ESRF	**Experiment title:** *PRECESSION DYNAMICS OF ORBITAL & SPIN MAGNETIZATIONS IN SUBSTITUTED YIG THIN FILMS*	**Experiment number**: **HE-2243**
Beamline: **ID-12**	**Date of experiment**: from: 31-OCT-2006 to: 07-NOV-2006	**Date of report**: 03-MAR-2008
Shifts: **18**	**Local contact(s)**: **A. ROGALEV and F. WILHELM**	*Received at ESRF:*

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1. X-RAY DETECTED MAGNETIC RESONANCE IN IRON GARNET THIN FILMS

X-ray Detected Magnetic Resonance (XDMR) is a novel spectroscopy[1,2] in which ***element selective*** X-ray Magnetic Circular Dichroism (XMCD) is used to probe the resonant precession of the magnetization caused by a strong microwave pump field $\mathbf{h_1}$ perpendicular to the static bias field $\mathbf{H_0}$. As illustrated with Figure 1, two different geometries can be envisaged to probe the precession dynamics.

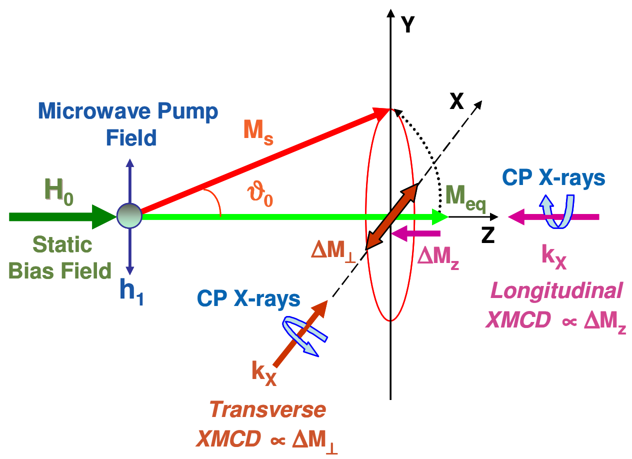

Figure 1

In the *longitudinal* geometry[1], the wavevector $\mathbf{k_x}(\parallel)$ of the incident circularly polarized X-rays is parallel to $\mathbf{H_0}$. The precession induces a steady-state change ΔM_z of the magnetization probed by XMCD. The XDMR signal is then a 2nd order effect proportional to the microwave power and that probes how fast the damping torque drives the magnetization $\mathbf{M}$ back to $\mathbf{M_{eq}}$.

In the *transverse* geometry[1], the wavevector $\mathbf{k_x}(\perp)$ of the X-rays is perpendicular to both $\mathbf{H_0}$ and the microwave pump field $\mathbf{h_1}$. XMCD then probes the transverse component of the magnetization $\mathbf{\Delta M_\perp}$ which oscillates at the microwave resonance frequency: this requires a very special instrumentation[1].

The information which is most easily accessible from *longitudinal* XDMR experiments is the (*apparent*) opening angle of precession ϑ_0 that can be obtained from[1,2] : $\Delta\sigma_{XDMR}\,(k_{//})/\Delta\sigma_{XMCD}\,(k_{//}) \approx -1/2\,\tan^2\vartheta_0$. The aim of proposal HE-2243 was to check how far the measured opening angle of precession could vary at different absorbing elements. High quality yttrium iron garnet (YIG) thin films can be grown by LPE on well selected GGG substrates. On substituting partially the trivalent Y^{3+} cations with "diamagnetic" rare-earth

cations (La^{3+}, Lu^{3+}) or Bi^{3+}, one may taylor the magnetic (and magnetooptical) properties of these films for specific technological applications requiring either perpendicular or in-plane magnetization.

