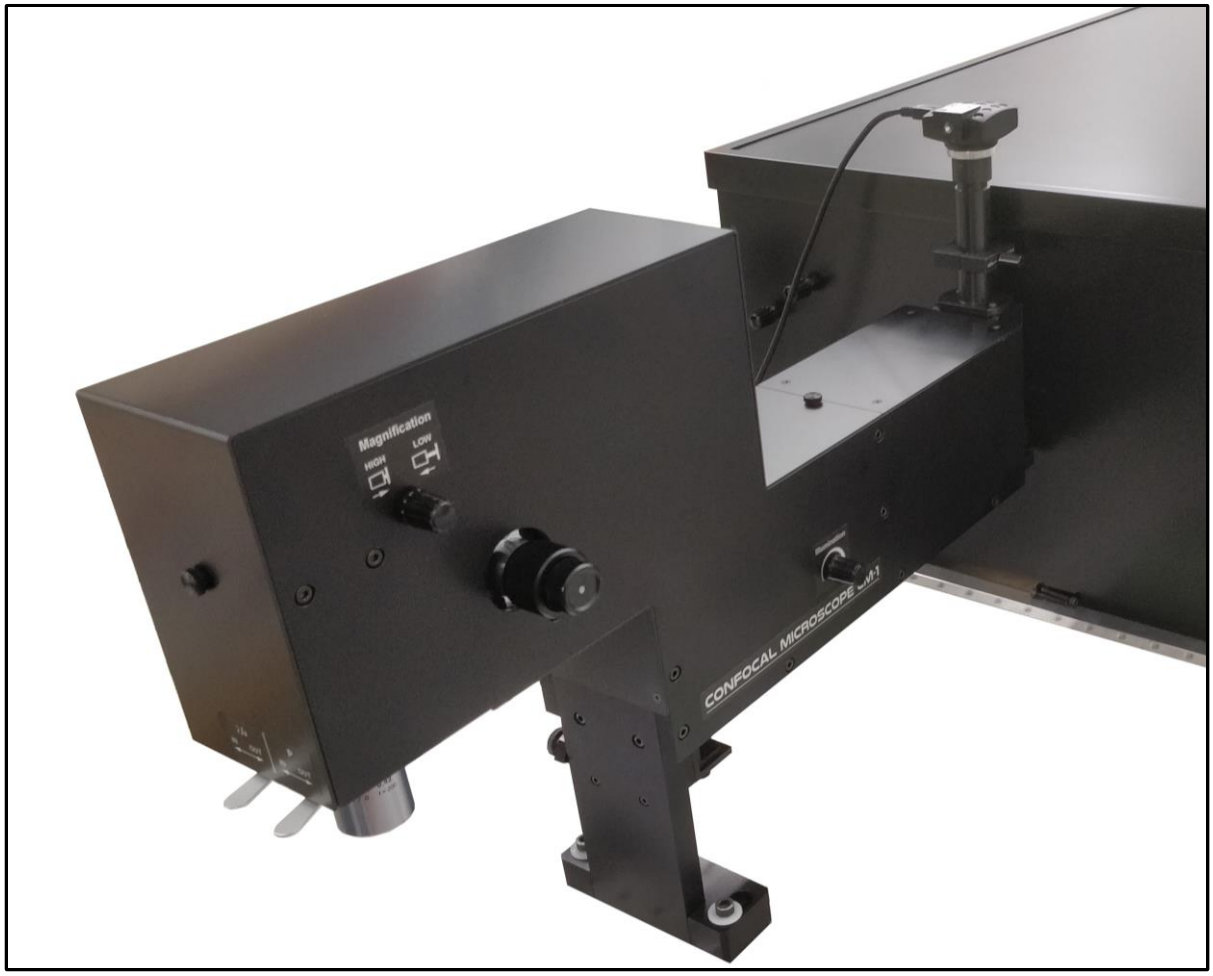
CONFOCAL MICROSCOPE CM-1

USER INSTRUCTIONS



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1. Properties of Confocal Microscope

- Built for a quick and easy installation and operation with Tablestable TFP Fabry-Peròt spectrometers. Easily removable, maintenance free.
- Selectable for depolarised, polarised and unpolarised scattering measurements without any change in the internal optical path.
- Large reach (130 mm) and height of the optical working plane (147 mm minimum).
- Provided with a very long working distance (20 mm) apochromatic objective, having a numerical aperture of 0.42 NA and providing a resolution better than 1 μm.
- Image of the sample available through a special version of the TFP viewer camera. A rotatable OD6 notch filter installed inside the camera tube to allow optimal vision of the sample surface when a laser spot is focused on it (standard filter provided at λ = 532nm).
- Coaxial white LED light illuminator with illumination intensity control.
- Slide-in ND3 filter at device entrance for microscope alignment and beam power reduction.
- The laser beam is expanded so as to fill the aperture of the objective provided and can be focussed independently of the sample.
- Auxiliary input/output port: the collimated beam from the sample can be optionally extracted from the microscope, or an external beam can be directed to the spectrometer without removing the microscope.
- Provision of a slide-in zoom optic to reduce the magnification by a factor 4.
- Smallest standard pinhole of 70 μm corresponds to about 4.7 μm on the sample. Smaller pinholes available on request.
- By placing a mirror under the objective, the laser beam can be redirected into the interferometer for alignment purposes.
- Ideal for use with diamond anvil cells.

Accessories provided with the instrument

- 2 M4x40 screws with special spacers
- 1 mounted corner cube retroreflector
- 1 power supply adaptor (7.5 V, 0.8A)
- 1 DC supply extension cable
- Spare LED illuminator lamps

2. Description of the optics

A scheme of the internal microscope optics is shown in Fig. 1.

