ESRF	**Experiment title:** *X-RAY DETECTION OF SPIN WAVES RESONANCES EXCITED IN PARALLEL PUMPING GEOMETRY*	**Experiment number:** HE-3286
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1. IN-PLANE & OBLIQUE PARALLEL PUMPING GEOMETRIES

Microwave ***Parallel Pumping*** (PP) is commonly used for the parametric excitation of exchange spin waves under *non-linear* coupling processes[1-6]. When the microwave pump field $\mathbf{h_p}$ is parallel to the equilibrium magnetization $\mathbf{M}_{eq}$, no uniform precession mode ($\mathbf{k}$=0) can be excited but Schlömann[3a] pointed out that spin waves ($\mathbf{k}\neq 0$) could be resonantly excited at half the pumping frequency (½ ω_p) due to the *elliptical* precession of thermaly activated magnons. For thin films, the latter requirements are most easily satisfied for *in-plane* magnetization with $\mathbf{h_p} \parallel \mathbf{H_0}$ (Fig.1).

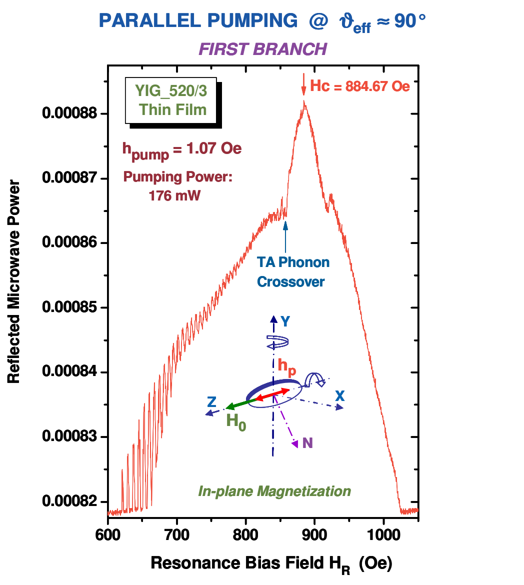


Fig. 1 PP microwave absorption spectrum of a YIG thin film recorded using a special microwave TE_{102} cavity designed to satisfy the requirement: $\mathbf{h_p} \parallel \mathbf{H_0} \perp \mathbf{N}$. Note the superstructure of narrow exchange-driven spin waves resonances[4-5].

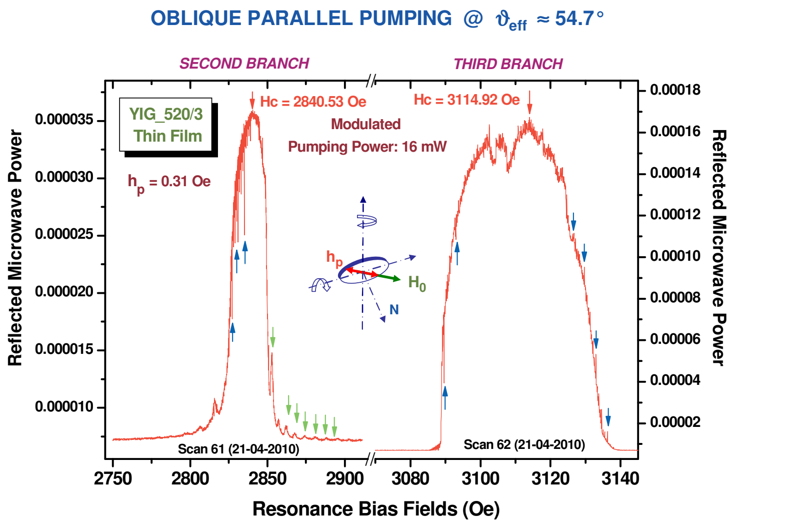


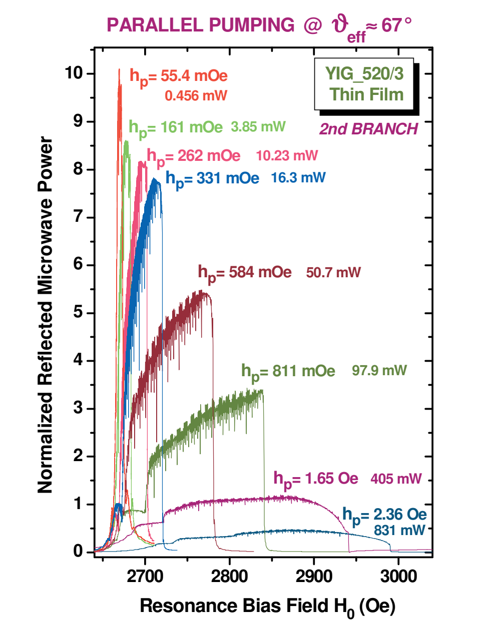
Fig. 2 In oblique PP experiments, the condition $\mathbf{h_p} \parallel \mathbf{H}_0$ is preserved but $\mathbf{H}_0$ is *not* parallel to the film. Additional branches grow up at higher bias field when $\mathbf{h_p}$ is not strictly parallel to the *effective* field $\mathbf{H}_{eff}$ of precession. Such branches also exhibit a superstructure of extremely narrow resonances that *cannot* be anymore assigned to exchange spin-waves.

