ESRF

Experiment title: *X-RAY DETECTED MAGNETIC RESONANCE USING LINEARLY POLARIZED X-RAYS*	**Experiment number:** HE-3139

Beamline: ID-12	**Date of experiment:** from: 20-JAN-2010 to: 26-JAN-2010	**Date of report:** 11-FEB-2011
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1. XMLD AS A NON-LINEAR PROBE OF MAGNETIZATION DYNAMICS ?

So far, only X-ray magnetic *circular* dichroism (XMCD) was used to *probe* locally the resonant precession of either orbital or spin magnetization components in response to a strong microwave field $\mathbf{h_p}$ oscillating along a direction which is orthogonal to the magnetic bias field $\mathbf{H_0}$ in standard FMR experiments that are most often carried out in the so-called perpendicular pumping geometry[1,2]. It was the aim of proposal HE-3139 to explore whether one could exploit X-ray Magnetic ***Linear*** Dichroism (XMLD) to probe new aspects of the dynamics of the resonant precession[2,3].

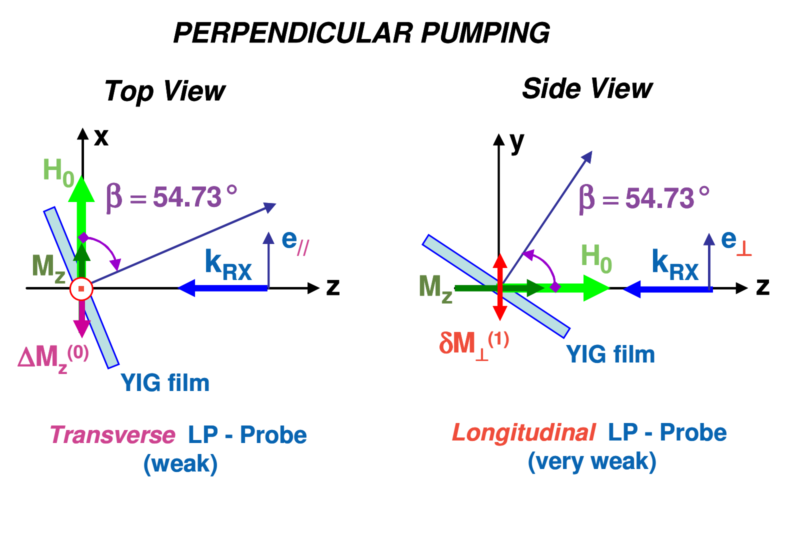

Figure 1: Alternative detection schemes for XDMR experiments under perpendicular pumping using Linearly Polarized (LP) X-rays. The normal to the film was arbitrarily rotated at the magic angle. The *transverse* geometry for the X-ray probe looks preferable (see text).

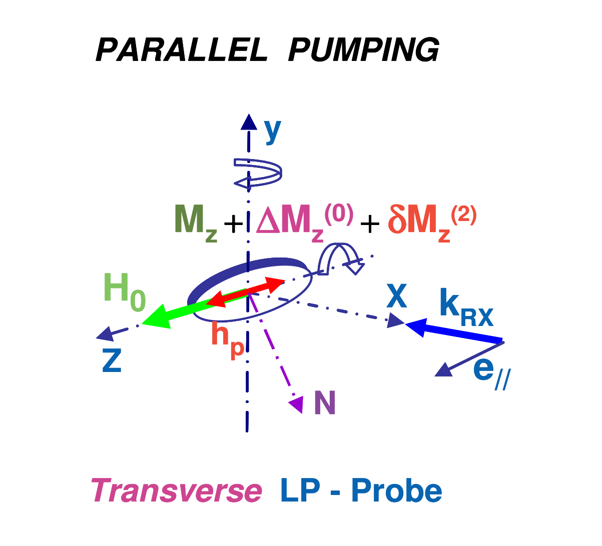

Figure 2: Configuration ultimately preferred for LP-XDMR experiments in parallel pumping geometry. Either *oblique* or *in-plane* parallel pumping is possible if the film is rotated around the Y-axis.

