and trim off with scalpel.

7. Bend separated cables to their input point.

8. Leave a little excess and trim off by using scalpel on the clean, green part of the board (no components or wires).

9. Pick up wire with pliers, holding the wire at distance from the end that marks the excess requires for soldering.

10. Strip by making four cuts (top, bottom, left, right) by using a scalpel against pliers.

11. Pull the end of the wire off using pliers while holding the bottom of the wire with pliers: bend the stripped cable at 90degree compared to the non stripped part This technique ensures that no tension is exerted on the cable.

12. Heat the conductive circle of the pcb and Fill the input hole for the wire (on the PCB) with solder. You can first try to place wire in the hole but it may not stay, in which case just fill the hole with solder as above.

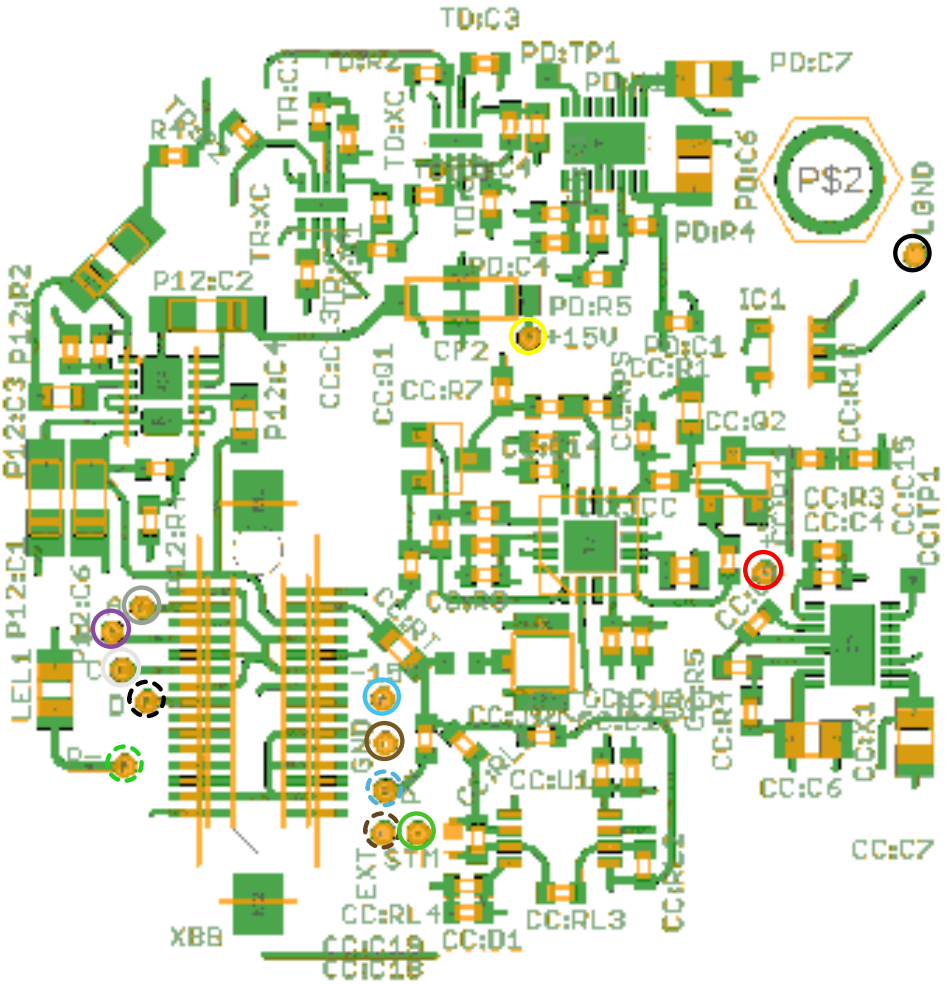
13. Use tweezers to manipulate the wire onto/into the hole and use the soldering iron to fix the cable in place.

14. Extra solder may be used to clean up the soldering to ensure all wires are soldered and not touching others (tresse).

15. Repeat through board, starting by the cable and working out in order 1-3

    N.B.: The orange (+LED), white and red wires are NOT used. There are two black and white cables. Check pin II (clear) with the cable ends for connections. Use a Multimeter (in 'Smart Ohm Shift' mode).

