Spin wave computing and mode engineering using hard media bias field

(in-depth report)

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We describe a spin wave computing device where an algorithm is encoded by recording a corresponding magnetization pattern onto a hard magnetic material. The bias field produced by such pattern in turn engineers a mode with a predetermined properties in the adjacent soft magnetic layer. Analytical theory and modeling confirm that such modes can be used to perform complex algorithms consisting of multiple additive, multiplicative and conditional operators including logic expressions. Each of these computational algorithms defines a specific relationship between some physical parameter characterizing a specific input value and amplitudes and possibly phases of the excited spin wave mode measured in specific areas which serve as outputs. For the inputs, conventionally one relies on a set of independent sources of the RF field, however we demonstrate a more simple solution using adjustable external quasistatic magnetic fields. Such fields can be generated by a set of current bearing wires and locally impact the magnetic susceptibility in the same way as the bias field produced by the magnetization pattern, affecting the mode's amplitude, phase and resonant frequencies.

In terms of available algorithms, we so far were able to access almost every single option previously demonstrated in optical and other forms of wave based computing, including some quantum computing schemes (Grover search, variational eigensolver, neural networks). As with other proposed wave computing chips there is many orders of magnitude performance improvement (speed, power, element density) compared to CMOS implementations.

The key advantage however lies in the fact that magnetic systems have a unique capability where the physical properties can be "rewritten" directly by changing the stable magnetization in lieu of relying on a complex lithographic process to tailor the geometry of elements. This allows for an exceptionally cheap, fast to produce, rad hard and reprogrammable device.

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