

Handbook of Time-Resolved Scanning Kerr Microscopy in G31a

F.B. Mushenok, C.S. Davies, V.V. Kruglyak

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1 Introduction

The purpose of this manual is to collect and organize the best practices of measurement with Time-Resolved Scanning Kerr Microscopy setup in G31. Some parts of the manual were copied from manual of Carl Davies. Please, fill free to amend and improve the manual (if you are confident in what are you doing).

F. Mushenok (mushenokf@gmail.com)

2 Laser safety

Before any experimental work in the lab, you should be familiar with laser safety rules. Please adhere to the best practise rules:

3 Cold start

4 Preliminary work

The laser system is maintained at a constant temperature, of 18 degrees celsius, by a coolant. This should always be kept on. First of all, inspect floor, area around the

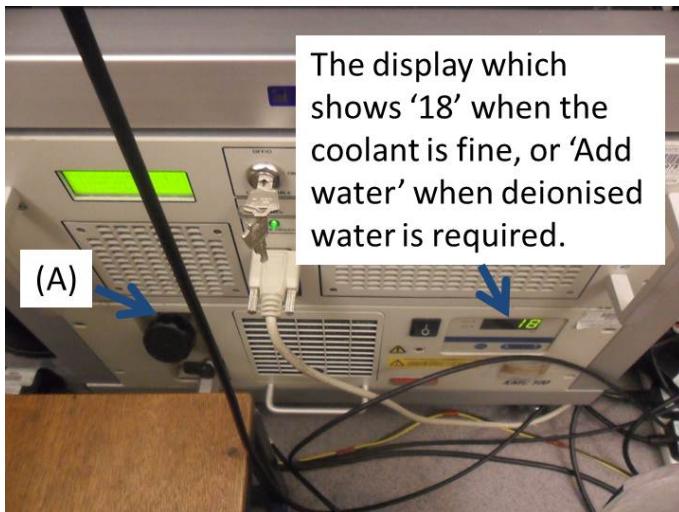


Figure 1: The front panel of the laser coolant

laser and bench surface for water leaks. If there are any water droplets or spillages, find the reason and amend it. Keep in mind potential danger of water spillage.

If the chiller is off, then press the button and switch it on, wait a couple of minutes and make sure the chiller's display indicates 18 degree. If the display indicates "ADD", then fill a canister with distilled water, open the large black cap (labelled (A) in Figure 1.1), and refill the coolant until the display reverts back to '18'.

IMPORTANT!!! Every six months the water filter (on the rear side of the chiller) should be replaced on the new one.

5 Setup alignment

6 Laser optimization

Switch the Thorlabs S142C power meter on, and adjust the meter so that it measures in units of mW, and reads the intensity of 800nm (infrared) light. Place the power meter after beam splitters (see Fig. 3) and rotate the meter until the power incident is maximised. Adjust the dials on top of the Tsunami Laser until the power recorded is maximised further (Fig. 2). From experience, it is recommended that this step be repeated, as this often provides a further maximisation. A detailed explanation of



Figure 2: Turn the dials A, B, C and D to maximise the output power.

optimization process could be found in Tsunami manual (page 7-3). With the power now maximised, the power meter can be removed and put aside.

7 Optical alignment

Optical alignment is the most important part of the experimental work and main condition of robust and repeatable measurements.

General advice:

- Follow the safety rules **ALWAYS!!!** You have two eyes only.
- Use holders, screws and fasten optical components to the table. Firstly, it will prevent occasional movement of the component and disruption of alignment. Secondly, all components are extremely expensive and one accidental falling of a mirror can cost hundreds of pounds.
- Block and properly dump back reflections of filters and mirrors.
- Check operating wavelength of mirrors. Make sure it fits your setup.
- something else???

Outline of the beam path for Time-Resolved Scanning Kerr Microscope (TRSKM)