The laser beam is introduced into the microscope at a height of 100 mm. The incident laser is expanded by a factor of 4 by means of a pair of lenses whose distance can be adjusted to compensate for any divergence in the laser beam.

The beam is coupled into the microscope using a polarising beam splitter cube, which is also used to send the scattered light to the output. Without additional polarising components therefore mainly depolarised scattered light will be observed (spin-wave scattering for example). A couple of mirrors is used to ensure correct angle and positioning on the focussing objective. A quarter wave plate and a polariser can be switched into the beam path. A beam splitter placed immediately before the objective is used to coaxially merge the laser light beam with the light necessary to illuminate the sample surface. The white light for illumination is produced by an LED source.

The objective provided with the microscope is an apochromatic long working distance (20 mm) 20x bright field objective. The objective is used to focus the collimated laser beam on the sample, as well as for illuminating the surface around the focus point.

Using only the quarter wave plate, scattering from isotropic media can be observed without loss of signal due to the beam splitter. With both quarter wave and polariser, polarised scattering from general media can be observed, but with an efficiency of only 25% due to the losses in the beam splitter and polariser.

In order to match the output optimally to the interferometer the primary output beam must fill an aperture of f/18. As shown in Fig. 1, this is achieved by the 150 mm focal length lens, given the internal beam diameter limited at about 8 mm. Using the objective provided, which has a focal length of 10 mm (approx. f/1.2), the microscope reaches a magnification of 15.

The optics block, upper left, in Fig. 1, shows the additional switchable optics in place for reduced magnification. When coupled to the f/18 entrance aperture of the interferometer, this reduces the used beam diameter from the objective to just 2 mm (f/4.8) and the magnification to x3.75 (with the objective provided).

The microscope can be used with any mechanically compatible infinity-corrected objective (microscope objective thread is M26, 36TPI).

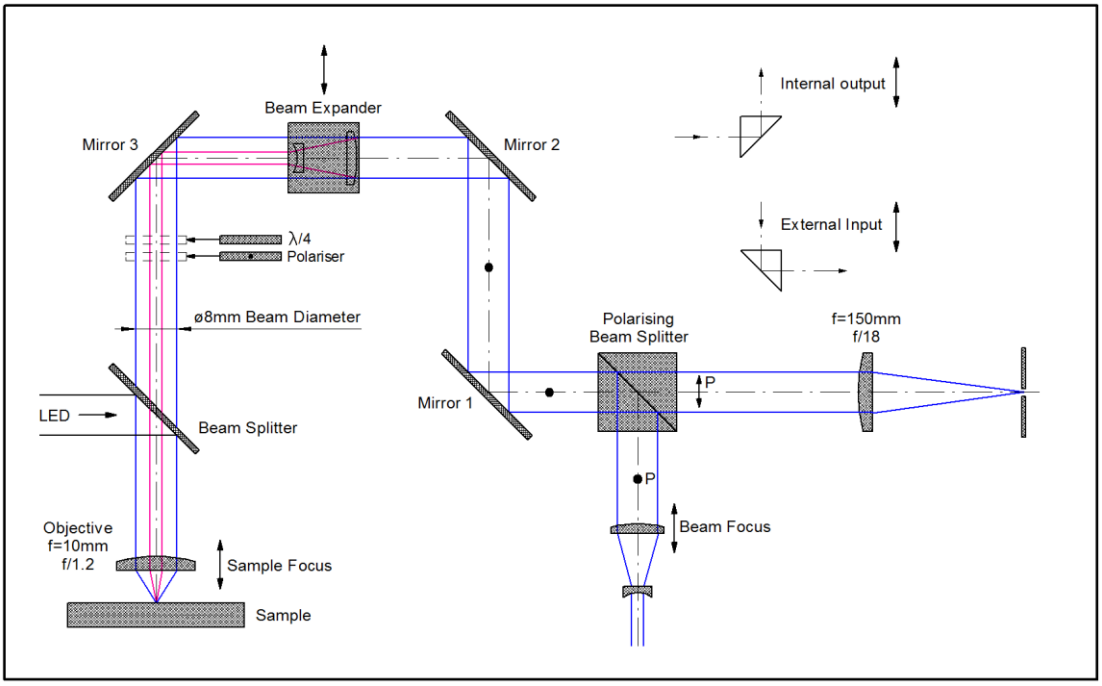

Fig. 1 : Optical scheme of the device

3. Device controls and parts

The following figures show the controls on the instrument and the main parts.

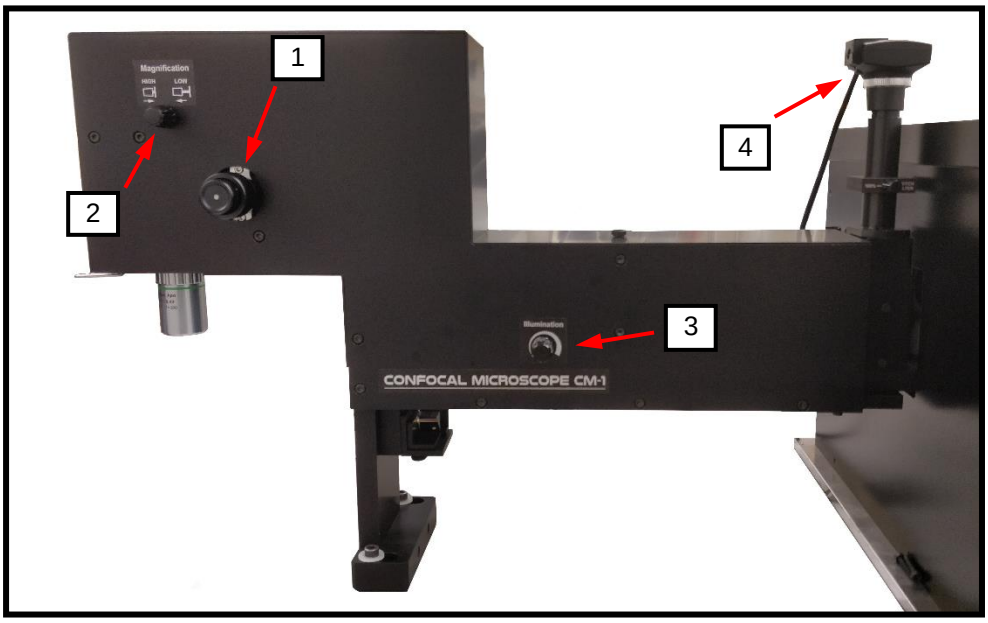

Fig. 2 : Front side parts and controls

1: coarse and fine adjustment knobs for objective focus
2: magnification knob - push for high magnification, pull for low magnification
3: illumination control knob
4: microscope camera

