ESRF	**Experiment title:** ***TRANSVERSE XDMR PHASE-LAG BETWEEN FERRIMAGNETICALLY COUPLED SUBLATTICES***	**Experiment number:** **HE-2709**
Beamline: **ID-12**	**Date of experiment:** from: 23-JUL-2008 to: 30-JUL-2008	**Date of report:** 18-FEB-2009
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1. XDMR OF A FERRIMAGNETIC GdIG SINGLE CRYSTAL

Even though gadolinium iron garnet (GdIG) and yttrium iron garnet (YIG) have essentially the same crystal structure, the FMR spectra of GdIG are considerably more complicate because, in addition to the strong exchange field acting on the two non-equivalent iron sites, there is a much weaker, temperature-dependent antiferromagnetic coupling between the Fe^{3+} ions and the Gd^{3+} ions. Although the two iron sublattices are most often treated (artificially) as one in FMR experiments, the problem remains quite complicate.

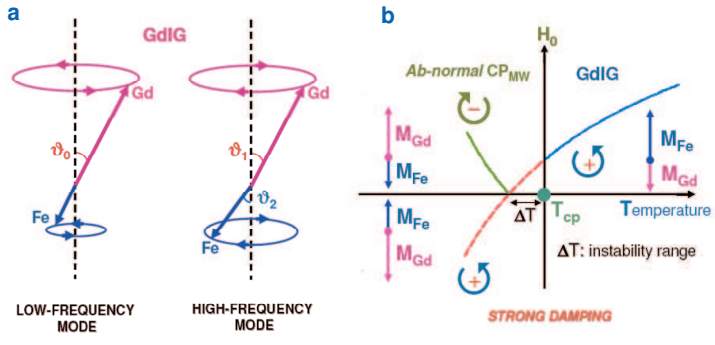

Figure 1: a) Low- and high-frequency precession modes in GdIG. b) The magnetization components are expected to precess with opposite chirality on both sides of the compensation temperature T_{cp} = 284K.

As illustrated with Figure 1a, two different precession modes can be excited which have the opposite chirality: in the low-frequency mode which is not influenced by exchange, the two magnetization components would precess with the same opening angle (ϑ_0) and the same phase (Φ_0) as in a ferromagnet, while this is not true for the high frequency (exchange-coupled) mode. Figure 1b shows that there is an instability range near the compensation temperature (T_{cp} = 284K) at which the FMR linewidth becomes extremely broad.

Let us emphasize that, as illustrated with Figure 1b, the precession should have the opposite chirality on both sides of T_{cp} : it was precisely the aim of the present proposal to check whether one could use the *phase information* of XDMR experiments recorded in the transverse detection mode[1,2] to probe such a change of chirality.

2. XDMR SPECTRA RECORDED ABOVE AND BELOW T_{cp}

In 2007-2008, the ID12 team has invested much time and effort in designing and commissionning a new, fully modular XDMR spectrometer. Spectra of very high quality were recorded in the transverse detection geometry on YIG thin films using an advanced super-heterodyne detection using a 180° biphase modulation technique (BPSK). The same experimental configuration was used to record XDMR spectra at the Fe K-edge and Gd L-edges with a GdIG single crystal borrowed from J. Ben Youssef (*Université de Bretagne Occidentale* in Brest, France). XDMR experiments GdIG were much more difficult due to the broad linewidth of the FMR spectra (e.g. ΔH = 280 Oe at 200K) as compared with YIG (i.e. ΔH = 7.5 Oe at 300K). Moreover, there was the handicap that the incident microwave power had to be kept below 1W during the allocated beamtime due to the accidental failure of one microwave component.

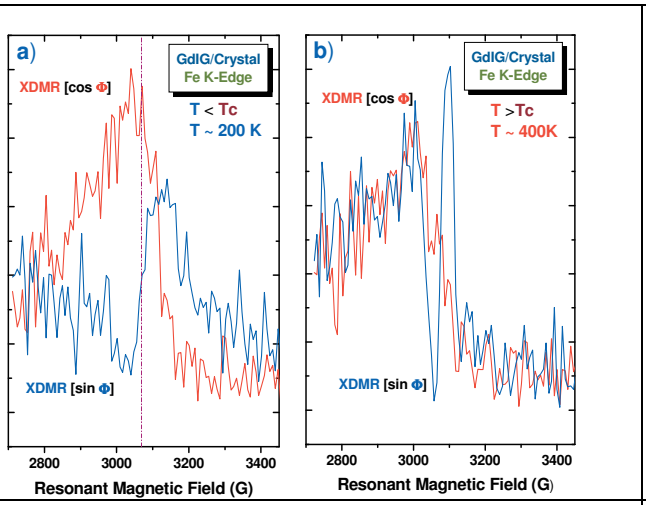

Figure 2: Quadrature phase components of XDMR spectra recorded at the Fe K-edge with a GdIG crystal: a) below T_{cp} ; b) above T_{cp}. At 400K, only the broad component ∝ sin Φ has the opposite sign but, there is an (unexpected) additional signa with a narrow linewidth.

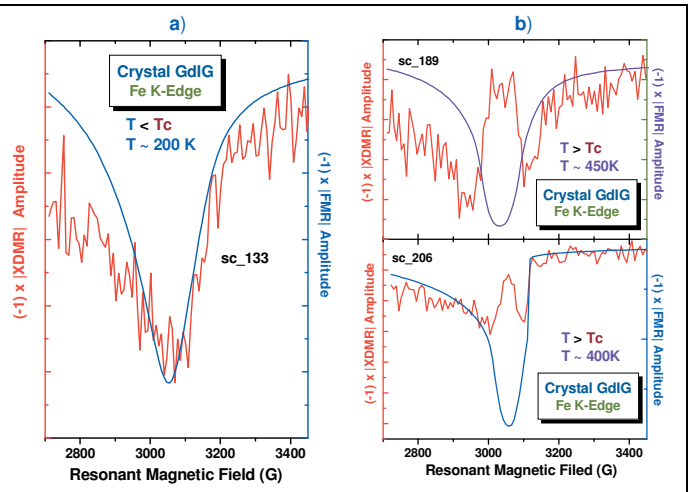

Figure 3: Comparison of |XDMR| and |FMR| spectra a) below T_{cp} ; b) above T_{cp}. Split lines were systematically found above the compensation temperature but not below.

The XDMR spectra shown in Fig. 2 refer to components in precession phase quadrature: they were recorded at the Fe K-edge either well below (a) or well above (b) T_{cp}. There is obviously a change in the chirality of the precession of the *orbital* magnetization components at the iron sites because the component ∝ sin Φ has the opposite sign at 200K and 400K, whereas this is not the case for the component ∝ cos Φ. What was, however, totally unexpected is the appearance of a strong additional signature at resonance, with a rather narrow linewidth.

In a further effort to figure out what could be the origin of this additional signature, we have reproduced in Figure 3 the modulus of the relevant complex vector. Whereas the |XDMR| and |FMR| plots look rather similar at low temperature (200K), this is not the case at high temperatures (e.g. 400K or 450K) where the XDMR line is clearly split. Recall that the XDMR spectra recorded at the Fe K-edge result from two non-equivalent magnetic sublattices associated with Fe atoms in octahedral coordination (16a sites) or tetrahedral coordination (24d sites) and antiferromagnetically coupled. Indeed, the forced precession of the all *orbital* magnetization components should be fully coherent, but it is our interpretation that a destructive interference of the two oscillating XDMR signals could be envisaged under specific phase-lag conditions[2].

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