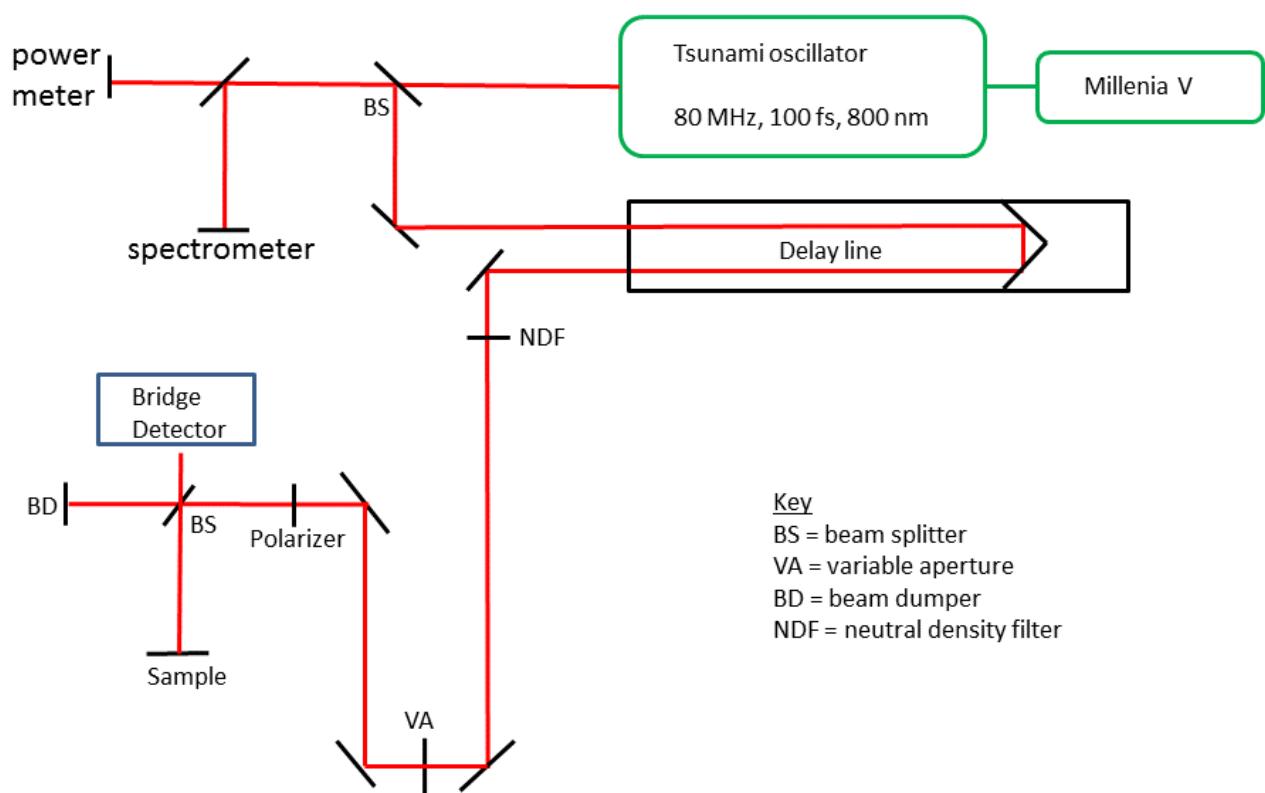


Figure 3: Outline of optical part of the TRSKM setup

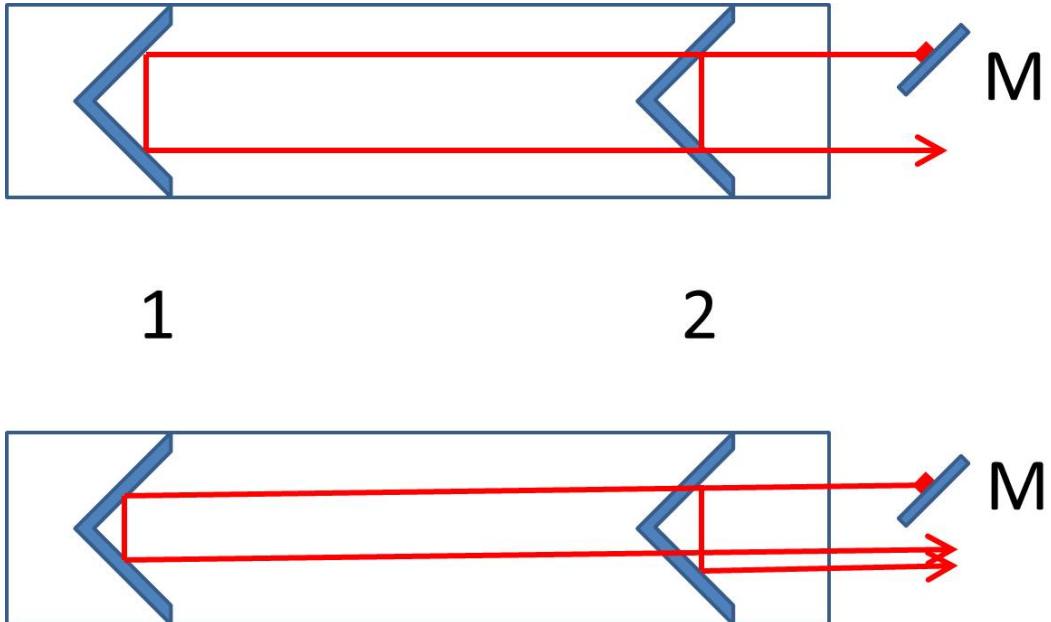


Figure 4: Optical path of the laser beam in aligned (top) and misaligned (bottom) delay line.

Retroreflector.jpg

7.1 Delay line

Delay line allows one to change length of optical path and introduce time delay between excitation of the investigated sample and moment of measurement.

Ideally the laser beam goes parallel to the rail of DL, incidents to the corner reflectors and reflects to the rotating mirror. Incident and reflected beams should be exactly parallel to each other. Otherwise, reflected beam walks up-down or left-right with DL movement and alignment of subsequent optical elements is impossible (Fig.4).

The top sketch corresponds to a good alignment: the stage travel strictly parallel to the directions of the beams (it is the key property of the retro-reflector to send the incident beam exactly in the antiparallel direction), and so, the beam hits exactly the same points of the retroreflector in both positions. The bottom sketch illustrates what happens when the beam is slightly deviated from the direction of stage's travel: the beam hits different points of the retroreflector in its different positions on the translation stage, and as a result, the beam gets translated as the stage travels.

How to:

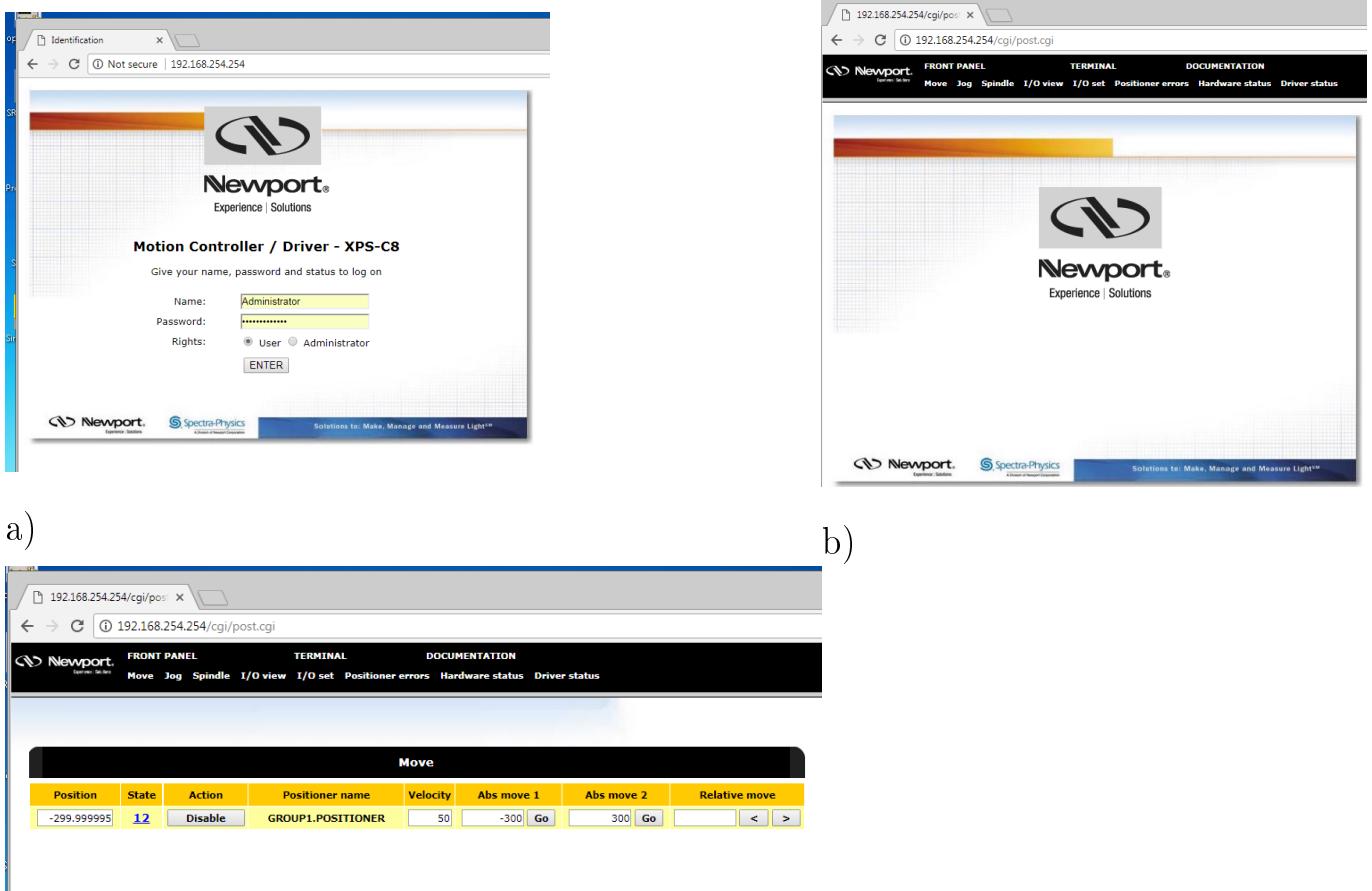


Figure 5: Control panel of delay line.

