Ferromagnetic Resonance (FMR) Installation Guide

Safety precautions

Follow all guidelines in Lake Shore's MeasureReady® MCS-EMP and 8600 Series VSM System user's manuals, and NanOsc's user's manual.

Introduction

FMR explained

Ferromagnetic resonance (FMR) measurements allow the magneto dynamic properties of thin-film magnetic materials in the 10s of GHz range to be determined. The most widely used electrical FMR instruments are those based on a vector network analyzer (VNA). A thin-film sample is placed on a co-planar waveguide (CPW), which is connected to the VNA, and a mutually perpendicular static (DC) applied field and a microwave (AC) field are oriented either in-plane (IP) or out-of-plane (OOP) with respect to the film plane. The reflection and transmission coefficients are then determined by the VNA at either fixed frequency where the magnetic field is swept or at fixed field while the frequency is swept. FMR measurements are used to obtain values for the effective magnetization $Meff$, anisotropy constant K, Gilbert damping parameter α, and the gyromagnetic ratio γ.

FMR spectrometry in an EM platform or VSM using broadband FMR spectrometers

The NanOsc Instruments AB line of FMR spectrometers provide a simple solution to magnetodynamics research for frequencies ranging from 2 to 40 GHz (for more information visit nanosc.se). When combined with a Lake Shore Cryotronics MeasureReady® MCS-EMP, or an 8600 Series VSM system using the CPW holder (FMR-CPW-U-KIT), broadband FMR measurements to variable DC magnetic fields >2.3 T for IP and >2.9 T for OOP orientations are possible.

Key Features

- Both static and dynamic magnetic properties can be measured when used as an option to the 8600 Series VSM system
- Variable magnetic fields to >2.3 T for IP orientation or >2.9 T for OOP orientation for perpendicular magnetic anisotropy (PMA) thin films
- Low-noise 4-quadrant electromagnet power supply
- Integrated tesla meter for closed-loop field control
- MeasureLINK™-MCS control software license for magnet control integration with NanOsc data collection software[1]
- FMR-CPW-U-KIT includes bracket for mounting NanOsc standard U-type CPW on MCS-EMP and 8600 Series VSM magnet platforms. Does not include NanOsc-supplied CPW, Helmholtz coils, cables, and FMR instruments[2]

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[1] Will also require NanOsc software with Lake Shore MeasureLINK interface module for use with MCS-EMP and for use with 8600 VSM (which requires MeasureLINK software for FMR application modes, not available using standard 8600 VSM software).

[2] The NanOsc FMR instrument, cabling, reaction coils, and U-type CPW must be purchased from NanOsc.

Specifications

NanOsc FMR bandwidth

Instrument	Bandwidth
PhaseFMR	2 to 18 GHz
PhaseFMR-40	2 to 40 GHz

MCS-EMP and 8600 Series maximum fields when configured with the NanOsc FRM option

Model	In-plane (IP) maximum field	Out-of-plane (OOP) maximum field
MCS-EMP-4	1.69 T	2.41 T
MCS-EMP-7	2.34 T	2.91 T
8604 VSM	1.54 T	1.96 T
8607 VSM	2.23 T	2.55 T
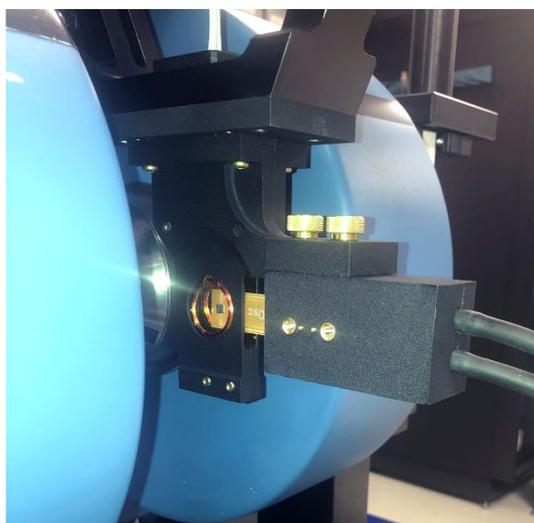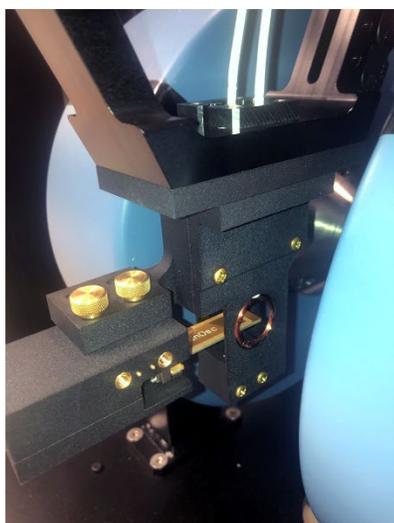
FMR-CPW-U-KIT sample mount shown with an integrated IP (left) and OOP (right) co-planar waveguide