Soldering Connector cable (details and order)

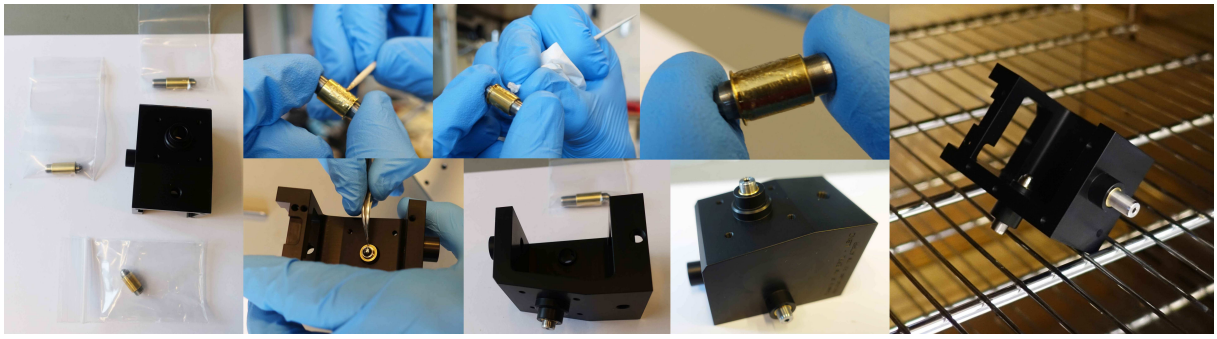


Wire colour	**Signal**	Pin
Black	Laser Ground LGND	1
Brown	Analog Ground GND	2
Red	Laser +5V	3
Orange	+LED (NOT USED)	4
Yellow	+15V	5
Green	STM	6
Blue	-15V	7
Violet	PD B	8
Gray	PD A	9
White	PD C	10
Black/White	PD D	11
Brown/White	Extra EXT	12
Red/White	(NOT USED)	13
Green/White	Piezo Ground P-	14
Blue/White	Piezo Drive P+	15
White/Black	NOT USED	-

2.8 Housing

Alignment and Focus Screws

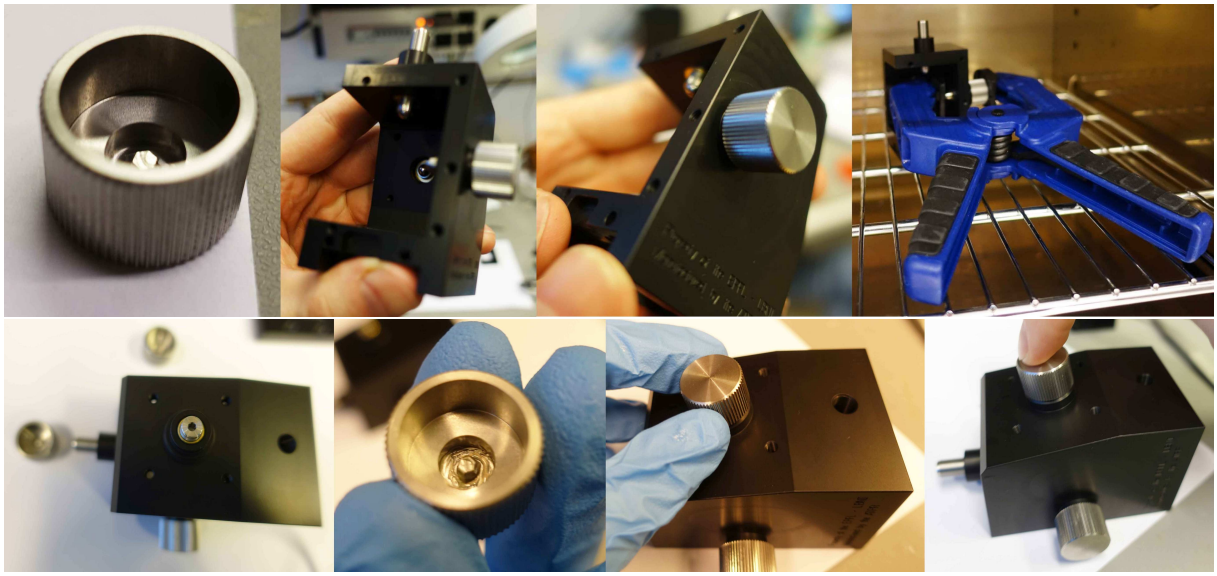
The purpose of this step is to fit precision screws (rounded end) to housing.