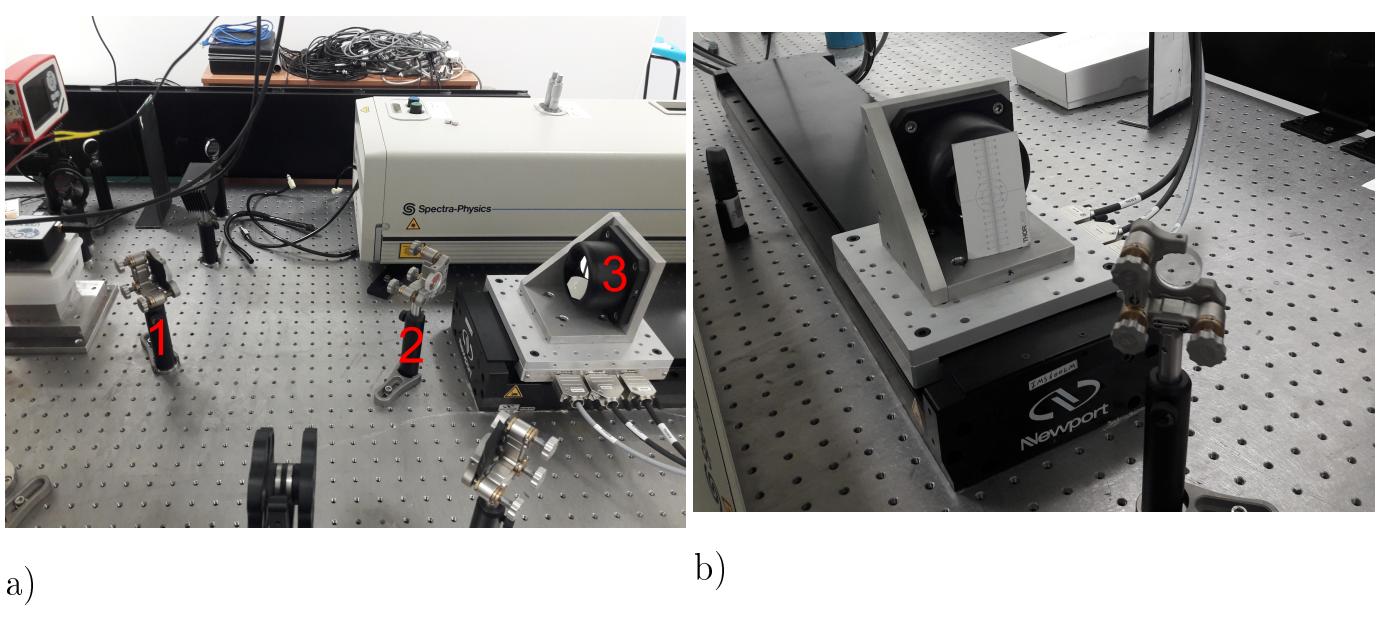


Figure 6: Delay line: 1 - directing mirror, 2 - rotating mirror, 3- corner retroreflector.

1. Open web-browser, login to the url <http://192.168.254.254> and open control panel of the delay line (Fig. 5).
2. Install a screen before the corner reflector (Fig. 6).
3. Using the directing mirror send the beam to the screen. The incident point should be over against left half of the reflector.
4. Remove the screen, install it somewhere near the directing mirror and catch spot of the reflected beam.
5. Using screws of the directing mirror, adjust position of the spot thus to make incident and reflected beams are roughly parallel.
6. Put a screen before the reflector and check where the beam goes to. If the incident beam is very close to the reflector's edge, move the directing mirror perpendicular to DL axis and fix it.
7. Repeat steps 4-5.
8. Install, connect and focus the CCD camera thus to see image of reflected spot on the TV screen.
9. Notice the spot position.
10. Open control panel of the DL
11. Make a small step of DL in positive direction (for instance, 10 mm).
12. Most likely, position of the spot will be changed. Rotate the direction mirror screws and set the spot in initial position.
13. Repeat steps 11 and 12 till position of the spot depends on DL shift. If you achieve opposite end of the DL (+300 mm), move it to the origin (-300 mm) and continue alignment. If the incident beam is very close to the reflector's edge, move the directing mirror perpendicular to DL axis and fix it.

14. Install the rotating mirror to send the beam to the microscope.
15. Put the screen after the rotating mirror and repeat steps 8 - 13.

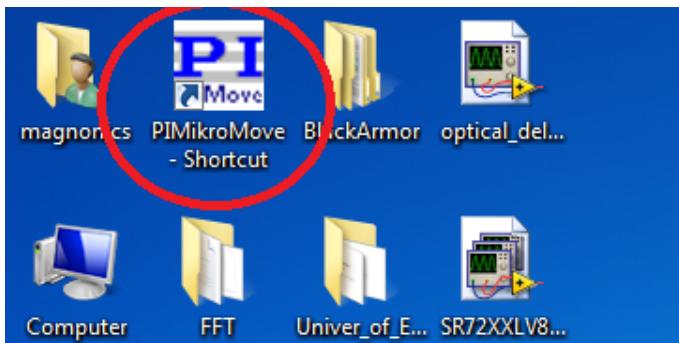
7.2 Microscope

8 Sample installation

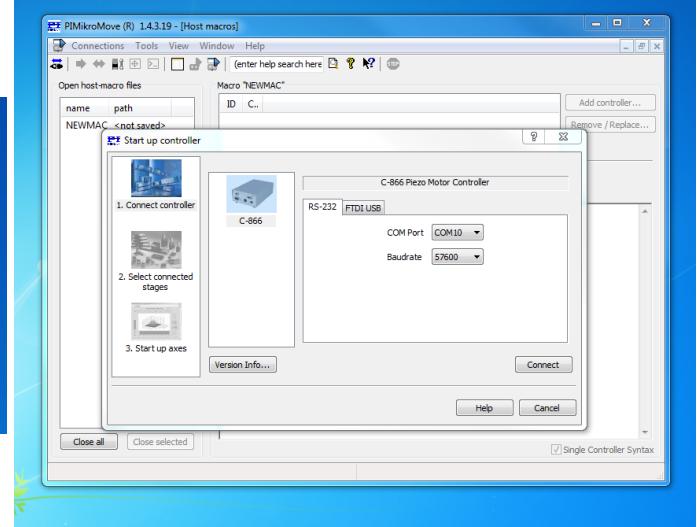
8.1 Connection of mechanical stage

Make sure that the stage can move without any nuisance (otherwise, you will hurt the stage). NEVER try to move the mechanical stage manually when it is connected and under control.

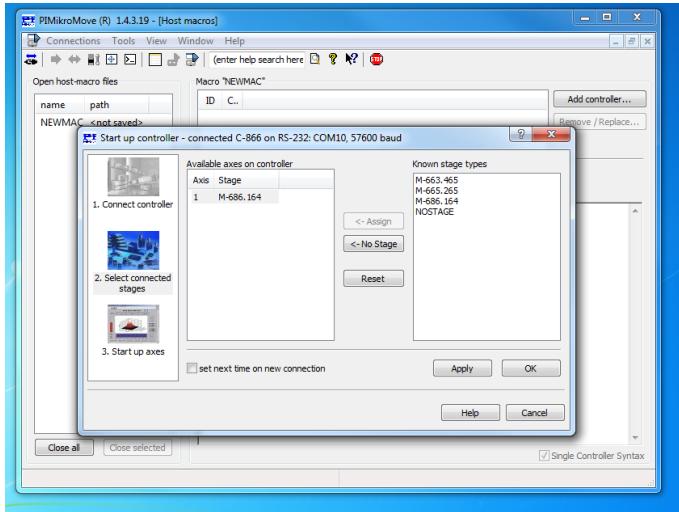
1. Make sure that both controllers of the stage are on.
2. Run "PIMicroMove" (Fig.7a)
3. Choose proper COM port and press "Connect" (Fig.7b)
4. You will see type of the connected stage on the left panel. It should be "M-686.164" (Fig.7c). (If the left panel is empty, select "M-686.164" on the right panel, press "Assign"). Press "OK".
5. In new window press "Automatic" (Fig.7e) and "Start". The stage will be moved in a reference position. Close the window.
6. Now you see that one axis of the stage is connected.
7. In main menu open "Conection" -> "New..." and repeat steps 3 - 5 for second axis of the stage (it will be another port address).
8. As a result, both axis of the stage should be connected and adjusted. You will see two axis in the main window.



