## A.9: Studies of Spin Wave Instabilities in Ferrite and Garnets for CW Ferrite Circulators

High power ferrite circulators have become as indispensable component for CW RF systems of Accelerators. Power handling capability of circulator depends mainly on the power threshold of ferrites. Spin wave instability is an important measurement required to determine the power handling of ferrite materials. In this article, we provide a brief overview of studies of spin wave instabilities in ferrite and garnets conducted at Tezpur University under BRNS project as a collaborative work between Ferrite Lab, RRCAT and Tezpur University, Assam.

Spin wave measuring set up has been developed at Tezpur University. The measuring setup is shown in Fig. A.9.1.It consists of pulsed power magnetron, TE102 cavity with ferrite spherical sample and a rotating electromagnet. RF power is applied parallel to the static magnetic field and at low power, negligible microwave power is absorbed by the ferrite samples. Beyond a certain critical or threshold value, there is an abrupt increase in the absorbed power level that gives rise to non-linear effects. The butterfly curve data is obtained by sweeping microwave power over a range of static magnetic field. An abrupt increase in absorption of microwave power marks the onset of nonlinearity. Instability is determined by the threshold microwave power level (advent of nonlinearity).

*Fig. A.9.1: Spin wave measuring set up*

RF field is swept over ferrite or garnet samples placed in the sample holder at different dc-magnetic field and determine the onset of instability and from that point spin wave instability. The power handling capability of ferrites in terms of threshold microwave field is given by $h_{crit} = \frac{\omega}{\omega_m} \cdot \frac{\Delta H_k}{\sin^2 \theta_k}$ where $\omega = 2\pi\nu$, $\nu$ is the operating microwave frequency, $\omega_m = \gamma . 4\pi M_s$ and $\theta_k$ is the angle between the wave vector and internal magnetic field.

The threshold $h_{crit}$ is evaluated from measuring return loss at various microwave power levels with varying static magnetic field and determining the onset of nonlinearity. Spherical samples (1-2 mm diameter) have been developed at Ferrite Lab.

Measurement is carried out on spherical YIG samples, placed at a point of minimum microwave electric and maximum microwave magnetic field. The Butterfly curve data is obtained by sweeping microwave power over a range of static magnetic field.

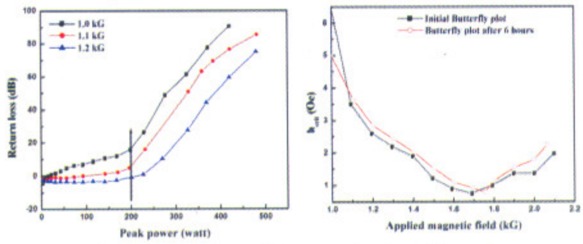


*Fig. A.9.2: Variation of Return loss with peak power at varying Magnetic bias*

The threshold microwave power, Pcrit above which abrupt rise in the peak power marked by arrows. The value of hcrit$|_{min}$ is taken from the minimum point of the butterfly curve plot. From hcrit, the spin wave instability ΔHk (Oe) is calculated for YIG sample which is found to be 18.5/$M_s$ (Gauss). Figure A.9.3 shows variation of parallel pump instability threshold ($h_{crit}$) as a function of dc magnetic field ($H_0$) for spinel ferrite sample03 (CAT-3/2 $Ni_{0.4}Zn_{0.6}Fe_2O_4$) and sample03 (nanophase $Gd_{1.50}Y_{1.50}Fe_5O_{12}$, sintered at 1250 $^0$C for 6 hrs)

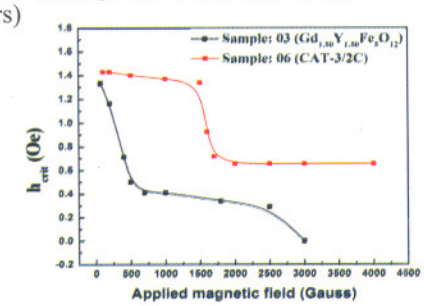


*Fig. A.9.3: Variation $h_{cri}$ as a function of dc magnetic field ($H_0$) for ferrite samples*

From the threshold value plots, power handling capability of the samples have been predicted, which are larger than that reported in literature for similar system up to 3kG and no nonlinearity is observed. This could be because of nano-phase of the ferrite samples. Smaller grain sizes generally increases the power handling capability which is called as transit - time theory and more power will be required to overcome the losses and produce instability, thus increasing the peak power handling capability in the material. Thus, there is an inverse relation between spin wave line width and grain size ($\Delta H_k \propto a^{-1}$). Detailed studies of spin wave instabilities at high power (200 kW peak) are under progress. This important study will help in development of high performance ferrite/garnet disks for indigenous high power CW Ferrite Circulators being developed for Proton Linac and future accelerators at RRCAT.

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