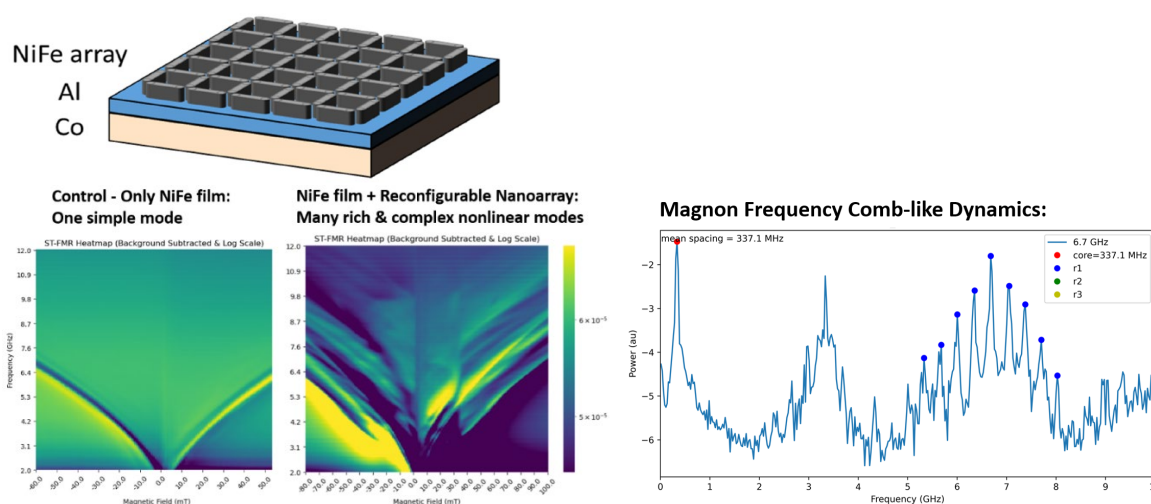


Fabricating 3D Nanomagnetic Arrays for Reconfigurable Magnon Frequency Combs and Neuromorphic Computing

With the kind support of the IMR & Tohoku University, a breakthrough result was obtained where for the first time it was demonstrated that fabrication of a quasi 3D magnetic nanodevice comprising a reconfigurable nanomagnetic array strongly dipolar-coupled to a continuous thin magnetic film can lead to the generation of a huge number of reconfigurable magnon modes and magnon frequency comb-like phenomena



Figures 1 & 2: **Top** Schematic of the device architecture comprising NiFe nanoarray, coupled via dipolar magnetic field through a nonmagnetic spacer (here Al) to a continuous ferromagnetic film (here Co, also NiFe). **Bottom Left** Control broadband ferromagnetic resonance spectra – bare thin film with no nanoarray. A simple, single resonant magnon mode is observed. **Bottom middle** Equivalent spectra for device comprising a nanoarray coupled to the film, as shown in the schematic at the top. Here, a broad variety of complex ferromagnetic resonant modes are observed – dynamically imprinted by the reconfigurable nanorray. **Bottom right** Data showing an evenly spaced set of comb-like resonant modes – magnon frequency comb behaviour.

The study and visit confirmed that coupling a magnetic nanoarray with programmable state allows for the imprinting of a broad range of

complex, reconfigurable magnon modes with frequency comb-like dynamics into a simple ferromagnetic continuous thin film. This was hypothesized in our initial proposal, but until the visit to the IMR at Tohoku this had not been observed. This is a significant finding and represents strong progress and scientific value & international collaboration enabled by the IMR visiting professor scheme. These results would not have been possible at Imperial College London or Tohoku alone, requiring careful combination of nanoarray design and magnetic state control developed at Imperial College London, UK with advanced thin film technologies and GHz magnetic spectroscopy facilities and expertise provided by the IMR in Tohoku, Japan and the expertise, skills and facilities provided by host Prof. Seki and group, notably PDRA Varun Kushwara.

The expanded range of frequency dynamics will enable for far stronger parallelization of GHz neuromorphic computing processing, a key step

towards delivering low carbon AI-specific hardware for future computing technologies, alongside enabling study of intriguing emergent physical phenomena – namely the imprinting of complex magnon dynamics with non-trivial spatial and dynamic character into magnetic thin films.

This study represents the first step towards a larger

continued research programme between the UK and Japan, and Imperial College London and Tohoku University – ideally supported by future international visits and exchange of personnel, skills and ideas.

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