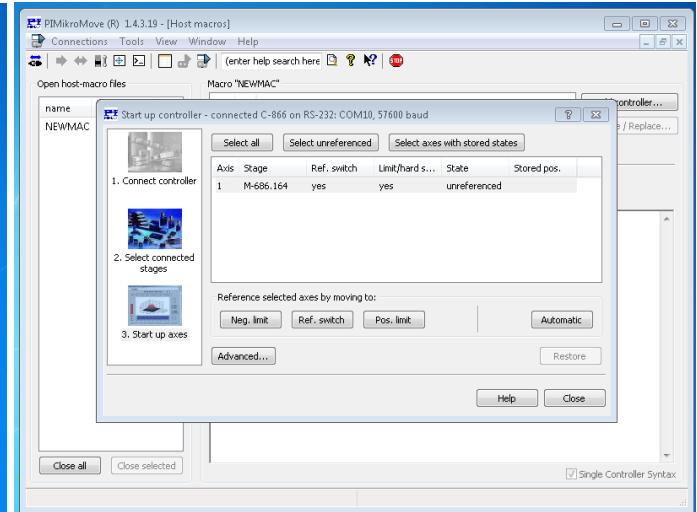
a)



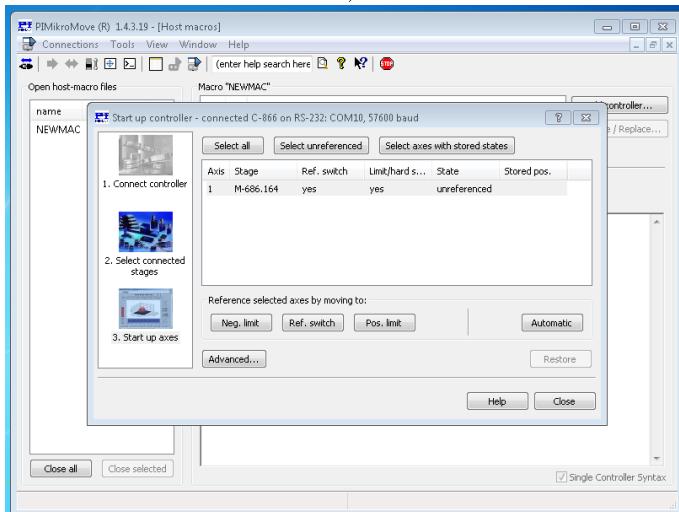
b)



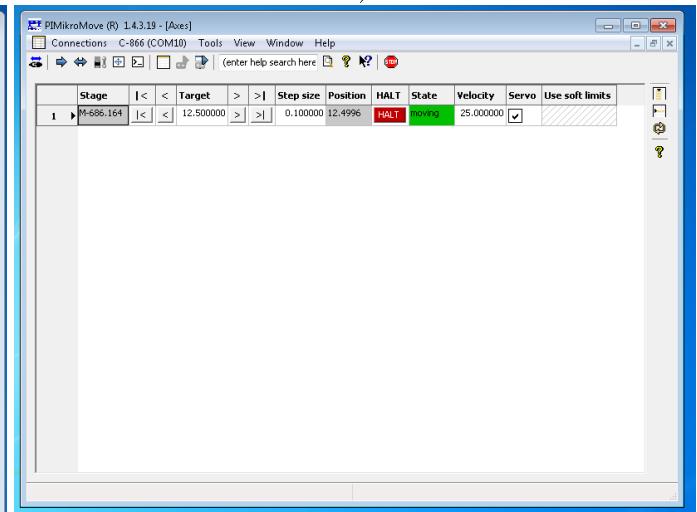
c)



d)



e)



f)

Figure 7: Connection of the mechanical stage

8.2 Mounting the sample

Usually the structure we wish to study lies on a substrate. Typical examples include a permalloy structure mounted on a silicon substrate, or a GaAs structure mounted on a glass substrate. The structure must first be attached to the printed circuit board (*PCB*), and to do this, we simply apply sticky-tape. Wearing latex gloves, and preferably with the help of a magnifying glass/angled lamp, the structure should be laid on top of the signal line of the PCB (the PCB consists of ground(yellow)-signal-ground(yellow) lines. The substrate should also be lying fully on the PCB. Care should be taken to ensure this is done correctly - in my personal experience, it has sometimes taken up to an hour to do this.

A good way to double-check this step has been done correctly is to take a photo of the sample (where you can see it), and then a second photo of the sample lying on the PCB (scratches on the PCB invariably make the structure on the substrate impossible to discern). Using an application as simple as Microsoft Powerpoint gives us a way to verify that the structure is lying on the signal line (Fig. 8)

With the sample now mounted on the PCB, the PCB can now be dropped on to the piezo-electric stage. After ensuring the magnetic ring is switched off, magnet (1) can be pulled out, breaking the circle. The piezo-electric stage can then be gently pulled towards the space left by magnet (1), and the sample merely dropped in to the slot at the centre of the stage. The two green cables, held in place either side of the stage by two clamps, can then be screwed on to the PCB. These two cables provide the electrical field with which we pump the structure.