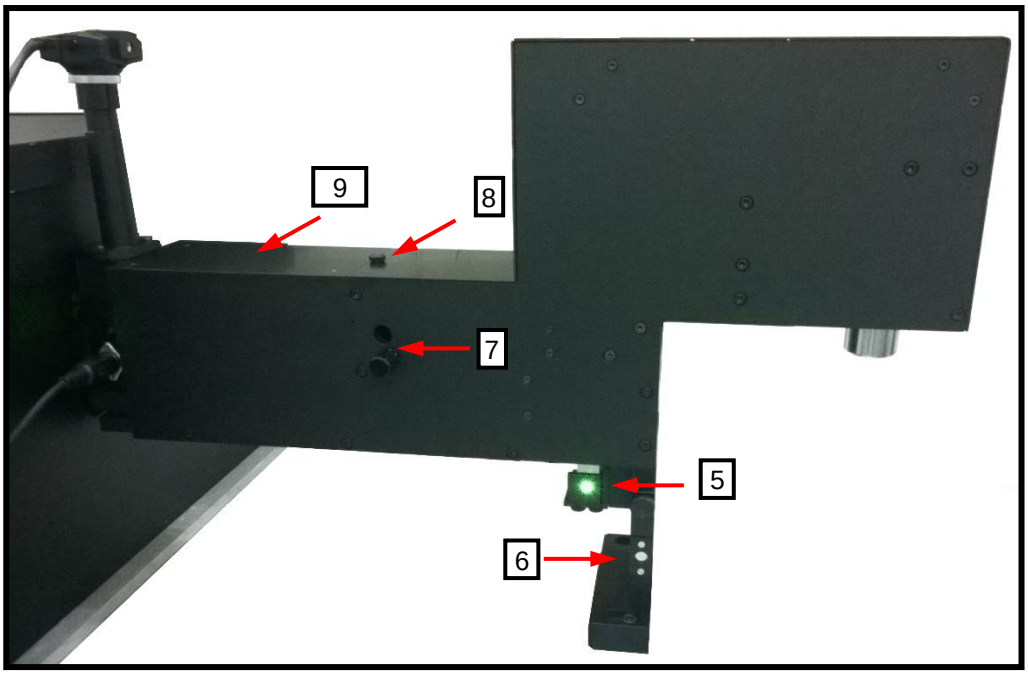

Fig. 3 : Back side parts and controls

5: light input aperture
6: slide-in input neutral density filter (OD3) and reference alignment surface
7: secondary beam input/output port. When used as an output, the out coming beam will be collimated, with a maximal diameter of about 8 mm. Since this beam exits before the pinhole, this is no longer confocal. When used as an input, the beam must be carefully aligned to hit properly the spectrometer input pinhole.
8: securing screw for the top panel
9: secondary top lid

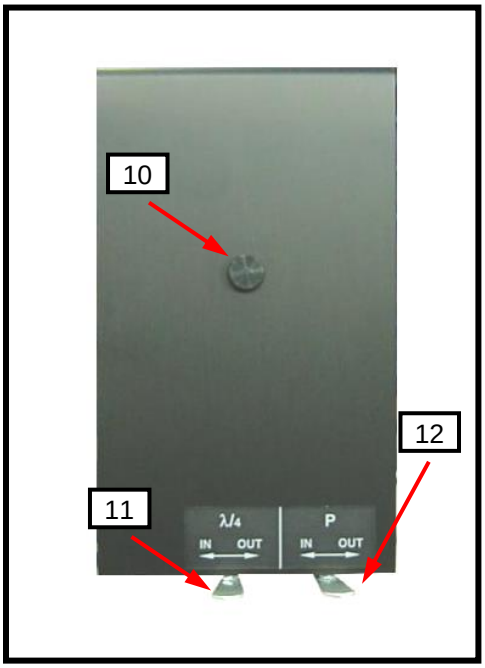

Fig. 4 : Controls and parts on the left side of the device

10: securing screw for the top panel
11: λ/4 retarder selector. When in the OUT position microscope will select depolarized scattering from the sample; in the IN position, microscope will measure all scattering from the sample.
12: slide-in polariser selector. The IN position can only be used in conjunction with the λ/4 retarder, to reject depolarized scattering signal.

4. Attaching and removing the microscope

4.1. Microscope installation

To install the microscope to the interferometer, it is necessary to remove the secondary top lid (Fig. 3, n.9). The lid is removed by pulling gently upwards.

The right (output) end of the microscope has two holes at the bottom. These holes are used for fixing it to the interferometer, using the two screws that hold the input pinhole turret to the interferometer internal optical plate. These screws are M4 threaded and 25 mm long. See Fig. 5 for information on the location of these.
At first, slide the microscope carefully into position so that the two holes fall over the heads of the original two screws (don't remove these yet!). Attach the foot of the microscope by means of the M6 screws loosely to the table, to prevent it from falling during the following procedure.