Typical results

Measured and fitted data for $Ni_{80}Fe_{20}$ (10 nm)/Ta (5 nm) thin film as a function of IP field to 0.12 T at frequencies of 2, 4, 6, 8, and 10 GHz (figure 1), and as a function of IP field to 0.94 T at frequencies of 30, 32, 34, and 36 GHz (figure 2).
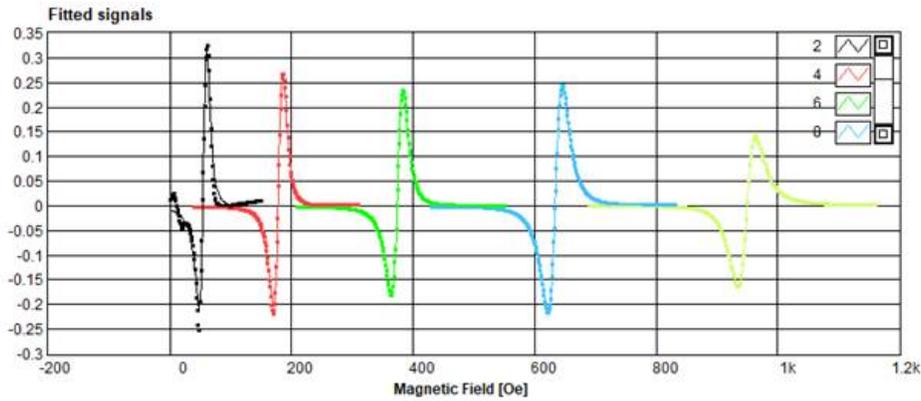
Figure 1: **Measured and fitted data for $Ni_{80}Fe_{20}$ (10 nm)/Ta (5 nm) thin film as a function of IP field to 0.12 T at frequencies of 2, 4, 6, 8, and 10 GHz**
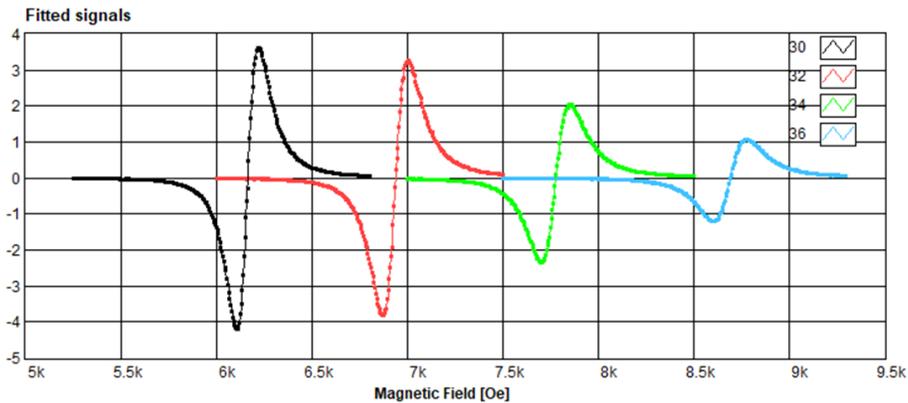
Figure 2: **Measured and fitted data for $Ni_{80}Fe_{20}$ (10 nm)/Ta (5 nm) thin film as a function of IP field to 0.94 T at frequencies of 30, 32, 34, and 36 GHz**

