Design and test of a combined DC and high frequency measurement setup

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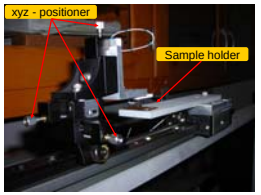
Introduction:

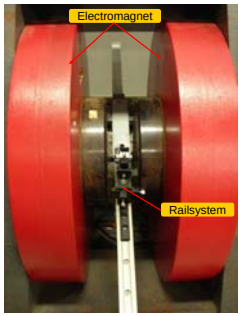
The injection of DC currents with high densities into nanoscale magnetic multilayer systems has been shown to produce microwave oscillations of the magnetization in the magnetic layers caused by spin torque [1].
Conversely the injection of microwave currents is known to produce a DC response [2].
When multiple nanoscale devices are in close proximity they have been found to mutually phase lock, i.e. they synchronize – this provides a way to achieve higher output power of the devices [3].
Recently a paramagnetic maser driven by spin injection has been proposed [4]

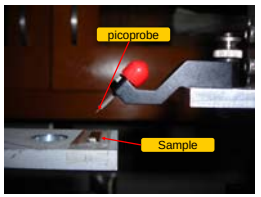
Mechanical setup:



The image on the left shows the railsystem that allows fine positioning of the probe with respect to the sample surface.

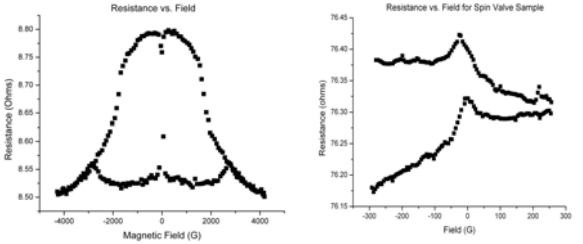
The entire system slides between the pole pieces of an electromagnet as shown on the right.





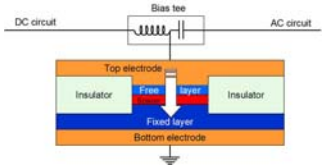
On the left the picoprobe that is used for combined DC and microwave measurements is mounted on the railsystem.

DC measurements



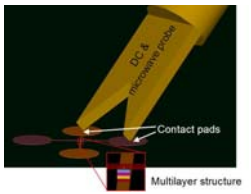
The plot above left shows a test dc measurement using the probe system on a *Ta5/Cr5/CoPt5/Ru0.8/CoFe2/Cu2.5/CoFe1/Ta5* spin valve (thicknesses in nm). Above right is a similar measurement on a 100nm NiFe layer, where Joule heating has caused a drift in the measurement

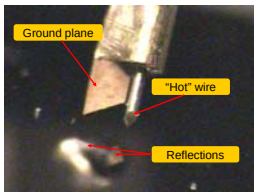
Combined DC and microwave contacts:



In order to carry out combined DC and microwave measurements the two circuits are separated using a Bias tee.

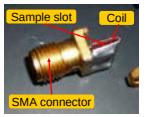
The contacts to the device under test are made with a precision microwave probe (picoprobe). The figure on the right shows a schematic of the contacting scheme.



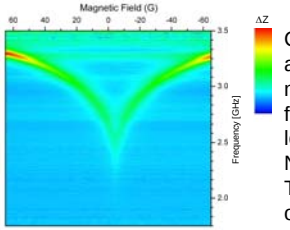


The image on the left shows the picoprobe just prior to making contact with the sample surface. The flexible ground contact, the central conductor („hot“ wire) and their reflections from the sample surface are visible.

Microwave measurements



Improved coil design for permeability measurements:
- Frequencies up to 4.5 GHz
- Sample size 8mm × 4 mm



Change of the coil impedance as a function of the external magnetic field and microwave frequency. The coil was loaded with a 20nm thick NiFe film.
The ferromagnetic resonance of the film is clearly visible.

References:

[1]: J.C. Slonczewski, Magn. Magn. Mater. **159**, L1 (1996).
[2]: A.A. Tulapurkar et al., Nature **438**, 339 (2005).
[3]: S. Kaka et al., Nature **437**, 389 (2005).
[4]: S.M. Watts, B.J. van Wees, PRL **97**, 116601 (2006).

Conclusion & Outlook:

- Developed a mechanically stable setup for making reliable DC and microwave contacts.
- DC measurements show GMR effect and the effect of Joule heating.
- Microwave contact spacing of 500 μm.
- Improved microwave coil design capable usable up to 4.5 GHz for permeability measurements.
- Microwave measurements show the field dependence of the ferromagnetic resonance.

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