Pinning Effects on the Magnetostatic Modes of a Thick Yttrium Iron Garnet Film.

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Summary. — Ferromagnetic-resonance experiments in a 30 μm thick single crystal have led to results which cannot be interpreted in terms of the Sparks theory for the fully unpinned-pinned magnetostatic modes. A generalization of the theory to intermediate values of the pinning parameter (0 < p < 1) has been worked out which seems to be in fair agreement with the experimental data.

1. – Introduction.

In the last few years, a remarkable number of theoretical works has attempted to explain the behaviour of the resonance modes in thin ferromagnetic and ferrimagnetic films (1-5). At the same time, the chemical vapour deposition (6) (CVD) and the liquid-phase epitaxy (7) (LPE) techniques were introduced to grow good-quality single-crystal garnet films. Yttrium iron garnet (YIG) films, particularly, provided very satisfactory samples to check those models. In the related literature, however, ferromagnetic-resonance (FMR)
analyses on YIG epilayers are not numerous and they usually refer to rather thin samples (9,11) (i.e. having thicknesses $S < 12 \mu m$).

From a general point of view, the normal modes of an infinite ferromagnetic film are ordinary spin waves having

\begin{equation}
M = M_\sigma \hat{z} + m(r),
\end{equation}

where $\hat{z}$ is an unit vector along the equilibrium direction of the static magnetization $M_\sigma$, and $m(r)$ is a small transverse microwave component of the total magnetization $M$.

When the spin waves have wavelengths comparable in magnitude with the linear dimensions of the specimen and the exchange energy is negligible, the modes are called magnetostatic and are exclusively dependent on microwave demagnetization effects. In fact, since the exchange energy is proportional to $S^{-2}$, in the case of the YIG films the exchange term begins to be relevant only for $S$ of the order of one $\mu m$. Mixed configurations in which both magnetostatic and exchange modes are present (magneto-exchange branches) have been treated extensively (12).

In a rectangular film having sides $L_x$, $L_y$ and thickness $S$ along the $z$-axis (see fig. 1a)), the normal modes are expected to have 0, 1, 2, ... nodes along the Cartesian axes. The transverse rf magnetization $m$ is chosen to be \(^{(*)}\), for the even modes,

\begin{equation}
m = m_0 \cos k_x x \cdot \cos k_y y \cdot \cos k_z z.
\end{equation}

The spins are assumed to be pinned at the small edges of the sample ($x = \pm L_x/2$, $y = \pm L_y/2$); thus the planar-propagation wave vectors $k_x$, $k_y$ are given by

\begin{equation}
k_x = \frac{n_x \pi}{L_x}, \quad k_y = \frac{n_y \pi}{L_y} \quad \text{with } n_x, n_y = 1, 2, 3, \ldots.
\end{equation}

The pinning conditions at the surfaces ($z = \pm S/2$) of the film are included into the perpendicular-propagation wave vector $k_z$ by writing \(^{(8)}\)

\begin{equation}
k_z = (n_z - p) \frac{\pi}{S} \quad \text{with } n_z = 1, 2, 3, \ldots.
\end{equation}