Compatibility to NanOsc specific parts

	Cables		Co-planar waveguide (CPW)	
Frequency	NanOsc PN	Description	NanOsc PN	Description
18 GHz	55100	RF coaxial cables, length 36" (18 GHz)	00801	CPW large magnet (18 GHz)
40 GHz	55101	RF coaxial cables, length 36" (40 GHz)	00802	CPW large magnet, 2.92 mm (40 GHz)

Software

MeasureLINK™-MCS Software configuration for the NanOsc FMR

Lake Shore Cryotronics has added an FMR measurement option to both the 8600 VSM (vibrating sample magnetometer) and the MCS-EMP (electromagnet platform) by integrating the NanOsc FMR solution into each of these platforms. This document covers the installation and integration of the NanOsc and Lake Shore software packages.

System layout

The 8600 Series VSM system and the MeasureReady® MCS-EMP system share a common electromagnet but have separate field control and software systems. The 8600 system relies on the 737 VSM controller for field control, and uses 8600 Series VSM software which is highly optimized for magnetic measurements. The MCS-EMP system utilizes the F71/41 teslameter for field control, and uses MeasureLINK™-MCS software to support a wide range of configurable measurements.
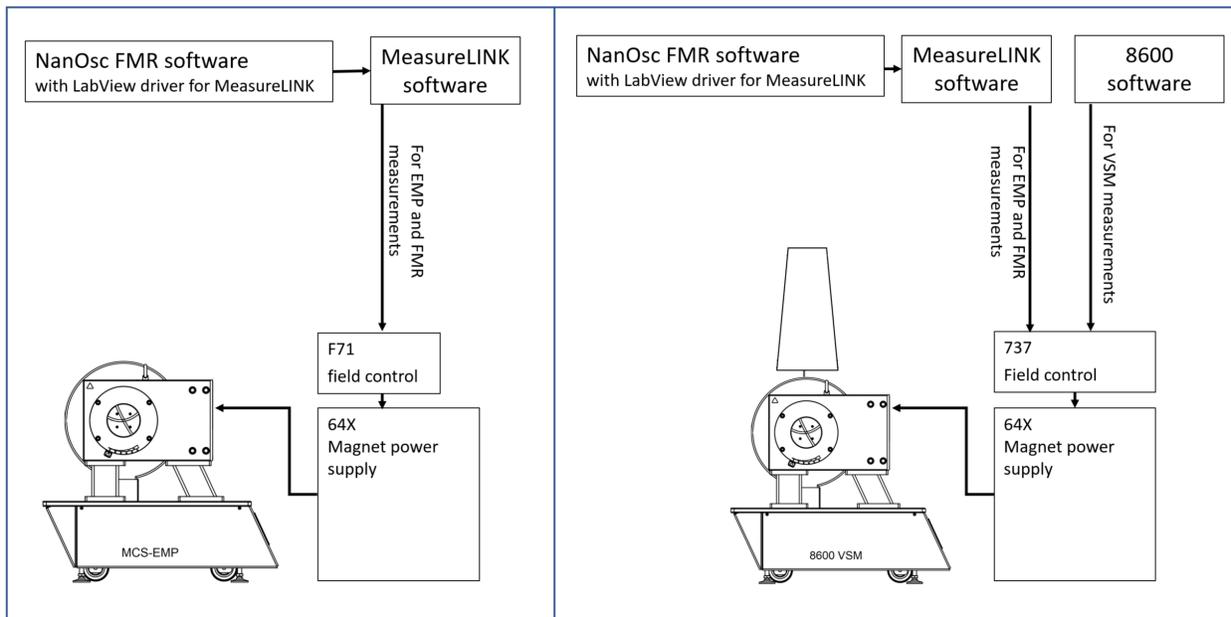
Figure 3: **System architecture, including the integrated FMR.**
Left: MeasureReady® MCS-EMP system; Right: 8600 Series VSM system is shown on the right.

