Magnetisation Dynamics of Nanoscale Magnetic Materials and Spintronics

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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Abstract

The magnetisation dynamics of a single square nanomagnet, the interaction between a pair of nanodiscs, a partially built writer structure and a range of magnetic tunnel junction sensor heads were studied using Time Resolved Scanning Kerr Microscopy (TRSKM) and four probe contact DC electrical transport measurements. Large amplitude magnetisation dynamics of a single square nanomagnet have been studied by TRSKM. Experimental spectra revealed that only a single mode was excited for all bias field values. Micromagnetic simulations demonstrate that at larger pulsed field amplitudes the center mode dominates the dynamic response while the edge mode is almost completely suppressed. The magnetisation dynamics occurring in a system comprised of two laterally separated magnetic nano-discs were also investigated. The polar Magneto-Optical Kerr Effect was used to measure the dynamic response of each disc independently so as to demonstrate that dynamic dipolar interactions between non-uniform spin wave modes in the different discs may be identified from the difference in their phase of oscillation. Results show a stronger dynamic dipolar interaction than expected from micromagnetic simulations highlighting both the need for characterisation and control of magnetic properties at the deep nanoscale and the potential use of dynamic interactions for the realization of useful magnetic nanotechnologies.

TRSKM measurements were made simultaneously of the three Cartesian components of the magnetisation vector, by means of a quadrant photodiode polarisation bridge detector, on partially built hard disk writer structures. The rise time, relaxation time, and amplitude of each component has been related to the magnetic ground state, the initial torque, and flux propagation through the yoke and pole piece. Dynamic images reveal “flux-beaming” in which the magnetisation component parallel to the symmetry axis of the yoke is largest along that axis. A comparison of the magnetisation dynamics excited with different pulsed excitation amplitudes was also made. The results shows that more effective flux beaming is observed for higher pulse amplitudes.

Lastly the microwave emission of Tunnel Magnetoresistance (TMR) nanopillars has been measured using a four probe contact DC electrical transport measurement technique as a magnetic field is applied in the plane of the film at different angles (ϕ_H) with respect to the easy axis. Experimental spectra revealed that a more complicated spectrum containing several modes is observed as ϕ_H is increased. The modes were identified as edge and higher order modes from the statistical distribution of modes from different devices and micromagnetic simulations. The in-plane and out-of-plane components of the Spin Transfer Torque (STT) were estimated by analytical fitting of experimental data for the lowest frequency edge mode for the value of ϕ_H where the amplitude of the said mode was a maximum and its frequency a minimum. The estimated values are larger than expected perhaps due to the macrospin approximation made in deriving the analytical model.

The results presented in this thesis can contribute to the understanding of magnetisation dynamics in industrially relevant data storage devices as well as the realization of a dipolar field coupling mechanism for arrays of nanooscillators.

List of Contents