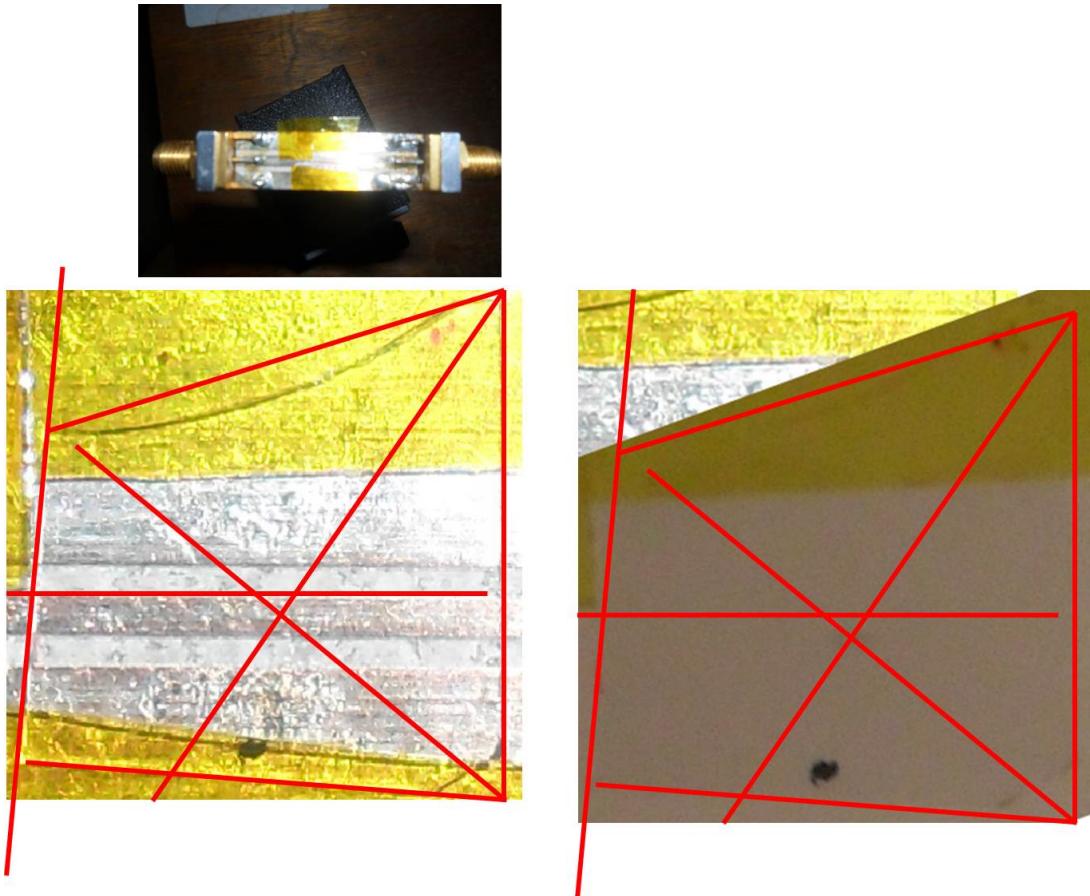


Figure 8: Using Microsoft Powerpoint, we can verify the sample lies on the signal line. We can see the sample in the left photo, but the scratches on the PCB make the sample invisible to the naked eye in the photo on the right. By making a series of reference points (here, we have used lines surrounding the glass), we can copy and paste this overlaying 'net', therefore showing the position of the sample relative to the PCB

8.3 Preliminary work

Make sure that current passing through the magnet is zero (Fig. 9a).

Move away one removable magnet pole (Fig. 9 b-c).

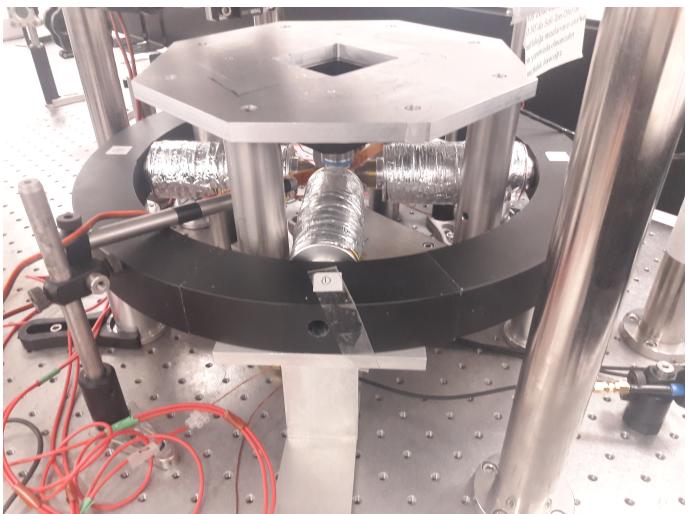
8.4 Positioning the sample/Focussing the laser beam

1. Highlight the top option displayed, click 'connect', and then 'ok'
2. Press 'negative Limit', and then 'start'
3. Wait a few seconds until the program has finished running, and then press
4. In the new window that has opened, open the tab 'connections', and click 'new'
5. Highlight the remaining axis, and click 'connect'
6. Click 'ok', press 'negative limit', 'start', wait until the program stops, and then 'close'

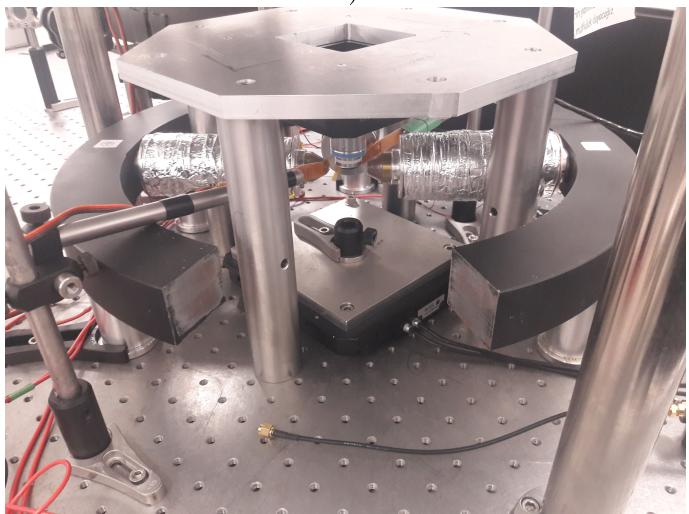
The window that has now opened displays the two axes. Change the step size on both axes to 3mm, and then incrementally move the PCB to 21mm x 21mm. This has centred the PCB.

We also need to centre the objective lens. Open the program 'Measurement & Automation Explorer', and double-click "devices" on the left panel. Right click 'device 0' or '1', and communicate with the instrument. We want to communicate with GPIB 15. In this panel, type:

- Typing '1TP', '2TP' or '3TP' then pressing 'query' returns the position of the PCB in the x-,y- and z- axes.
- Typing '1MAxxx', '2MAxxx' or '3MAxxx', where xxx is a co-ordinate in μm , and pressing 'write' moves the PCB to the appropriate co-ordinate in the x-, y- or z- axes.



a)



b)



c)



d)



c)

d)