NanOsc has a version of their standard software that has been modified to include a LabView driver, which enables the NanOsc FMR software to control the electromagnet directly through the MeasureLINK control API. In this case, MeasureLINK software performs the magnet field control, and NanOsc software controls the field setpoints to execute the FMR measurement.

NOTE: The NanOsc instrument and standard software can supply a +/- 10V signal to control the electromagnet directly. However, this requires re-wiring the electromagnet and field controller each time the VSM/EMP operation is switched. In the control scheme shown above, the VSM or EMP measurement option can be used interchangeably with no system wiring changes required.

MeasureLINK™-MCS Software

Operation of the NanOsc FMR on the Lake Shore 8600 Series VSM system or the MeasureReady® MCS-EMP system requires the installation of MeasureLINK-MCS software. For the MCS-EMP system, MeasureLINK software will be pre-installed before delivery and should be ready to use. For the 8600 VSM system, MeasureLINK will need to be installed and configured in addition to the 8600 Series VSM software.

MeasureLINK Installation

1. *Prequisites.* Download and install the following from the Lake Shore Software page:
   https://www.lakeshore.com/resources/software
   a. The Lake Shore USB driver. This should be done to allow the MeasureLINK software to correctly identify any Lake Shore hardware connected to the system.
   b. The most current release of MeasureLINK-MCS software.
   c. The MeasureLINK-MCS field control application pack should also be downloaded. This will add the necessary field control instrument drivers that are need for the FMR application.

2. *Install.* Run the MeasureLINK install program. To install the program for all users, Administrator access will be required.

3. *Activation.* The standard MeasureLINK software is free of charge but does require the user to activate the product for each installation. The download process requires a valid e-mail address where the activation code will be e-mailed automatically. To activate MeasureLINK:
   a. In MeasureLINK-MCS software, click the **Utilities** tab and then select **License Management**.
   b. If the computer is connected to the Internet, fill in the required fields in and then click **Activate**. If internet access is not possible, enter the information and click **Copy to clipboard**. Then e-mail the information to support@lakeshore.com.
   c. A license file will be returned by e-mail.

4. *Install application packs.* MeasureLINK installation includes several optional application packs that extend the functionality of MeasureLINK software. These packs include the drivers needed to communicate with the instruments, prewritten scripts, and documentation. The FMR applications requires the field control application pack. To install an application pack:
   a. In MeasureLINK-MCS software, click the **Utilities** tab and then click **Application Packs**.
   b. Click the **Install** button on the ribbon.
   c. A dialog box appears. Navigate to the location of the downloaded application pack file, and then click **Open**.
   d. A dialog box appears, confirming the installation. Click **OK**.
   e. The application pack is listed in bold type, showing that it is staged for installation when MeasureLINK is restarted.
   f. Restart the MeasureLINK software to complete the application pack installation process.
   g. All successfully installed application packs are listed in the **Installed Application Pack** table.

5. *Instrument Configuration.* Depending on the platform being used, the correct field control instrument driver must be installed. To install a driver:
   a. In MeasureLINK-MCS software, click the **Home** tab and then click **System Configuration**.
   b. Click the **Configuration** button on the ribbon, then select an existing or new configuration.

    c.   Click the **Add** button to display a list of all available devices. The 737 VSM controller and F71/41 teslameter drivers will be present in the list if the field control application pack is installed correctly.

    d.   For the MCS-EMP system, select the F71/41 teslameter. For the 8600 VSM system, select the 737 VSM controller, then click **OK**.

    e.   Once added to the configuration, click the field controller in the list to complete the configuration. There are three tabs that need to be filled out:

- General
- Communications: ensure that the correct communications protocol and settings are entered on the communication sub-tab
- Field: the Field tab contains many instrument specific parameters that can be set on startup.

    f.   When settings have been updated, click the **Apply Configuration** button to apply the updated configuration to MeasureLINK.

    g.   Click the **Save** button to save the currently selected system configuration.