Whereas XMCD is time-reversal ***odd***, XMLD is time-reversal ***even***, *i.e.* its sign does not depend on the direction of the static bias field $\mathbf{H_0}$. This implies that XMLD can only probe *non-linear* susceptibilities $\chi^{(0)}$ and $\chi^{(2)}(2\omega)$. Depending on the pumping geometry, one may probe a variety of non-linear processes of different nature: 2nd order effects involving the uniform precession mode (k=0) are best investigated in perpendicular pumping whereas non-linear processes resulting in the direct excitation of spin-waves ($k \neq 0$) are most easily investigated in *parallel* pumping geometry[2,4]. *Oblique* parallel pumping is a convenient way to combine both options since the corresponding non-linear processes contribute to well resolved distinct spectral branches. Owing to the weakness of the expected XDMR signal, the *transverse* detection geometry did look to us most favourable since we could hope to measure *cross-terms* in the series expansion :

$$\Delta\sigma_{XMLD} \propto \; [M_z]^2 + 2M_z.\Delta M_z^{(0)} + 2M_z.\delta M_z^{(2)}(2\omega) + \; [\Delta M_z^{(0)}]^2 \; + \ldots \qquad (1)$$

in which M_z refers to the equilibrium magnetization, $\Delta M_z^{(0)}$ being the time-invariant change of M_z probed with XMCD in longitudinal XDMR geometry, whereas $\delta M_z^{(2)}(2\omega)$ is another nonlinear term due to elliptic precession. The highest priority was thus given to experiments carried out in parallel pumping geometry on the same YIG/GGG thin film that was used for our previous CP-XDMR experiments. What made such experiments particularly challenging was the ***very weak*** intensity of the *static* XMLD signatures measured at the Fe K-edge in YIG given that σ_{XMLD} hardly exceeded 2.5×10^{-4} of the edge jump[5].

2. RESULTS

In the two PSD spectra reproduced in Fig 3, one would expect the LP-XDMR signatures to show up again as AM side-bands of the X-ray macrobunch repetition frequency F_0 = 355.043 kHz. Unfortunately, the very low level (*ca.* –115.dB) of the detected sidebands makes the story rather inconclusive because, at high pumping power, we could never get rid of a weak modulation residual peaking at *ca.* –117 dB even when the X-rays were switched off.

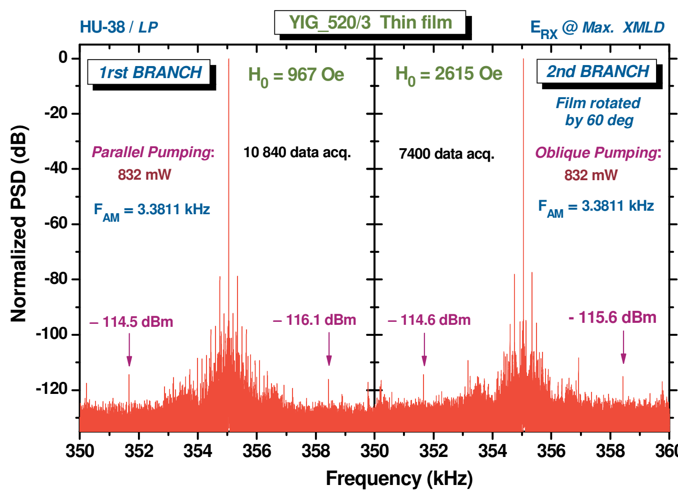

Figure 3: In these normalized VSA PSD spectra, modulation sidebands are visible at $F_0 \pm F_{AM}$ where F_{AM} = 3.381 kHz is the frequency of the amplitude modulation (AM) of the microwave pumping power, the level of which was quite high (832 mW). The X-rays photons generated by the helical undulator HU-38 were ***linearly*** polarized along the direction of $\mathbf{H}_0$ and their energy was tuned to the maximum of the weak, static XMLD signal measured in the Fe K-edge prepeak.

In parallel pumping geometry, the ***first branch*** of the microwave absorption spectrum is peaking at *low* bias field (967 Oe): it is assigned to the parametric excitation of two spin waves with precession frequency $\omega_p/2$ and wave vector $\pm$ **k**.

The FMR-like ***second branch*** is found at much higher bias field (2615 Oe). The corresponding PSD spectrum was recorded in *oblique* pumping geometry, i.e. with the normal to the film rotated by ca. 60° around the vertical (Y) axis.

Thus, XMLD does not appear to be a practical way to probe the resonant precession of local magnetization components, at least at the Fe K-edge of YIG thin films: the interference term $M_z.\Delta M_z^{(0)}$ predicted by eqn (1) can contribute at best to a LP-XDMR signal lying *ca.* 30 dB below the level of the XDMR signal $\propto \Delta M_z^{(0)}$ measured in longitudinal detection geometry with CP X-rays under similar pumping conditions. This led us to conclude that the effective operator associated with XMLD at the Fe K-edge[6], *i.e.* the ***electric charge quadrupole*** Q_{ZZ} component is very weakly affected by the precession of the local magnetization components.

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