2. ELEMENT-RESOLVED XMCD AND XDMR SPECTRA

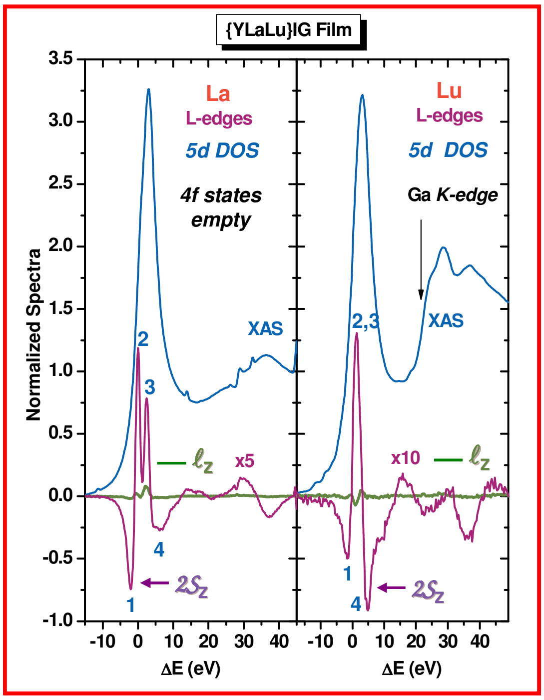

Figure 2

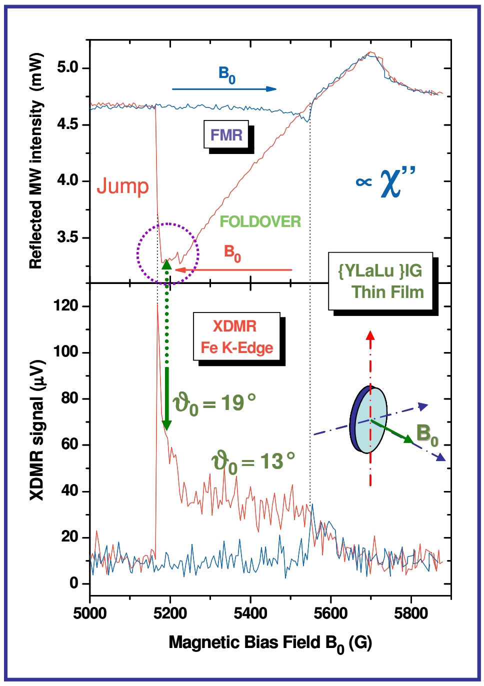

Figure 3

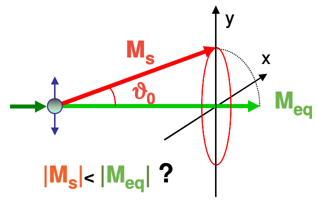

Figure 4

$\{Y_{1.3}La_{0.47}Lu_{1.3}\}Fe_{4.84}O_{12}$

Fe K-edge	E_1
Energy (eV)	7113.7
$\Delta\sigma_{XDMR}$/atom	$2.65\ 10^{-4}$
$\vartheta_{ORBITAL}$	19.1°
La L_{III}-edge	E_1
Energy (eV)	5484.5
$\Delta\sigma_{XDMR}$/atom	$3.99\ 10^{-5}$
ϑ_{SPIN}	4.7°

Table 1

High quality thin films of "*pure*" YIG and rare-earth substituted $\{Y_{1.3}La_{0.47}Lu_{1.3}\}$IG garnets were grown by LPE in Brest. Detailed XMCD studies were carried out at the Fe K-edge as well as at the relevant Y, La and Lu $L_{2,3}$-edges. Obviously XMCD cannot resolve the contributions of the two ferrimagnetic coupled Fe sub-lattices with S_4 (24d) or S_6(16a) coordination, but E1 selection rules favor the tetrahedral sites. Anyhow, the Fe K-edge XMCD arises from magnetized 4p- or 3d- projected *orbital* DOS. In contrast, XMCD at the Y, La, Lu L-edges predominantly arises from 4d- or 5d-projected *spin* DOS (Fig. 2) that are magnetically polarized along the direction of the bias field H_0 due to oxygen mediated superexchange coupling with the iron sublattices. Note that the corresponding integrated spin moments are, however, very weak.

XDMR measurements were carried out in the *longitudinal* geometry at these various edges. In these experiments performed at high pumping power (28 dBm), the resonance field approached closely the *foldover* jump. Whereas the opening angles of the precessing spin components were systematically less than 6° at the Y, La, Lu edges (see table 1), surprisingly we measured under strictly the same experimental conditions an (*apparent*) opening angle as large as 19.1° for the orbital components precessing at the Fe sites for the rare-earth substituted film $\{Y_{1.3}La_{0.47}Lu_{1.3}\}$IG. Obviously this confirms that ϑ_0 is not uniformly identical at *all* absorbing sites probed with XDMR. Moreover, as illustrated with Fig. 3, we measured a spectacular *increase* of ϑ_0 very near the foldover jump field. It is our interpretation that, under such conditions, the XDMR experiment does not allow us anymore to determine the true opening angle of precession: this is because, according to Suhl's theory of Spin-Wave instability, we are in a non-linear regime where 2nd order instability processes (*i.e.* 2-magnon annihilation) develop and cause a premature saturation of ϑ_0 and a *reduction of the effective length* M_S of the precessing vector (Fig. 4). Obviously such a decrease of M_S will cause an *increase* of ΔM_Z which is directly probed by XMCD: this is fully consistent with the measurement of too large (apparent) angles of precession.

REFERENCES

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2. J. Goulon, A. Rogalev, F. Wilhelm, N. Jaouen, Ch. Goulon-Ginet and Ch. Brouder, *Eur. Phys. J.* B **53**, (2006), 169-184.