6.   ***Monitor window.*** The status and state of the driver can be monitored and controlled from the monitor window. When a system configuration containing the field control driver is applied, the monitor window will update automatically. The field control window contains controls to connect to the instrument, change the setpoint, and enable the closed loop field control option. This window also displays the real-time readings from the controller.

At this point, MeasureLINK is ready to coordinate field control with the NanOsc FMR software.

Unpacking and installation
1. Remove the GlideLOCK™ plate and FMR mount from the box.
2. Unscrew the IP body screws and CPW screws, indicated by the green arrows below.
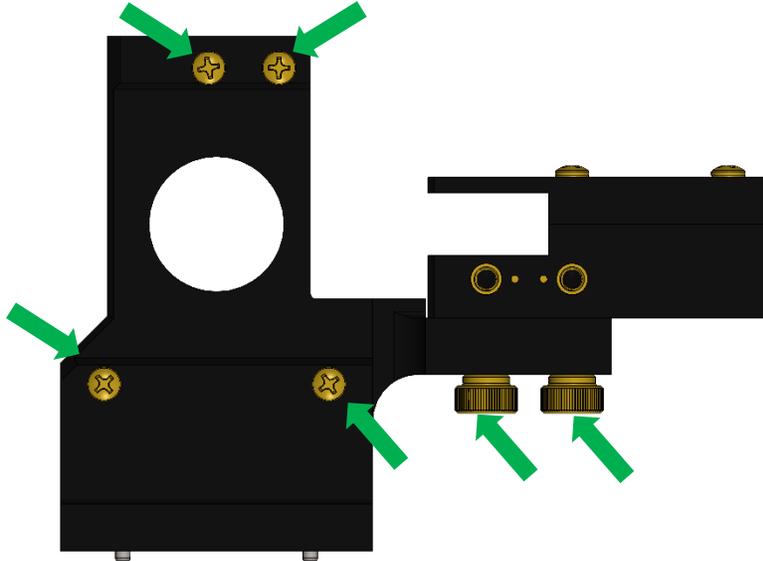
Figure 4: **Unpacking and installation**

3. Install and secure the Helmholtz coils using Kapton tape.
   NOTE: The coils are delicate; handle them with care and do not cut them.

   a. Insert the coil through the hole and apply tape as shown.
   b. Align the coil to the FMR body Helmholtz mount and press it into the tape.
      NOTE: The coils need have the same rotation direction. See the NanOsc user's manual.
   c. Repeat the process for second coil. Remove the tape in the center of the coil for better viewing.
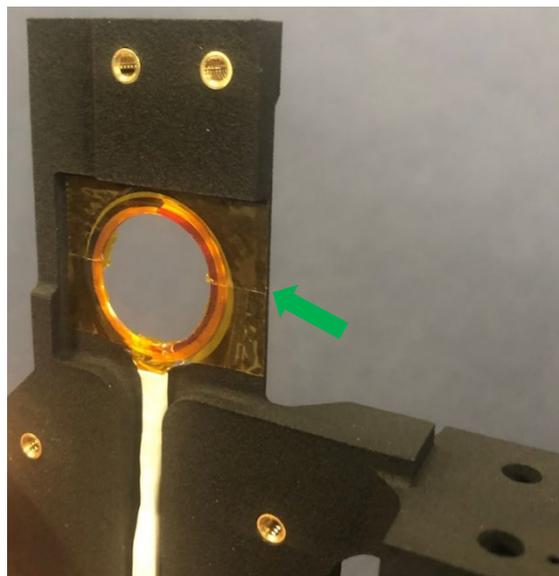
Figure 5: **Installing the coils**