Looking from the top of the instrument, you should see what is also depicted in Fig. 6. The arrow in Fig. 6 indicates a reference 10 mm block that is useful microscope positioning. If the microscope is fixed while maintaining contact between the reference block and the left side of the turret base, the horizontal position of the instrument will be more reproducible and the alignment will require less adjustments every time the device is removed and installed again. While fixing the device, be as careful as possible to obtain an orthogonal orientation with respect to the input pinhole.

The microscope must be attached to the interferometer **without changing the position of the input pinhole turret**. In order to obtain this, remove **just one** of the M4 screws and replace it with the M4 x 40 screw and spacer provided with the microscope. **Tighten** this screw and **then** replace the second screw in the same manner. Finally tighten the M6 screw on the microscope foot. Store the original interferometer screws in a safe place.

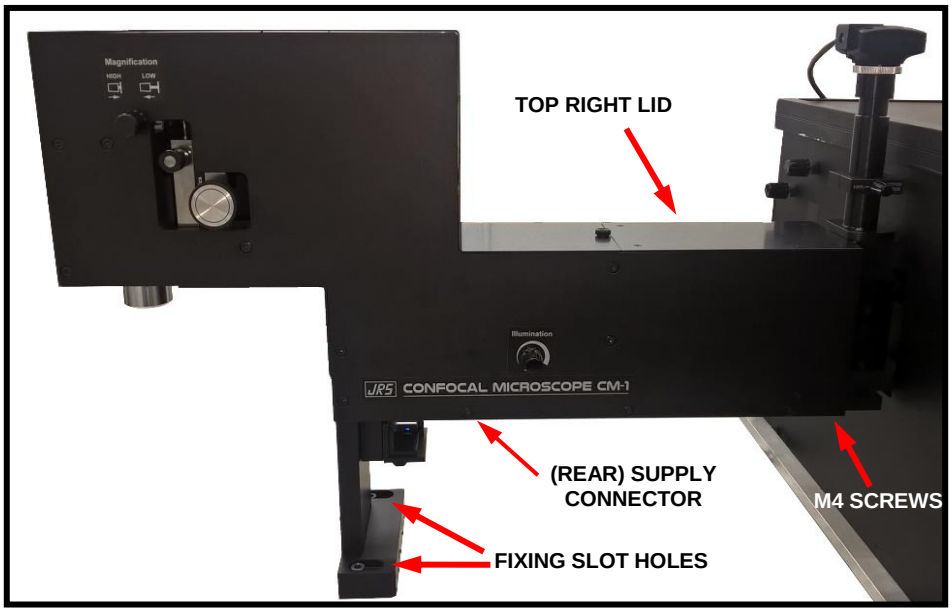

Fig. 5 : Fixing elements for the microscope

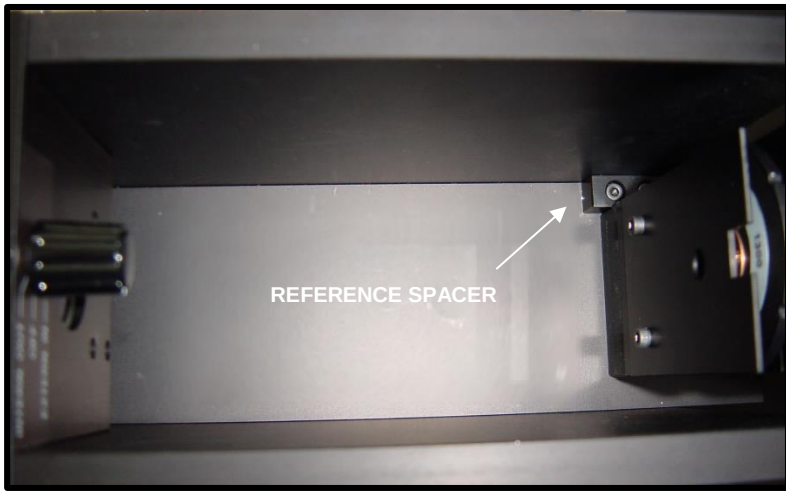

Fig. 6 : output section of the microscope attached to the interferometer input turret

Connect the cable provided for the LED co-axial illumination to the socket on the rear side of the microscope (see Fig. 5) and connect the power supply. A barrel plug extension cable is provided for your convenience. The LED illumination intensity can be set using the front panel knob.

The microscope can be optically aligned following the instructions in the following chapter 5. The first series of adjustments should be performed before mounting the objective lens.

The microscopic objective lens is eventually attached by screwing to the holder from underneath the microscope until it stops in position. When the objective lens threading is too dry, the motion will not be smooth and it could be difficult to correctly engage; in such a case, apply a tiny quantity of grease on the microscope objective threading. **The presence of a thin grease layer on such fine threading is fundamental to prevent damage and to reduce wearing, particularly if the microscope objective is frequently removed.**

4.2 Removing the microscope from the interferometer

In order to remove the microscope from the interferometer, you can exactly reverse the installation procedure described above. Again, pay particular attention to the replacement of the input turret screws: remove only a screw at a time, while keeping the other one tightened.
Store the microscope M4x40 screws and special washers in a safe place. It is better to remove the objective lens and keep it in its original plastic container to prevent any damage. In order to preserve the quality of the microscope objective threading, it is beneficial to ensure that the threading in the plastic container is not too dry, especially if the lens needs to be stored for a long time. If necessary, a tiny quantity of grease can be applied before storing the microscope objective.

5. Optical alignment

It is necessary to check the alignment of the instrument every time the microscope is removed and installed again, or if a change in the external optics on the input beam has been made. The first set of operations must be performed without the objective lens.