There are three lengths of screws: smallest screw (top of the housing), biggest screw (small side) and the remaining screw is inserted in to the back (largest side).

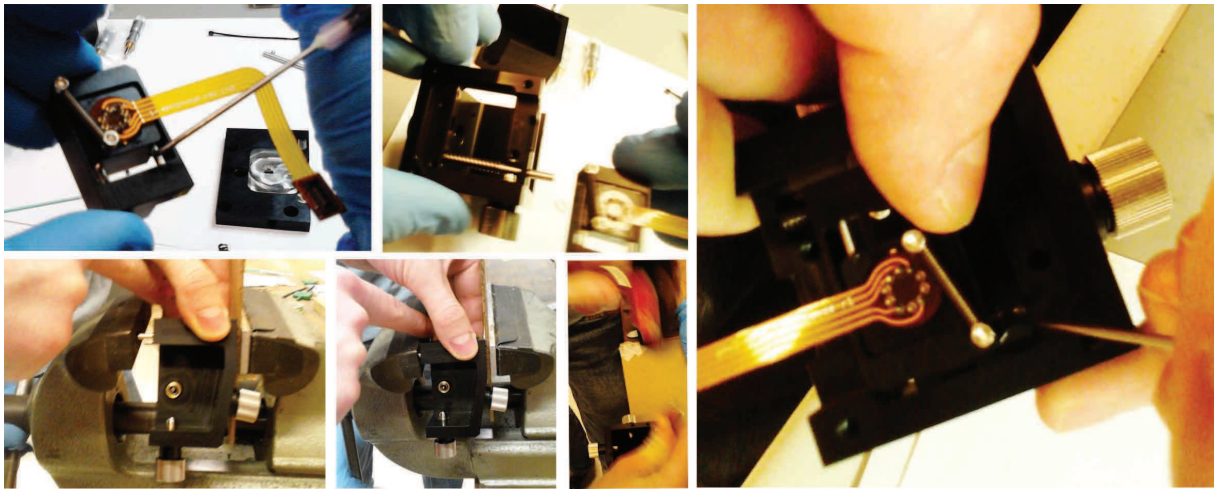
1. Put a small amount of epoxy around the screw bushing (golden part).
   Do not put epoxy on the thread, this will stop the thread from turning.
2. Spread the epoxy with a toothpick: if there is too much glue, remove with a tissue.
3. Slide the screws in from inside of housing, pushing against the end of the screw. The balls of the screws should be inside. The circular bigger step is the stopper inside. Insert the backward one and the side one always from inside. Remove unwanted traces of glue.
4. Clamp the screws if possible and cure in oven. As it may be difficult to clamp, place the head in the oven so that gravity pushes the screws downward.

Housing Alignment Screw Caps



1. Glue central area of the screw caps with a thin layer and insert onto matching hex at the end of the screw - do this one at a time so that you can clamp and cure in oven.

Placing the photodiode assembly in the head housing



1. Place greased rods through the photodiode assembly into main housing: the rod without spring goes first.
2. Load spring-loaded rod onto the left hand side. This requires manipulation to get the placement correct.
3. The rods will stick out (press fit) therefore place into a vice and push slowly together.
4. Use hammer and punch to push the rods in the last few millimetres.

Photodiode Micrometre screws

1. Screw the micrometre screws (which will control the photodiode assembly) in to the top and side.
2. Vary the position until the photodiode surface is aligned in the plane of the micrometre screw.
3. Lock in place with the locking nut.