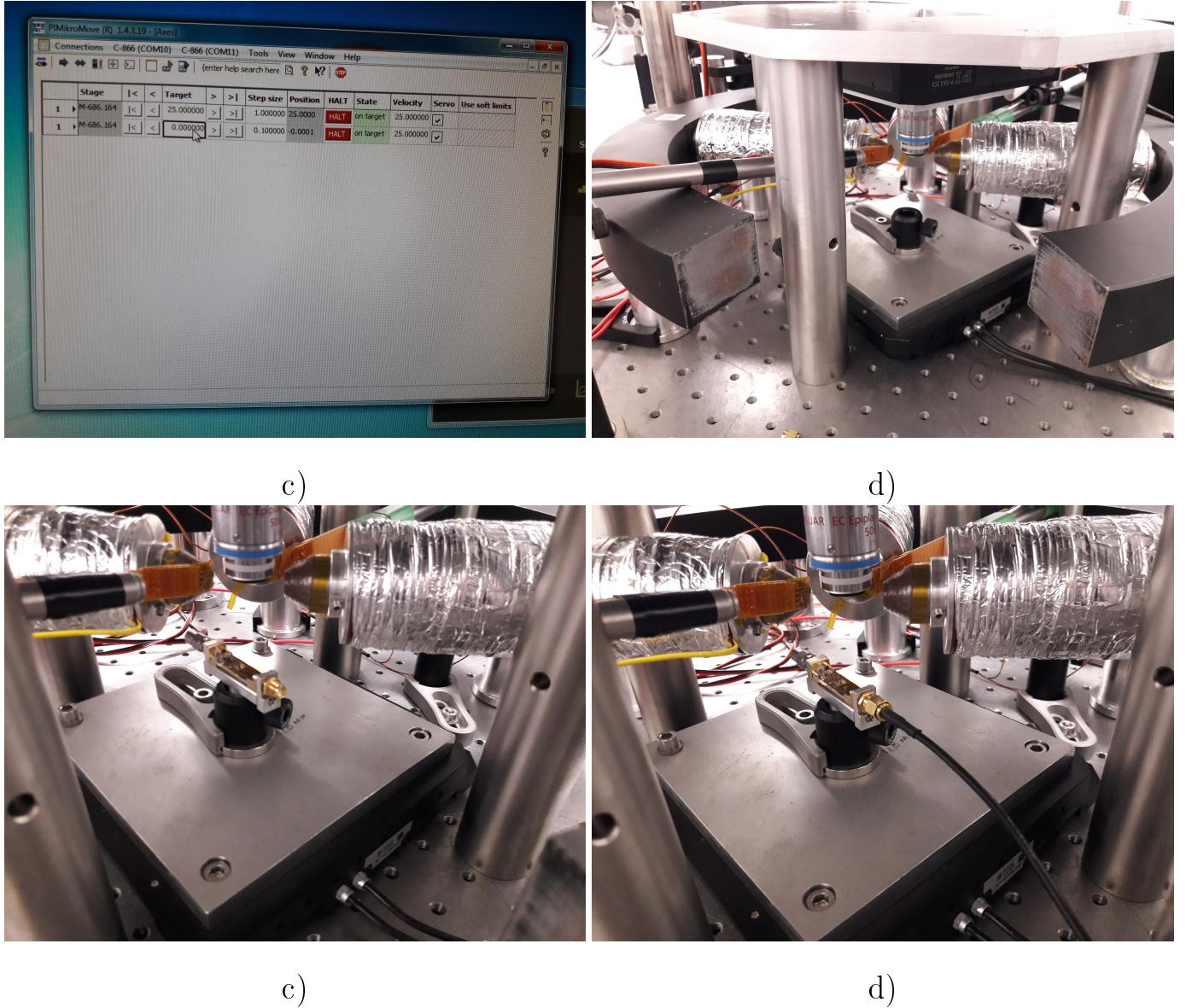


Figure 9: Sample installation

Move the objective lens such that it lies directly above the top of the PCB ie. write the commands '1MA150' and '2MA150'.

We now need to focus the sample. Allow the laser beam to enter the TRSKM apparatus, and push the mirror in between the PCB and the objective lens. With your hands below magnet 1 (which is still pulled out of the circle), carefully raise the PCB towards the objective lens using your left hand. Do not push the PCB in any transverse or longitudinal direction. Once the laser beam is reflected on to the piece of card, such that there are 2 dots visible, carefully raise or lower the PCB until the 2nd dot is strongly concentrated, and use your right hand to turn the dial under the PCB to tighten its position. Switch the tv on next to the display monitor, and you should be able to see a rough surface. If not, again raise or lower the sample until you can see the PCB board in focus on the CCTV monitor.

Open the window 'PI Mikromove', and now, in increments of $20\mu\text{m}$, move the piezo-electric stage until the structure can be seen on the CCTV monitor. This is mainly done through trial and error. The CCTV monitor can now be switched off, and the mirror above the PCB can be pulled out. The laser beam is now entering the objective lens, and is being collected by the photodetectors.

9 Pulse measurement

10 CW measurement

10.1 Configuring the laser

The workings of the Tsunami laser system has been described well in the Doctoral Thesis presented by Toby Davison¹. Here, I shall merely describe how to obtain an output laser beam, of wavelength 400nm. The mirror directly in front of the laser aperture should be raised, so as to protect the sample from the laser until it is configured correctly. The console next to the laser should display 'Standby'. This

¹<https://eric.exeter.ac.uk/repository/handle/10036/3675>

indicates, of course, the laser is on standby. Pressing and holding the upper-left button on the console switches the laser on, and now the power of the laser is displayed (initially this is ' $<0.1W$ '). Wait for around 2 minutes, until the laser outputs 12W. This is the maximum power of the laser, and we are now able to see the red laser beam reflected on to the card next to the laser aperture.

10.1.1 Check the pulse shape

10.1.2 Set modelock regime

Using the up-down arrows, the frequency displayed should be adjusted so it oscillates around 80.00000GHz: once this is achieved, the button to the left of the display should be pressed, thus locking the frequency after around 5s. The laser is now fully operational.

10.2 Adjusting the laser beam path

Before we manipulate the path of the laser beam across the bench-top, place the silver stand just before the piece of tubing, situated next to the microscope. The mirror in front of the laser aperture can now be lowered, and the blue laser beam should be visible on the silver stand's white paper. If the spot profile is circular, no adjustments need to be made. If however the laser beam is not circular, or not visible at all, the path of the laser beam must be misaligned. To repair this, use a small piece of card to observe the laser beam before it reflects off each individual mirror, and then adjust the mirror accordingly. Obviously, we should initially check the mirror closest to the laser aperture, and then move on to the next one step by step. Best practise also dictates the laser beam should ideally be reflected off the centre of each mirror.

11 Miscellaneous

11.1 System backup

Folder C:\Users \User \Documents is copied every morning to remote NAS PHY-Magnonocs. Backup process is organized with ROBOCOPY utilite (see C:\Program Files\backUp). Please check log file (C:\Program Files\backup.log) regularly.

11.2 Output files

Experimental results are saved in hierarchical *.h5 files (<https://en.wikipedia.org/wiki/HDF5>). An *.h5 file has a tree-like structure, where each branch ("group") has attributes (pair "name:value") and/or leafs. Each leaf is another branch ("group") or dataset (i.e. numerical array).

11.2.1 MatLab package installation

How to install MatLab package???

<https://github.com/PhySci/TRSKM-soft>

11.2.2 Raster scan signal

11.2.3 Time scan signal

1. Create an instance

```
ods = Kerr_ODS;
```

2. Load an experimental file

```
ods.open()
```

As a result, data from the experimental file will be loaded into "ods" object and graphs of Kerr signal and reflectivity will be displayed (Fig. 12).