4. Reassemble the main body using the IP body screws that were previously removed.
5. Guide the banana plugs through the GlideLOCK plate center holes.
6. Assemble the option into in-plane configuration using the screws from the body hardware bag.
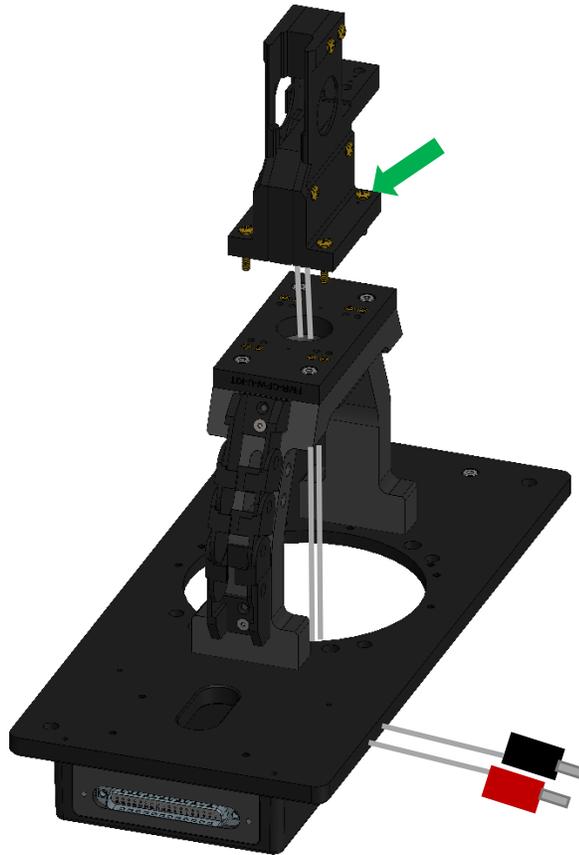
Figure 6: **Assembly**

7. Secure the Helmholtz wires using zip ties to tie the option down on top of the GlideLOCK plate. Do not over tighten.

Connections and wiring

Configurations

In-plane
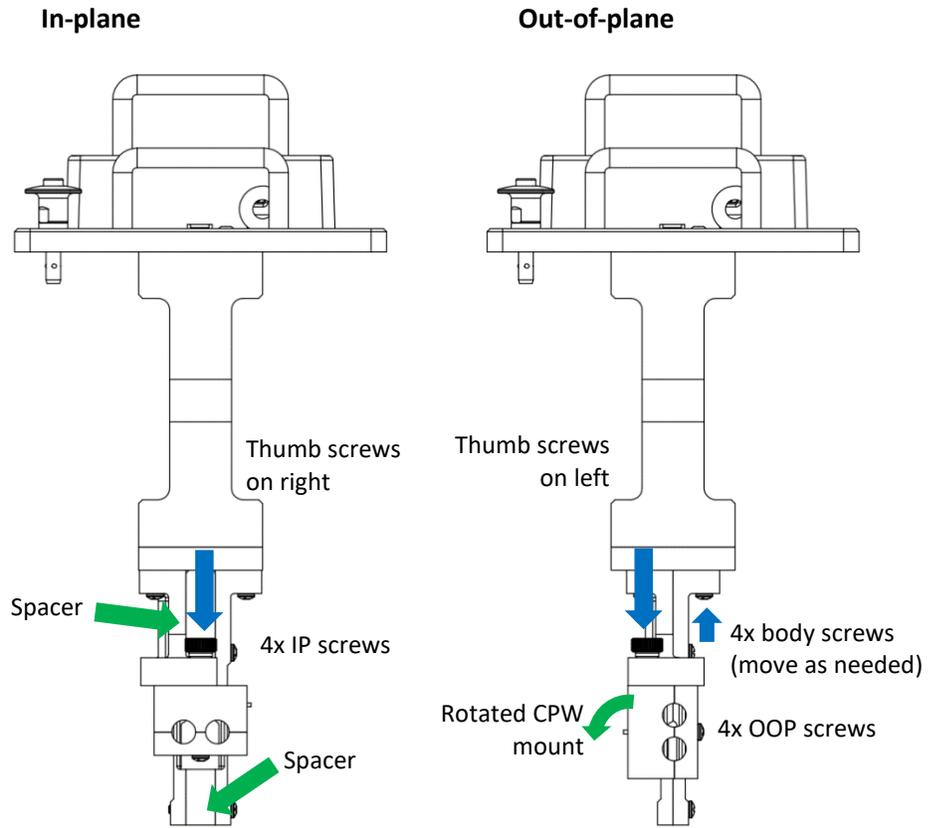
Out-of-plane

Figure 7: **Configurations.**
Left: in plane; Right: out of plane

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Co-planar waveguide (CPW) clamp