In *oblique* PP, *i.e.* when $\mathbf{H_0}$ is slightly inclined with respect to the film plane, there is still a weak (low-field) branch due to the parametric excitation of spin waves, but one or even two additional branches can be detected at higher resonance bias fields (Fig.2). The observation of a FMR-like branch indicates that either the *instantaneous* precession axis is not strictly parallel to the external field $\mathbf{H_0}$, or that the pump field $\mathbf{h_p}$ is not itself uniform inside the resonant cavity[2]. The origin of the 3rd branch is not yet fully understood.

One may observe on the low-field side of the 1rst branch a very dense superstructure assigned to standing wave resonances of exchange spin-waves since the peak spacing is $\propto [H_c - H_{bias}]^{1/2}$. Surprisingly, a rich superstructure of resonances was also observed on the 2nd and 3rd branches but with extremely narrow linewidths (< 0.3 Oe) : clearly, the latter resonances cannot be assigned anymore to exchange spin waves and it was an important subsidiary point for us to clarify their origin.

2. XDMR SPECTRA RECORDED IN OBLIQUE PARALLEL PUMPING

Up to now, we failed to detect any XDMR signal in the spectral range of the first branch. Further experiments carried out at rather high pumping power (800 mW) in oblique PP geometry revealed that unexpectedly intense XDMR signals could be measured in the *longitudinal* detection mode in the range of the FMR-like 2nd branch. Actually, for specific values of the bias field $\mathbf{H_0}$ and of the X-ray excitation energy (E_{RX}), the XDMR signatures were so strong that we could even observe auto-oscillations typically associated with a so-called *pre-chaotic* regime[6].



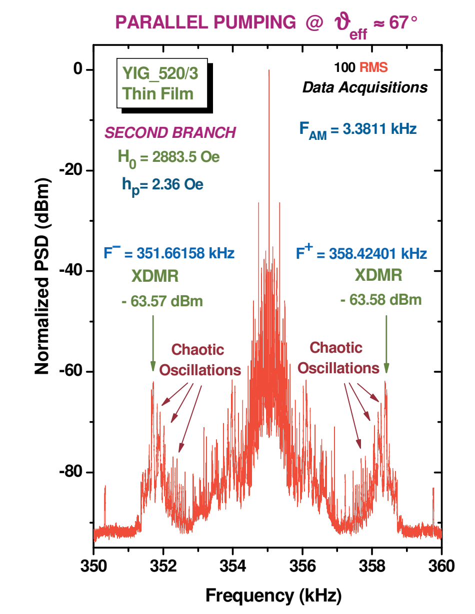


Fig.3 (left)
Not only the second branch gets heavily distorted and very broad for pumping powers above 100 mW, i.e. when h_p> 1Oe, but the ultra-narrow superstructure also tends to become much weaker.

Fig.4 (right)
Under a strong pump field (h_p = 2.36Oe), fairly intense XDMR signatures were measured in the longitudinal detection mode. This XDMR signall was so strong that we could even observe auto-oscillations that are often characteritic of a so-called ***pre-chaotic*** regime[6]. Such auto-oscillations were observed only for selected values of the bias field $\mathbf{H_0}$ and of the X-ray excitation energy E_{RX}. .

It remains to be clarified why we failed to detect any XDMR signal associated with the first branch. Recall that XDMR experiments carried out at the Fe K-edge probe the precession of *orbital* magnetization components not directly affected by exchange interactions. It is indeed a major limitation of the spin-wave theory that the Heisenberg model does not include spin-orbit interactions which are nevertheless essential to describe ***magneto-elastic*** coupling effects. It is the aim of a subsequent project (HE-3564) to confirm the existence in XDMR spectra of a well resolved superstructure due to magneto-elastic resonances which may be particularly strong in the crossover range of the TA phonon and magnon bands[3b,6].

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