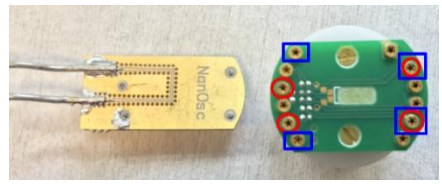
Pins and sockets?



First-time users will be unsure about alignment of the pins on the in-plane (IP) and out of plane (OOP) boards to the sockets on the FMR probe, so the photo will help. The IP board will plug into the sockets outlined in red on the FMR probe, while the OOP board plugs into the sockets outlined in blue. Shown here is the rotator adapter which is necessary to protect the pins on the boards while putting a sample on. To use it, please plug the gold board into the green adapter and plug the adapter into the P150 puck test station (stored in the transport accessories drawer).

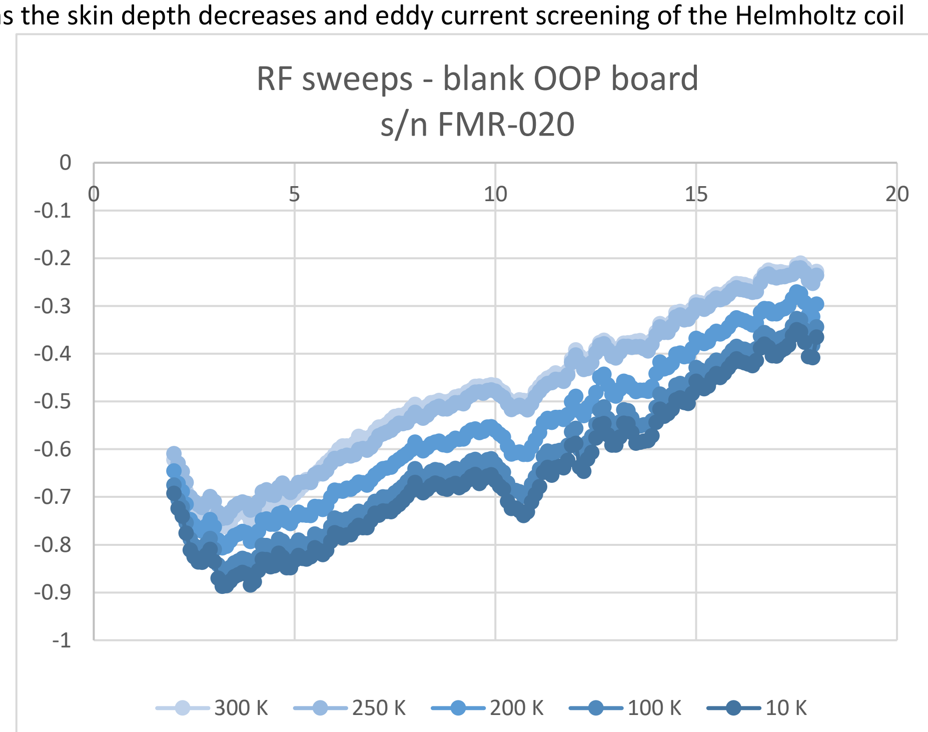
Remanent field correction

Saturation field must be at least **5000 Oe above** the start field in a sweep, and you should sweep to lower field values.

This will ensure that the PhaseFMR software's remanent field correction for the PPMS magnet is accurate. Otherwise remanence profile will be in between the up- and down- sweep envelopes. See PhaseFMR app note 2016-01 on this topic.

FMR performance at low temperatures

As the probe cools, the resistance in the RF transmission line decreases and this results in an increase in transmission as seen in the RF sweep data below. Another factor at low T is the increased screening of the 490 Hz modulation field by the isothermal region (pure Cu) of the sample chamber: its lower resistance at low T means the skin depth decreases and eddy current screening of the Helmholtz coil increases. This latter effect is still being investigated (Apr2021) by lowering the modulation frequency down to 100 Hz (min.).