During the microscope alignment sequences here described, a relatively large intensity of laser light will be sent to the interferometer in order to optimise the microscope alignment. **Keep the interferometer detector off, and preferably close the output pinhole in order to prevent any damage.**

Select the largest input pinhole on the interferometer input pinhole turret and ensure the TFP input shutter is off and the interferometer control unit powered on. Remove the secondary top panel of the microscope in order to access the input pinhole wheel. Remove also the larger cover of the microscope by undoing the two knurled M3 screws that hold it in position (no. 8 in Fig. 3 and no. 10 in Fig. 4).
Select the position of higher (normal) magnification by using the selection knob (Fig. 2, no. 2).
To perform this alignment procedure, an unmounted mirror, one 1.5 mm Allen wrench, one 2.5 mm and a non-transparent flat test surface will be also needed. An input power of 10 mW or higher is needed before the input aperture for the execution of the alignment procedure. Some of the procedures here shown require that a piece of paper is placed in the beam: if the beam image on the paper is too bright, reduce the power until it is visible but still comfortable to the eyes.

Whenever the microscope is used it is important to check that the laser beam is correctly aligned.

5.1. Alignment of the input beam

In order to achieve a repeatable optical alignment, the incoming laser beam must be centred to the entrance aperture on the side of the microscope (Fig. 3, no. 6) and directed orthogonal to the OD3 input filter (Fig. 3, no. 5). The input filter mount can be rotated to have the filter in front of the input aperture.
The height of the input aperture is 100 mm, its diameter is slightly less than 3 mm. The input filter can be used to reduce the power on the sample, and at the same time is used to provide a reference reflective surface for alignment. Do not use other surfaces as reference for the device alignment.

The input beam should be adjusted so that the reflection from the filter surface falls back on the incoming beam. With successive adjustments of the laser beam make sure that it hits the centre of the aperture (filter off from the beam) and that the reflection correctly falls back on itself (filter in place).

A final check of the alignment can be done by looking at the spot of light on the first lens inside the microscope. The lens is visible from the top, looking under the main cube beam splitter. The input intensity should look as centred as possible in the lens. If it is not, apply a further small change to the alignment of the input beam to make it so.

5.2. Alignment of the main polarising cube to the input

You will be able to see an expanded laser beam running vertically towards the two upper mirrors in the device. It will then exit vertically downwards at left, where the objective will be eventually placed. Make sure that both the λ/4 and the polariser are in the OUT position.
Place the provided corner cube reflector on the optical bench under the laser beam, making sure the laser beam is reflected onto itself (i.e. the corner cube is centred). You can verify this condition by looking at the first surface of the corner cube and to the mirrors surfaces: the spots created by the forward and backward beams must coincide.
The corner cube has a retardation effect on the light, so that the backward travelling light will be also partially sent to the interferometer input pinhole. The corner cube will produce an hexagonally symmetric modulation of the intensity on the beam, which can also be used to understand if the corned cube is correctly centred.
Open the lid of the TFP, select tandem mode and use the largest input pinhole: if you put a sheet of paper immediately before the first Fabry-Peròt pair, you should see the same image with hexagonal symmetry (see Fig. 7).

Rotate the input pinhole wheel to reduce the pinhole size. If the alignment is good enough, the same image will be visible at all the pinhole sizes, even if at the smallest sizes it will be quite blurred and not so much bright.

It the alignment is not perfect the main polarising cube should be adjusted using the red and green knobs on its holder (shown in Fig. 10).
Correct using the cube positioner knobs to improve the image inside the TFP. Every time you adjust the tilts of the beam splitter cube, you will also change the position of incidence of the beam on the corner cube and you will need to move the latter to keep the centring condition. Do small

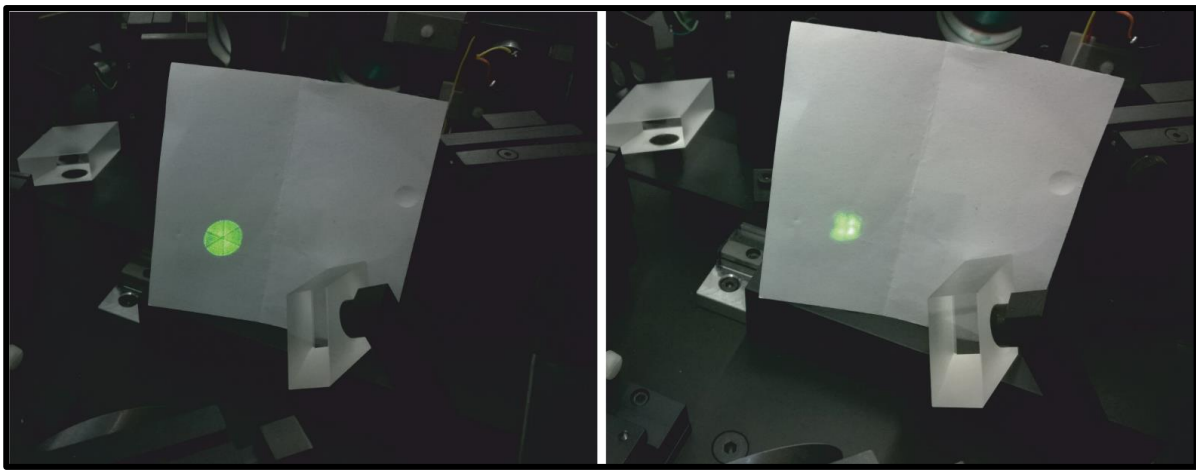

Fig. 7: Images of the microscope beam reflected by a corner cube, as seen inside the spectrometer. The image will look almost perfect when a large input pinhole is selected (left panel), while the quality will degrade at 70 μm pinhole size (right panel).

adjustments on the knobs until the best possible image of the cube signal is seen down to the smallest pinhole, or at least through the 150 μm pinhole. The central cube is now aligned.