Now you can find all experimental data inside "ods" structure (see Fig. 12 b, c):

- $fName$ is name of file

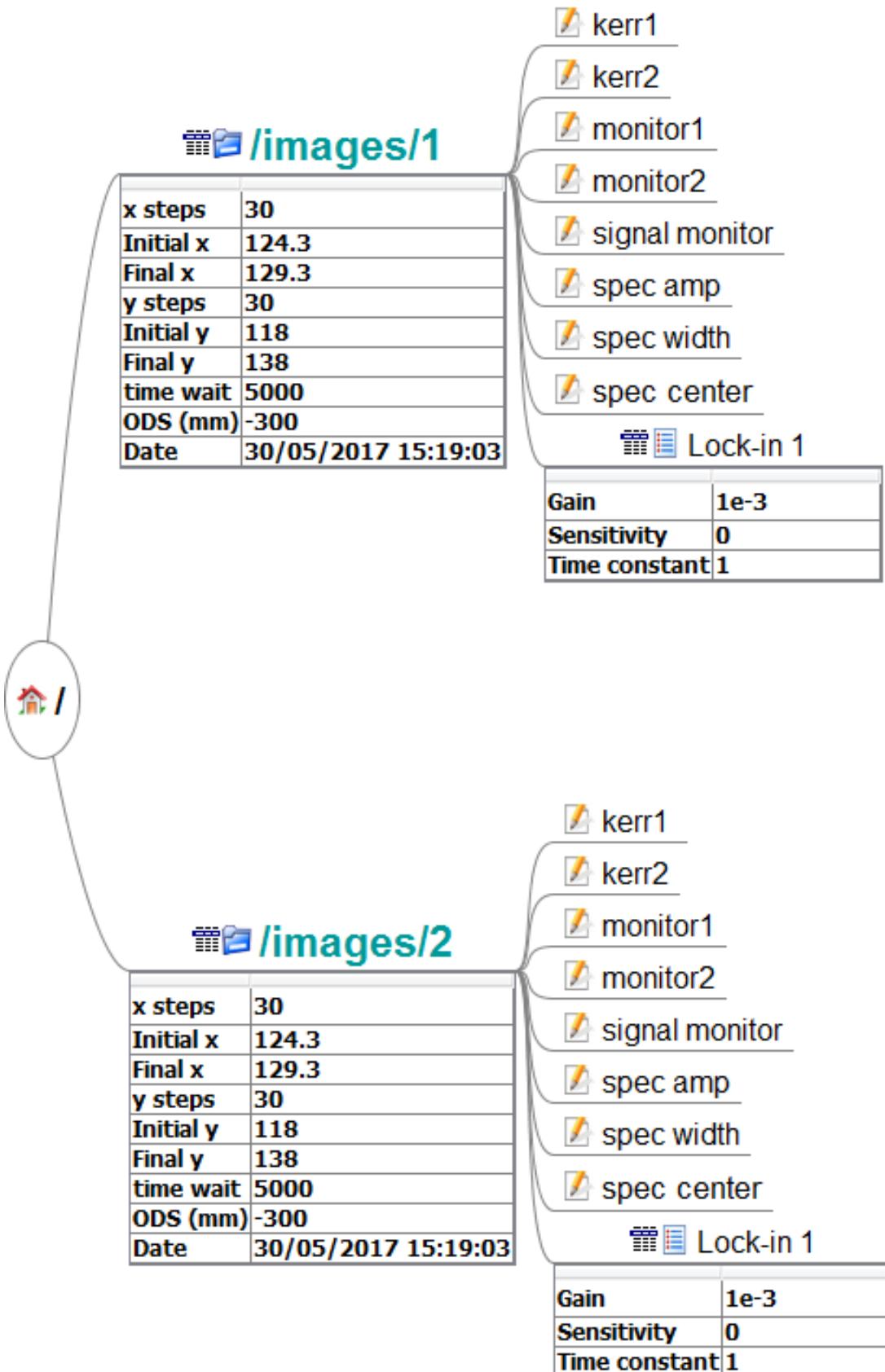


Figure 10: Structure of output HDF file for TR-SCM experiment (scanning mode).

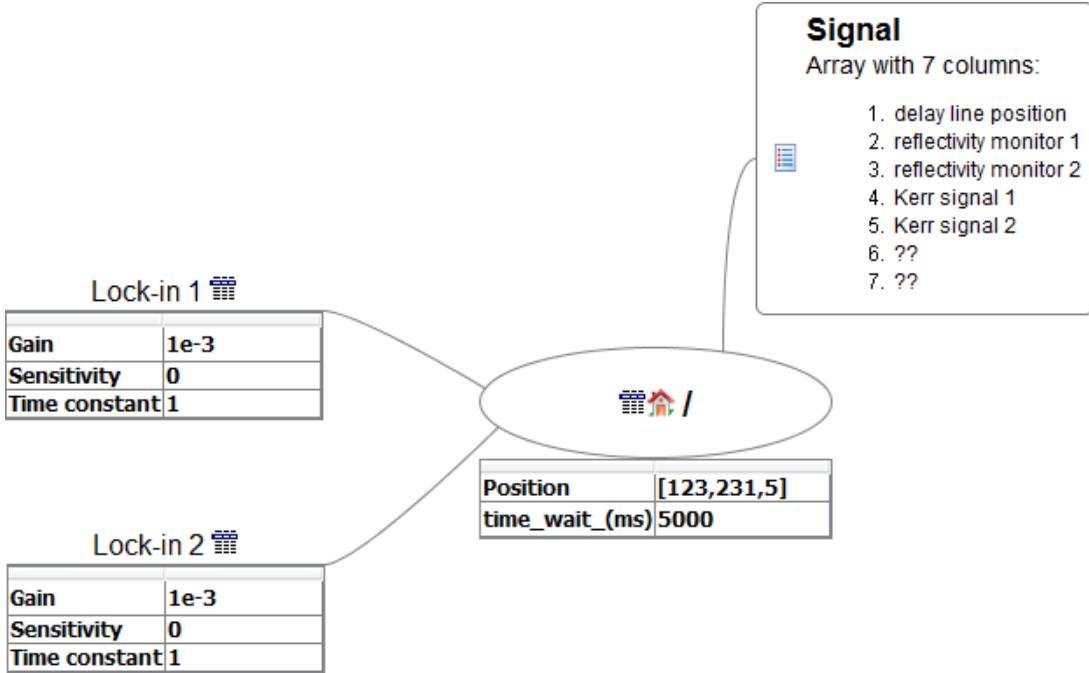


Figure 11: Structure of output HDF file for TR-SCM experiment (time-resolved mode).