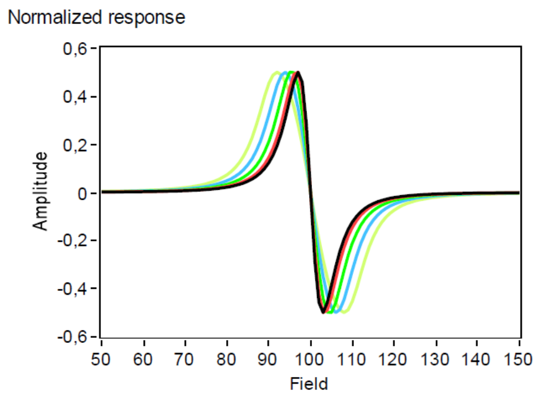


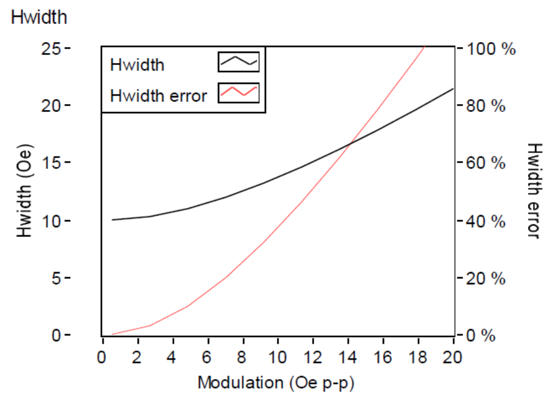
Modulation field vs. peak width

A higher AC modulation field (default frequency = 490 Hz) creates more signal, but too much modulation will blur out narrow resonance peaks with a resultant loss of information about the peak structure and also an overestimate of the damping. The Helmholtz coils in the Cryo-FMR probe produce 12 Oe (peak-to-peak) with modulation (a.u.) set to maximum of 0.45 in the software. So:

Modulation [a.u.] * 26.7 = modulation [Oe, peak-peak]

A good rule of thumb is to keep the peak-peak modulation < 10% of the linewidth.
A modulation (peak-to peak) with 10% of the linewidth will give 1% overreporting of the linewidth.
A modulation (peak-to peak) with 50% of the linewidth will give 10% overreporting of the linewidth.





Note that the Cu sample chamber walls will attenuate the modulation signal and create more heating at low temperatures. It is possible to lower the modulation frequency to 100 Hz to reduce this effect.

Peaks occurring near end of sweep

Note that peaks occurring close to end of a sweep will not be properly fit. A design decision was made by NanOsc that any fitting in which **Hres-dH/2** or **Hres+dH/2** is outside the sweep range is regarded as "baseline" and is removed from the combined "IQ" signal and a new fitting is applied to the remaining signal. It's always an option to post-process the data in another program if the PhaseFMR software isn't enough.

Small/Large signals in CryoFMR

Ways of improving signal to noise in samples with weak signals (thin ~nm films, small sample area like nanodot arrays, high damping materials…): increase **Modulation Amplitude to 0.45** (12 Oe peak-peak) and the **Input Gain to 1000x**.

Input Gain and Output Gain: The DAQ voltmeter that reads the two channel outputs FMR I and FMR Q has a resolution of 0.3 mV (see Section 8). The gain should be adjusted so that the measured signal is large compared to this value. To improve signal to noise ratio, prioritize increasing the Input Gain.

Large signals: Max range is +/- 10V. If you see the data is flat near +10 V or -10V, it has saturated the digitizer and the data is junk. Redo the scan with a smaller Input Gain.

Electrical probing in CryoFMR

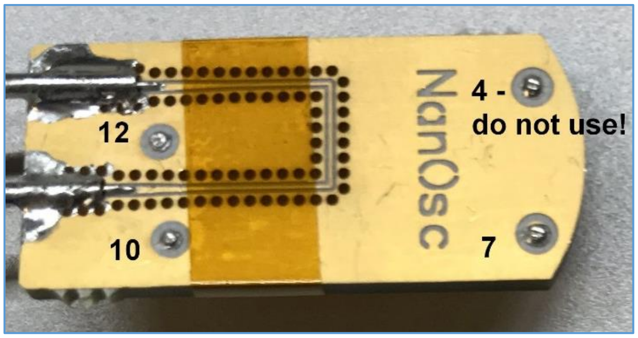
There are 4 pins that plug the FMR CPW into the CryoFMR probe and are mainly there for alignment. However, they also make electrical connection to the probe and this will allow measurement of voltages like inverse spin Hall effect (ISHE signal can be read by PhaseFMR, see BNC on front panel). One can also apply a voltage or current to affect the sample's magnetic properties (e.g., multiferroics).