5.3. Alignment of the beam on the objective aperture

Remove the corner cube and mount the microscope objective lens. The laser beam should pass through the lens and create a bright region on the optical workbench.
The beam hitting the objective lens must be parallel on its optical axis and centred on its input aperture; at this moment one or both of these conditions could not be still completely met. The angle and position of the beam can be modified using the tilt screws of the two upper mirrors (Fig. 8).

Use the 1.5 mm screwdriver on the adjustments of the **right** upper mirror to centre the beam on the objective input. This can better be judged if the white illumination is turned on.

Place a small unmounted mirror on the microscope illuminator, immediately over the objective lens holder. Use the λ/4 device in the beam (lever no. 11 in Fig. 4 to the left): this will allow the light reflected from the mirror to travel towards the input pinhole.

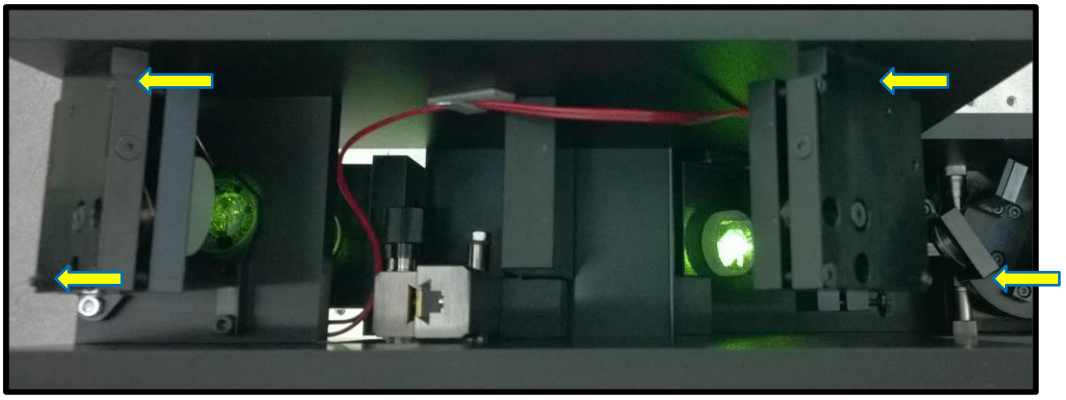

Fig. 8: adjustment screws of the top mirrors

Select an input pinhole large enough than the light can enter the instrument. Reduce progressively the input pinhole size and adjust the **left** upper mirror until you see light inside the interferometer even with the smallest one.

In order to check this condition, you can also prepare a piece of white paper of about 2x9 cm and make a hole at one end of it. Place this strip of paper just over the cube positioner, in such a way that the hole is near to the centre of the upgoing beam (see Fig. 9). When the reflection is well aligned, the light reflected from the mirror should appear as a bright spot on the top of the paper.

Iterate the right mirror adjustment (without the mirror) to center the beam and the left mirror adjustment (with mirror) until both the desired conditions are met.

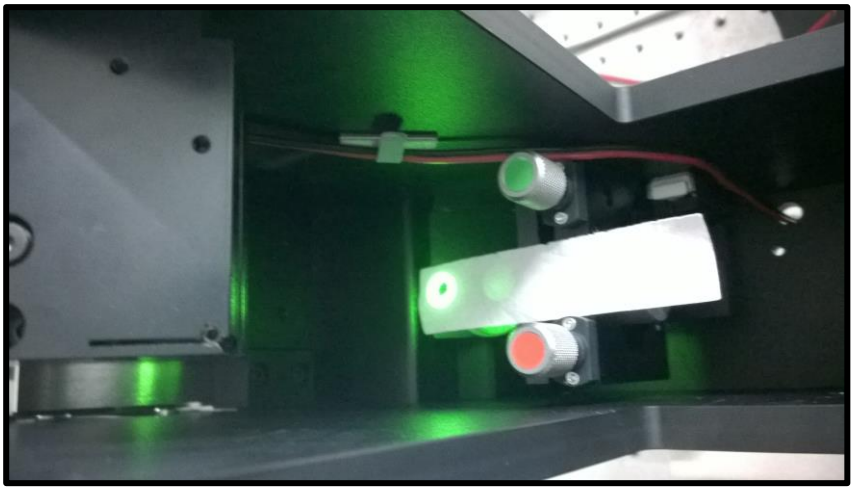

Fig. 9 : paper strip for alignment of the top mirrors

5.4. Fine centring of the focused output spot onto the pinhole

Place a test object under the microscope objective; the best subject is a flat, opaque and not very polished surface, whose image will be bright and easy to identify.

Move the objective using the focusing knobs (Fig. 2, no. 1) in order to have the focus close to the surface. Switch on the illumination power supply and ensure that an illuminated white spot is visible as well on the surface. Switch the TFP input pinhole to the largest size.
Switch on the pinhole camera viewer software. The pinhole area should be visible through the camera. If the pinhole area is not centred on the camera sensor, refer to the pinhole camera manual for additional instructions.
Looking at the image of the pinhole, change the focus until the sample surface image is visible. Adjust the image parameters and the illumination power if necessary.
If the laser power is saturating the camera and the full pinhole seems white, use the notch filter knob[1] (section 6.1 of this manual) to reduce the intensity.
You should be able to obtain a surface image in focus, with a small spot of light indicating the position of the laser beam.

By moving the focus, it should be possible to understand if the best focus position for the laser beam (smallest green spot) coincides with the best focus on the surface. If this does not happen follow the instructions in section 5.5.

By progressively reducing the input pinhole size, you will be able to evaluate if the input beam is centred on the interferometer input, with reference to the smallest pinhole area. If the previous steps were properly done, the light should be already passing through it, but you may want to apply a further correction for a fine centring. If this is the case, use again the two knobs for the cube, which will require only a very small correction. If you want to do things really well, you should then unmount the microscope objective and repeat the alignment procedure of the top mirrors: they will need very small corrections to compensate the change in the cube tilt.