1. Connect the wires to the CPW using NanOsc recommended best practices. Select the clamp which matches the wire type used.
2. Screw the clamp together with the RF cables so that the wires re snug but slide.
3. Use a ruler or flat edge to locate the depth of the insertion on the CPW; tighten the screws to the set position.

Flat edge or ruler
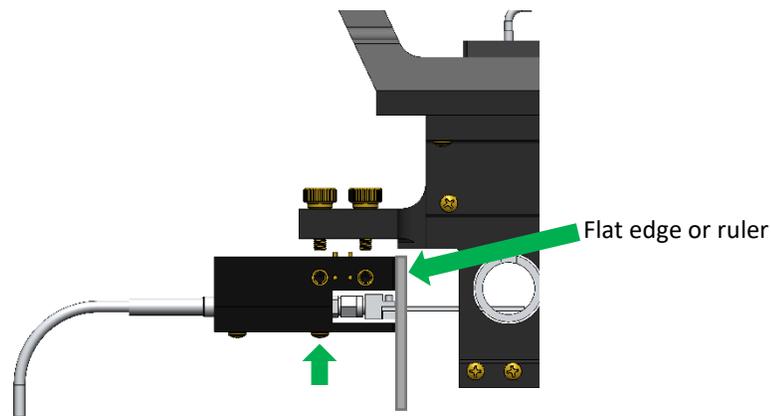
Figure 8: **Co-planar waveguide (CPW) clamp**

4. Apply the sample as guided by the NanOsc user's manual, film side down.
5. Attach the CPW clamp to the main body with the thumb screws.

Attaching to the magnet

Gap Setting

Model	Magnet gap	IP maximum field	Magnet gap	OOP maximum field
MCS-EMP-4	4	1.69 T	2	2.41 T
MCS-EMP-7	4	2.34 T	2	2.91 T
8604 VSM	5	1.54 T	3	1.96 T
8607 VSM	5	2.23 T	3	2.55 T

GlideLOCK™ installation

1. Place the GlideLOCK plate onto the GlideLOCK tray, in the extended position.
2. **MeasureReady® MCS-EMP only:** Lower the Hall sensor to where it is safe to push forward the FMR option's GlideLOCK plate.
   CAUTION: Use caution while sliding in the GlideLOCK plate, as it is easy to damage the MCS-EMP Hall sensor.
   a. Pull out the pull adjuster to more easily access the option in the gap.
   b. Push the insert forward to where it is fully inserted.
   c. Adjust the Hall sensor so that it is located in the center field location, just below the CPW.
   d. Gently pull out the insert and inspect it to see if the Hall sensor is in the correct position.
   e. Gently reinsert the GlideLOCK insert, making sure not to contact the Hall sensor.
3. Set the magnet gap according to the test mode.
4. Slide the FMR option's GlideLOCK plate forward and begin the test.

Operation

Follow the NanOsc user's manual.

Service

The most direct and efficient means of contacting Lake Shore is to complete the online service request form at http://www.lakeshore.com/Service/. Provide a detailed description of the problem and the required contact information. You will receive a response within 24 hours, or the next business day in the event of weekends or holidays.

If you wish to contact Systems Service by mail or telephone, use the following:

Lake Shore Cryotronics, Inc.
575 McCorkle Blvd.
Westerville, Ohio 43082 USA
Phone: 614-891-2243 (option 6)
Fax: 614-818-1608
e-mail: support@lakeshore.com