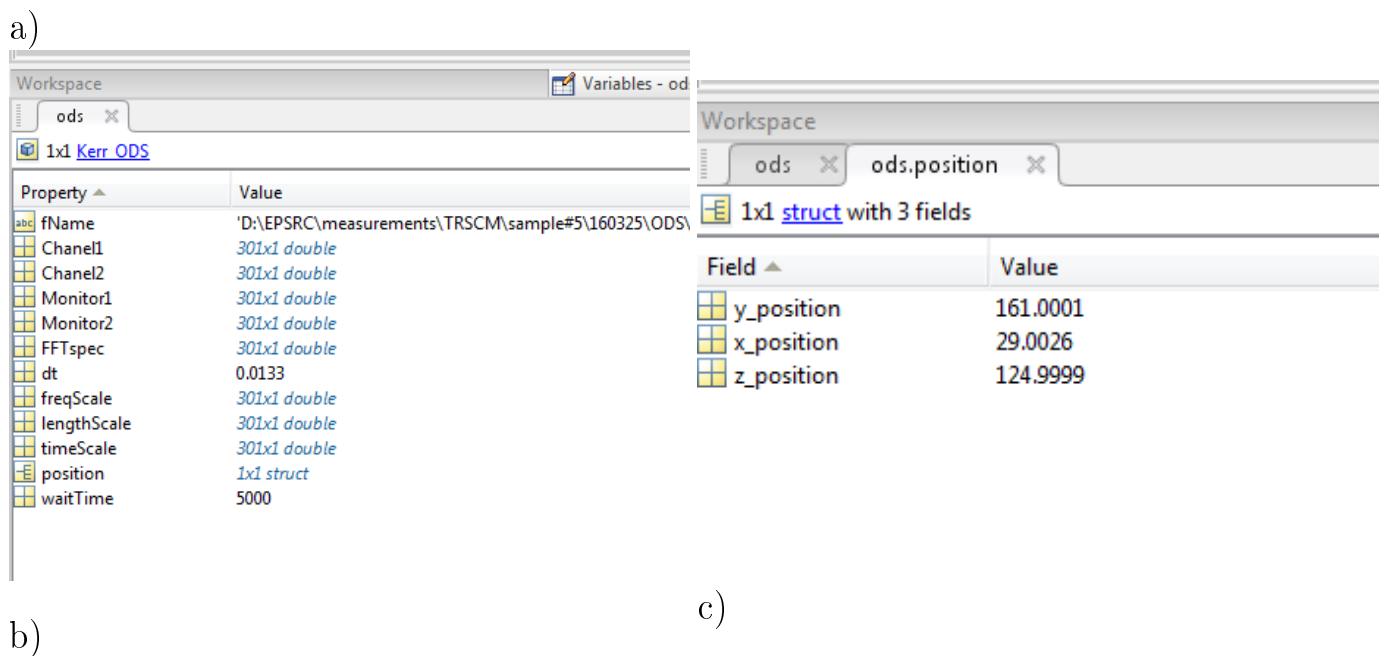
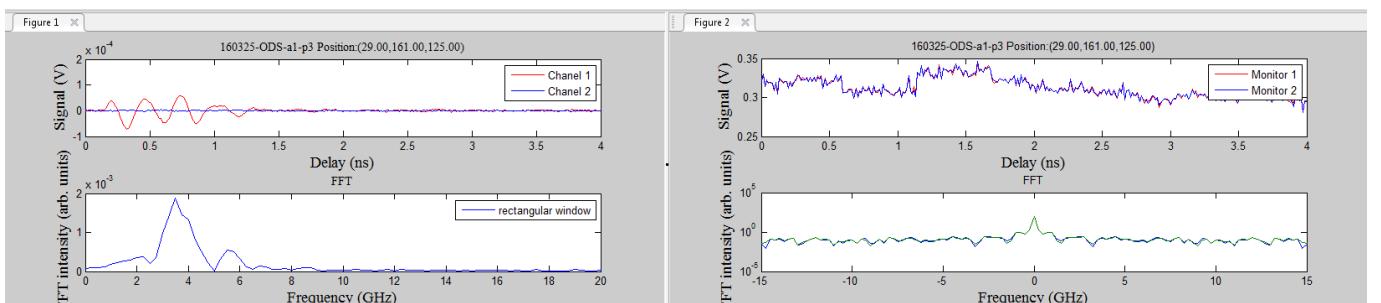


Figure 12: a) Example of time-resolved Kerr signals (left panel) and corresponding reflectivity monitors (right panel). b,c) Content of Kerr_ods object.

- *Channel1*, *Channel2* are Kerr rotation signals.
- *Monitor1*, *Monitor2* are reflectivity signals.
- *lengthScale* is a sequence of optical delay line positions.
- *timeScale* is a corresponding sequence of time delay.
- *freqScale* is a corresponding frequency scale (for FFT).
- *position* is X, Y and Z position of the piezostage.

Class *Kerr_ODS* has a few method for post-processing plotting of experimental results:

- *plotKerr* shows Kerr signal;
- *plotMonitors* shows reflectivity (monitors);
- *scanFolder* reads all files in the folder, calculates and averages FFT for them (obsolete).

Very often, raw signal needs be rotated in complex plane thus to put all useful signal into one channel. You are welcome to use "phaser" MatLab script which has graphical user interface². Ask me or VVK about idea of the rotation (or probably I will add description).

²<https://github.com/PhySci/TRSKM-soft/tree/master/phaser>

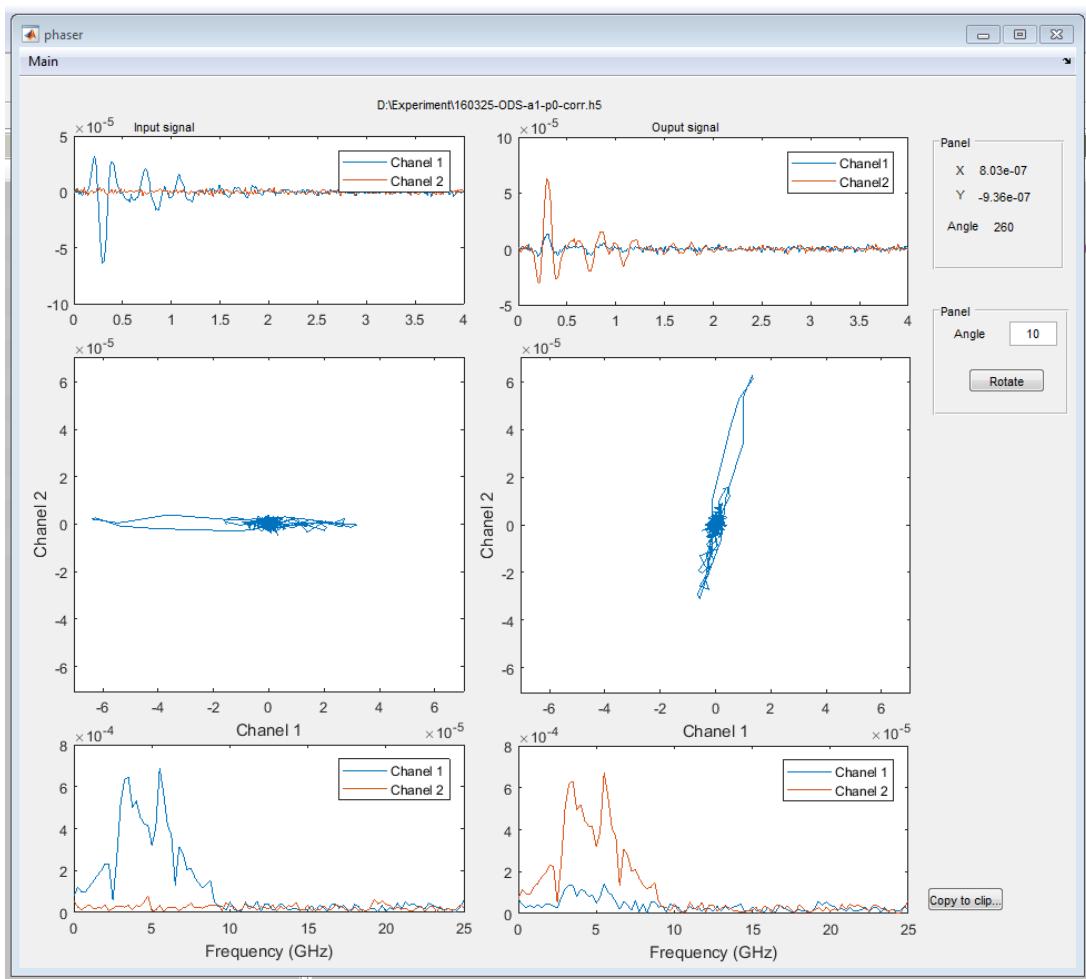


Figure 13: Rotation of signal's phase using script "phaser".