[1] If the notch filter is not available , reduce the laser beam intensity before the microscope input by means of a filter as necessary

5.5. Adjustment of laser beam focus

The laser beam can be focussed independently of the microscope focus by means of the M3 screw shown in Fig. 10 (focus). In order to access the regulation screw, the upper screen must be removed.
The focus adjustment would normally be a one-time adjustment: rotate the screw by means of the 2.5 mm hex screwdriver in either direction to get the smallest laser light spot possible on the surface of a test sample, while maintaining the surface in focus.

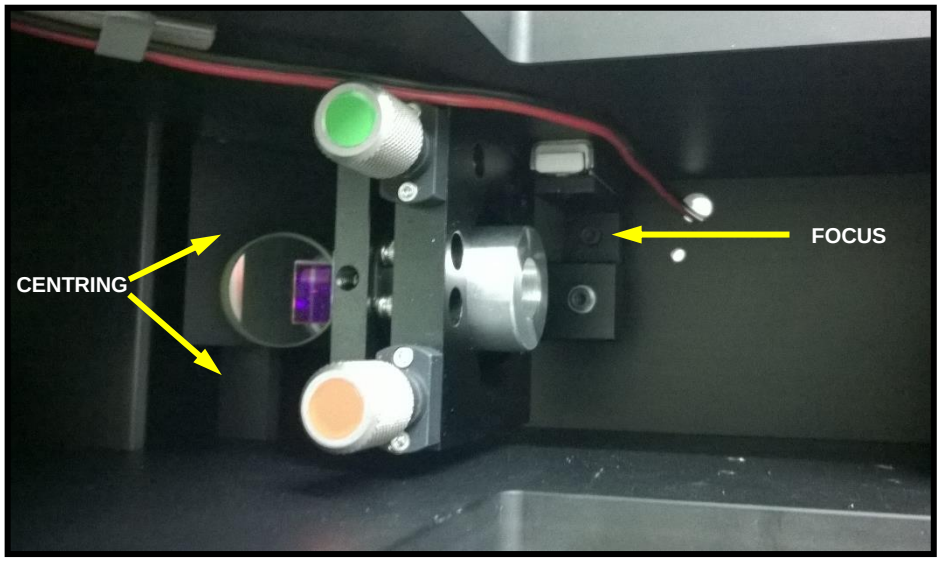

Fig. 10 : Top view of the instrument, internal adjustments for focus and beam positioning

5.6. Adjustment of light centring at low magnification

The microscope is now fully adjusted with the magnification reduction group out of the way (high magnification position, lever no.2 in Fig. 2 pushed towards the microscope surface). As a last step, it is possible to check and correct the alignment of the demagnification group. This group is intended to provide a glance of a larger region around the target position, and should not be used for measurements.
In order to check the group adjustment, switch the instrument to the low magnification position and look at the image of the sample on the camera. You should be able to see still a reasonably well focussed image, and the apparent position of the laser spot should be the same at both magnifications.
If the position differs between the two magnifications, adjust the position of the right lens of the zoom optics using the two small grub screws on the right end, to match the position to the one seen with the stronger magnification.

The microscope should now be ready to use. Once the device is aligned to a particular interferometer, it is expected that the condition is mostly preserved even when the microscope appendix is removed and then installed again.

Do not be tempted to make any other adjustments to the microscope!

5.6 Switchable auxiliary input/output beam port

The switchable input/output port assembly is shown in Fig. 11. The assembly can be rotated among 3 fixed positions.
The normal use position is the central one, when none of the two prisms intercepts the laser beam path.
In the other two positions, the laser beam will be either sent out of the instrument (INTERNAL OUT) or an external beam will be sent to microscope final lens and to the spectrometer (EXTERNAL IN position).
In both cases, a collimated beam not larger than 8 mm in diameter will be sent out or accepted in the microscope.
When the prism assembly is used in the EXTERNAL OUT position, the user should adjust the incoming external beam to have the focussed beam centred to the interferometer input pinhole, and orthogonally incident to the pinhole plane.

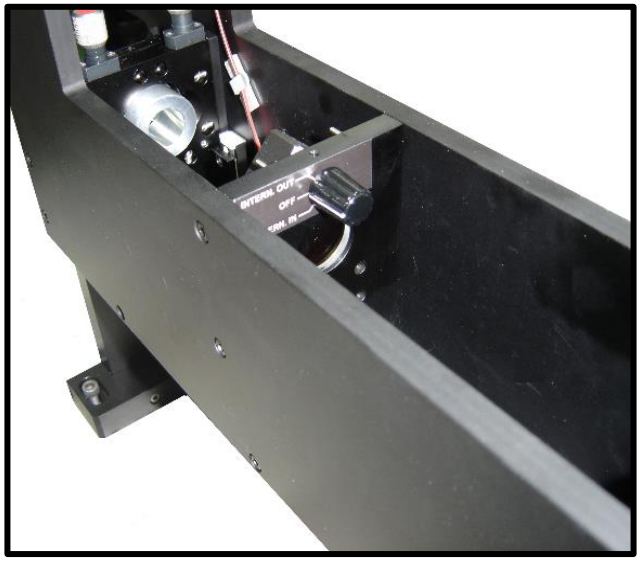

Fig. 11 : input/output prisms assembly

5.7 Troubleshooting: how to find the beam on the sample surface during alignment

In case the laser beam position on the sample surface cannot be seen by means of the camera, we suggest the following:

- Change the position of the notch filter to reduce the extinction of the beam.
- The camera viewer software provides several parameters to control the image. Among those the frame rate, sampling time and gain setting are the most important ones in order to get a good visibility of the sample. Try to optimise the parameters to emphasize the green light signal.
- The power could be too low. Try increasing the incoming power or eventually taking out the notch filter. In this second case, when you need to see the laser spot, you may need to add neutral density filters before the microscope input aperture to avoid camera sensor saturation.
- Verify that the beam is actually passing through the pinhole. By keeping the interferometer control unit switched on, detector off and shutter off, create a strong reflected light signal by focussing the objective on a mirror and using the $\lambda/4$ wave plate and open the lid of the interferometer. The light should be visible in the internal measurement before the first FP cavity. If nothing is visible, the microscope could be far from the operating conditions, and we suggest to check again the alignment from the beginning.
- If the previous check is successful but the camera is not evidencing the laser spot, then the laser beam could be still far from a correct focus condition when the sample is properly focussed. When the sample surface is in focus, the beam inside the spectrometer should reach the largest diameter.