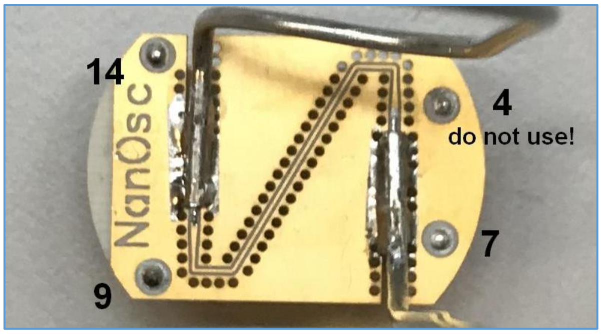
NOTE: to protect the wiring of the probe and DynaCool sample chamber, please observe:
maximum voltage = 50 V DC
maximum current = 100 mA
Also, put a Kapton tape down under your wires to insulate any ISHE signals or bias voltages from the RF lines.

If you want to go above this, please contact Neil. Higher voltages can be used under certain conditions.

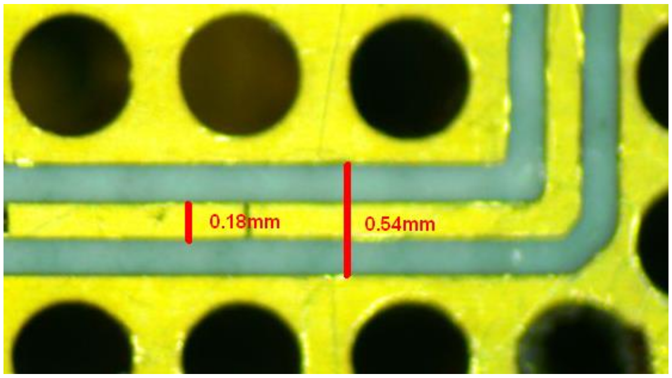
The photos show the sockets on CryoFMR probe that these pins in FMR boards connect to. Note that you should NOT use pin #4 since this is used for the thermometer. Furthermore, the Rotator/MFP Experiment cable 3084-010-02 is recommended in order to control the thermometer on the MFP probe (see Section 6 below of CryoFMR installation instructions below). When that experiment cable is in place, the pins will be remapped as follows:

Pin # at IP or OOP board (see photos below)	**Pin # after Rot/MFP Expt cable**
4	**- (do not use!)**
7	**3**
9	**5**
10	**6**
12	**8**
14	**10**



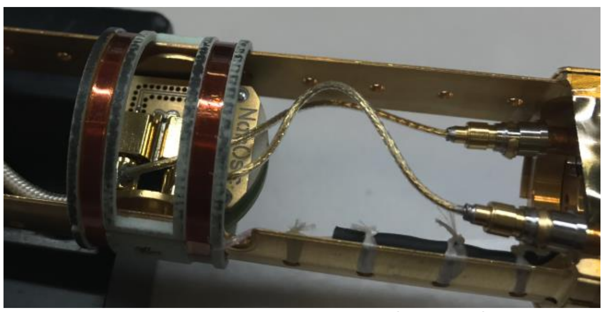


For example: I would like to apply bias voltage to a sample on the IP board, so I will choose pins **10 and 12** at the board. After plugging in the Rotator/MFP Expt cable and the Grey Lemo Breakout Box (see ETO section) into that, I will connect the voltage source to pins **6 and 8** at the breakout box.



Dimensions of CPW: shown below is the IP board, where we see the center conductor is *w* = 0.18mm and the gap in the ground plane is 0.54mm. According to Maksymov the magnetic film should be less than a height *w* from the strip since the B-field falls to about half its value when height = w (note when reading Fig. 7b of the paper the stripline is located at y=0.3*w so the sample is only above this height; also, it is a stripline not a CPW but I am assuming that the B-field profile is similar).