Optics blocks fixation

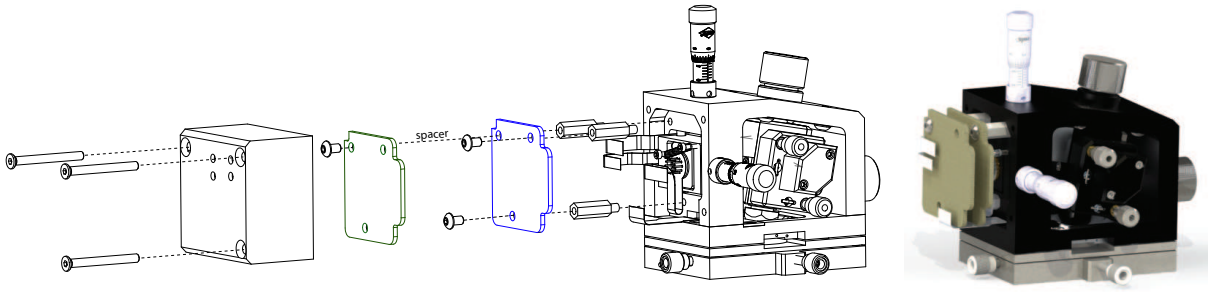
1. Screw the flexure inside the main housing using three M3 long screws and one short lentil head screw.
2. Insert the three screws loosely
3. Use long allen key to screw in short screw
4. Tighten all screws to hold optics block in place.

Attach Base plate to Head

1. Use five M3×10 countersunk screws to attach base plate to top part of head.

Boards onto Assembly

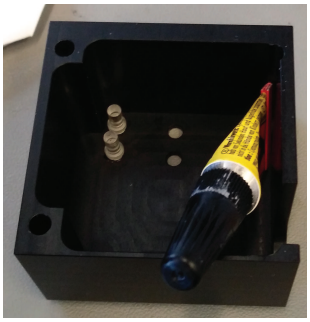
1. Use 3 standoffs of length 14mm for the boards.



2. Fold in photodiode flex twice at 90deg.
3. Clip readout board onto photodiode, ensure photodiode flex can fold correctly (twice at 180°).
4. Place readout board (blue) in place and screw in two of the three positions with 2 × M3 short screws.
5. Connect drive board (green) on top of readout board and screw in place with the last screw and a cylindrical spacer in between the boards.
6. Plug the three flex PCBs on the drive board making sure not to cross the readout and the drive.

LED, Buttons and Electronics Housing

1. Glue in light pipes in electronic housing. Push in to slots, using superglue from the back to hold in them in place. The long part is inside.
2. Insert the buttons in the center in the electronics housing.
3. Push board housing and screw with M3×30 countersunck screws.



Chapter 3

Testing

3.1 Cable Board: Drive Laser

Check nothing has shorted.

1. There are two ways to check that the drive board is working. Plug the cable in a Multimode base OR apply +15V and +5V to the relevant pins.

2. Check the connections when piezo/photothermal button - top one - is depressed (LED changes: green/orange).

3. Check when readout laser on/off button is depressed (LED changes: green/red).

4. Plug in readout board and check current. If there is a problem of dropping current : it can be that a capacitor was put the wrong way around (tantalum one: CBP10-CBP9 for ex).

5. Connect the two board. Use 2 power supply: Check +14V/-14V. The current should be stable.

6. On the drive board - PD:R1-PD:R2 (power drive laser): these two resistors should be adapted. If the ones already there are not adapted, rip them off and replace by only one 10kΩ resistor. There resistors are in serial, so it is ok to replace by one.

7. Laser check on the drive PCB. The current for the laser may be too low: the boards have a current limit so the multimode doesn't burn. But the modulator draws the current from the same board. If so, replace PD:R3 resistor by 8.5-9kΩ resistor instead of 15kω. This will give a current of 33mA

8. Measure the power of the drive laser with a powermeter: it should be between 0.5mW-3mW, not to burn the sample. It is better to have 1-1.5mW. For example, to drop from 2.2mW to 1mW, double the resistor (PDR1).

3.2 Adjusting the lasers on the head

Readout Laser Alignment

The bottom Led on the side of the head should be green. The screws with cap in the horizontal plane of the head move the optics block in the plane of the cantilever.

The top screw changes finely the focus. For any change of cantilever type or lens, the rough focus can be adjusted by turning the objective lens at the bottom of the optics block, using the laser cut key, or by screwing by hand with optical paper and/or gloves the lens holder, after having removed the cantilever holder.