6. Further notes for operation of the microscope after installation

6.1. Rotating notch filter usage

The CMOS sensor in the USB camera viewer is very sensitive and requires just a small amount of light to work properly. On the other hand, due to the small efficiency of the Brillouin phenomenon, the laser intensity needed to obtain a reasonable signal through the interferometer is comparatively enormous, and will easily saturate the sensor. This makes it in turn impossible to see the laser spot on the sample surface together with the wideband illumination under operating conditions.

Fig. 12 : camera viewer and rotatable notch filter knob

It is indeed possible to place neutral density filters before the microscope input, so that the laser power falls into an acceptable intensity for the sensor: usually an optical density between 4 and 6 will be needed. The CM-1 allows the user to do this by means of the input slide-in filter mount (element 6 in Fig. 3)
Microscope alignment can be checked this way, but assuming that the filter will be removed to perform measurements, the sample image will be not available during these.

The solution that was adopted in the case of this microscope is to install an OD6 notch filter inside the camera tube. This filter effect is controlled by rotating the knob on the front part of the camera tube. In the normal position (orthogonal to the internal beam) the filter will attenuate selectively the 532 nm laser light and allow, under most conditions, the position of the laser spot to be seen on the surface even during a Brillouin measurement.
When operating with low laser power or when in need of seeing very low laser power through the camera (i.e. when aligning the reference beam through the pinhole viewer) the notch filter attenuation can be reduced by rotating using the control knob. The effective optical density of the filter will decrease quickly when rotating the filter out of position, until the filter will be completely inefficient. The angular dependence can thus be used to tune the notch optical density. The normal (orthogonal) position of the filter is marked by the white line on the control knob, which should point to left for maximal laser light suppression.

6.2. Alternative beam splitter cube in the TFP input assembly

In the original design of the TFP spectrometers, a slide-in mirror is mounted inside the input pinhole turret, so that the light entering the instrument can be diverted to the camera when necessary. If this is done, the TFP does not receive any light (either from the reference or from the sample): this implies that the FP mirror stabilisation cannot work and that Brillouin measurements are impossible. In the normal case, the slide-in mirror is used only when adjusting the reference light beam splitter or when checking input alignment, so these limitations are irrelevant.

Using the CM-1, the camera is expected to be in use for long time and a continuous observation of the sample may be important or necessary, so the use of the slide-in mirror can be a relevant constraint.
For this reason, as an alternative for users of the CM-1 microscope, a tiny polarising beam splitter cube is provided and can be installed inside the pinhole turret, in such a way that only the horizontally polarised light passing through the pinhole is sent towards the camera. This is never a problem when using the CM-1 appendix, since the signal coming from the sample is always sent to the spectrometer with vertical polarisation.
The only drawback of this solution is that the image brightness obtained by means of the beam splitter is much lower than the one obtainable by means of the slide-in mirror.

When the CM-1 is removed from the spectrometer, the optional beam splitter cube can be left in the input assembly. The TFP-2 HC is polarization selective and only analyses vertically polarised light, so the presence of the optional beam splitter does not limit its measurement capabilities. Owners of a TFP-1 spectrometer should instead consider that their spectrometer is normally able to detect also horizontally polarised signal, and that if the optional beam splitter is in place, this would not be possible anymore. In case the experimental situation requires the observation of horizontally polarised light at input, the optional cube beam splitter must be removed.

Instruction for installation of the cube beam splitter are contained in the notch-camera manual. **Whenever the cube beam splitter is installed or removed from the input turret, the focus of the input lens L1 must be adjusted.**

6.3. Post-installation checks and adjustments on the spectrometer

Once the CM-1 appendix is installed and aligned or removed, if the TFP performance does not look optimal, some checks could be performed on the spectrometer. We suggest to try one or more of the following operations:

- Reference beam splitter check: check that the reference beam splitter is correctly aligned. Instructions about this operation are available in the pinhole camera manual and/or in the TFP operator manual.
- Output optimisation of the TFP: this can be normally done by means of the procedure at section 5.4 in the most recent version of the TFP-1 and TFP-2 HC manual, which is also a standard optimisation procedure for the instrument.
- Input check: the light coming out from the microscope should hit the FP1 cavity orthogonally. Work with detector off, shutter off and output pinhole closed.
    - Select the largest input pinhole
    - Focus the microscope as precisely as possible to a reflecting surface, with $\lambda/4$ plate in position, so that a strong beam of light enters the spectrometer and becomes visible in the section before FP1.

- In the TFP-2 HC, correct the input angle to FP1 using the Michelson-style tool on the first pass and G1 adjustment as described in the TFP operator manual.
  In the TFP-1, use a thin beam splitter plate just before the input pinhole, at a small tilt with respect to the input pinhole cover. The beam splitter will intercept the light reflected by the FP1 cavity and create a spot close to the input of the instrument. Correct the angle to FP1 in order to see the back-reflected signal even with the smallest input pinhole. Note that if you tilt the beam splitter too much, especially at small input pinhole, it will shift the inbound beam and you will not see the back reflected spot at all.