FMR Rotating CPW

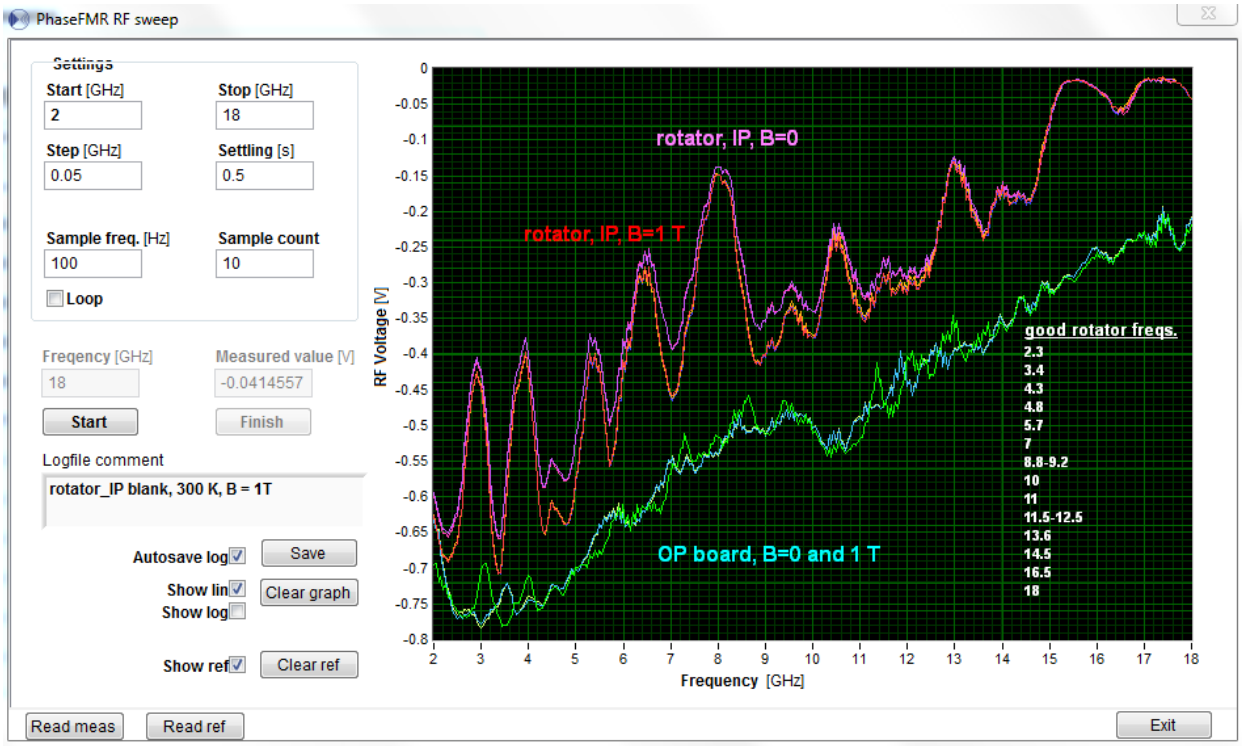


We have a board which rotates from IP to OOP (though no in situ rotation in PPMS) that provides a great capability but at the expense of signal/noise. Photo of the board in an IP alignment is shown here. Adjustment of the angle is made by loosening the screws holding the green sample mount in place by only a ½ a turn, then retightening. The angle can be measured using the AmScope software for the camera at the boom microscope in the Spin Lab. It has the ability to measure 4-point angles which are easily done when the angle is near 45 deg. Our concention is that horizontal = OOP = 0 degrees, and vertical = IP = 90 degrees. A frequency sweep comparing the transmitted power can easily be done in the PhaseFMR software:

> *Measure the transmitted power with the RF Sweep available under the Tools menu. This utility plots the RF diode's output voltage (negative voltages) vs the RF frequency so you will see the variation of the transmitted power as detected by the diode. Step through the frequencies from 2 to 18 GHz in for instance 0.1 or 0.2 GHz steps. A few things to note:*

- *The software will not prevent going beyond the frequency range 2-18 GHz, but do not go above 18 GHz. There is no risk below 2 GHz but the output power drops quickly.*
- *The automatically saved log files are saved where the configuration settings file .phasefmrconfig_2.0.ini is, not at the path you have given for saving the regular FMR logs.*
- *Connect a BNC-BNC cable between the front panel connectors ISHE and AUX for the RF Sweep. You can leave it there during regular FMR measurements.*

In the plot below -1.0 is perfect transmission and 0 is no transmission. We see a comb of dropouts for the rotator board while the fixed OP board has a more gradual decrease in transmission typical of these coax lines. A list of recommended frequencies for the rotator board is given in the plot.



PhaseFMR RF sweep
Settings
Start [GHz]
2
Stop [GHz]
18
Step [GHz]
0.05
Settling [s]
0.5
Sample freq. [Hz]
100
Sample count
10
Loop
Freqency [GHz]
18
Measured value [V]
-0.0414557
Start
Finish
Logfile comment
rotator_IP blank, 300 K, B = 1T
Autosave log
Save
Show lin
Clear graph
Show log
Show ref
Clear ref
Read meas
Read ref
Exit
RF Voltage [V]
Frequency [GHz]
rotator, IP, B=0
rotator, IP, B=1 T
OP board, B=0 and 1 T
good rotator freqs.
2.3
3.4
4.3
4.8
5.7
7
8.8-9.2
10
11
11.5-12.5
13.6
14.5
16.5
18