1. Use the horizontal screws to find the shadow of the cantilever. Adjust the laser spot to the end of the cantilever. The cantilever direction is from left (chip) to right (tip)

2. Once the cantilever has been found, adjust the fine focus so that the shadows of the end of the cantilever disappears very quickly with a small movement of the spot perpendicularly to the cantilever length.
   Other way to check; unfocusing a bit more leads to see a reversed projected cantilever shadow.

Photothermal excitation: Drive Laser Alignment

The readout laser should be align before adjusting the drive laser.

3. Turn off the readout laser by pressing the bottom button on the side of the head (the led turns red). Use the 2 front micrometric screws, sticking out of the optics blocks to move the drive laser spot on the cantilever: you should see the shadow of the cantilever.

4. Go back to the adjustment of the readout laser by powering it up with the button (+ drive) and look for the end of the cantilever.
   The two lasers positions are linked inside the optics block. Moving the readout moves the drive.

5. Send an excitation to the ANA1/Tapping channel of the head. The top button of the head should be green to send the excitation to the drive laser and not to the dither piezo)

6. Try to maximise the amplitude of the oscillations on the vertical deflection with the drive laser screws in the front. You may want to monitor your vertical deflection through an oscilloscope.

Chapter 4

Issues encountered

- **Bent cantilever holder (titanium)** Rebend the cantilever holder to compensate for this.

- **Bent drum underneath the piezo** Placed too much stress on piezo when tightening the piezo clamp. May also be too much glue under the piezo. Do not overtighten the piezo clamp. You can see this by piezo drum bending up – cantilever will not fit in cantilever holder. Try unscrewing the piezo clamp too.

- **Laser power too high** Change resistor on laser setpoint circuit. We had 2.2mW power using a 13K resistor, changed the resistor to 20K to reduce the power by a factor of 1.5.

- **No sum** Reverse bias pin trace has come off flex. Could have been poor soldering, could have been caused by screw failure on photodiode. Remove polymeric mask and solder stub from the end of the flex trace. Strip back to bare copper. Strip very thin single-core wire. Place between solder and trace on flex. Solder in place and trim excess. Check connection on the voltage reference chip. Re-attach boards.

- **Constant power readout circuit** Constant power circuit. Resistors determine the setpoint by working out the constant power to the circuit. Monitor diode converts. Small, high frequency components but with low voltage ratings. Compromise between the two to ensure average and peak voltage flow (dimension from that).

- **Drive laser is constant current** Much faster – no need to convert current to power and feedback on it. Resistors (13kOhm) change to 24kOhm. Sum is now 6.8V on FSA with long focal length lens. Noise is 10 fm2/Hz.

- **Check modulation (GHz scope)** Readout (530 MHz) sampling at 5GHz (prevents mode hopping). Drive at 500 MHz

- **Check piezo drive** Tapping mode in air. Sum 6.7V with FSA. Sense 42 nm/V. f = 1.63 (tuning in air). If the piezo drive works then epoxy the piezo in place. Epoxy around the piezo (not too much). It may be wise to use rapid dry epoxy to ensure that the movement is not too damped. Tighten the clamp, removing epoxy as you tighten, wiping away any excess with a toothpick. Fully tighten clamp BUT DO NOT overtighten. Cure.

- **Checking the assembly** Photothermal alignment is difficult as flex (drive) is pulling the optical assembly. Take base plate off to check (unplug the flex cable first).

- **Our baseplate flex cable (flex holder) was loose** Try tightening. Counter sink isn't deep enough. Adrian increased counter sink by 0.5 mm and re-screwed the base plate in (the fluid cell should be springy)

- **To operate in fluid...** Place sample disc on scanner. Sample should be flush with the top of the translation stage. Place water on sample. Take green gauge syringe and inject into volume to make a large bubble (through the fluid inlet). Refocus by moving the lens up, screwing in by half a turn (using the lens wrench). Check when z-focus is fully retracted that the cantilever is moving in correct way. Screw in to max z-focus so that the cantilever fully covers the spot. Check with sum 6V. Zero offsets. Ready to image. Remove cantilever holder using 'green' allen key Insert correct lens for optics (long = recessed lens, air = 1 line, water = 2 lines)

Chapter 5

Conclusion

For any question, please contact: georg.fantner@epfl.ch