Simulation of domain-wall assisted magnetic ordering

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INTRODUCTION

Research on magnetic computing devices is flourishing as they may enable ultra low-power operation and seamless combination of logic and nonvolatile storage functions, which are sought-after features of future nanoelectronic devices [1][2][3]. Switching of nanomagents requires strong, localized magnetic fields. Such fields can be provided by spin-torque structures or current-carrying wires, but both methods are fairly inefficient as most of the energy is dissipated as Joule heating. On-chip field generation also requires dense wiring or nanoscale contacts to individual magnets

We recently demonstrated that the field of magnetic domain walls (DWs) can be used to amplify externally applied fields [4]. The present paper shows that this amplified field can initiate magnetic ordering in single-domain permalloy nanomagents. This can be exploited in Nanomagnet Logic (NML) devices, where all logic operations are based on magnetic ordering.

SIMULATED GEOMETRY AND CASE STUDY

A possible geometry for DW assisted switching is shown in Fig 1. The nanomagnets are antiferromagnetically coupled to each other and to the domain wall conductor (DWC). This geometry was implemented in the OOMMF simulation software [5]. A strong external magnetic field first creates a wall in the corner of an L-shaped DWC (Fig. 2). Once created, the wall can be displaced with a small (approx. 10 mT) field, but stray field of the moving wall approached 200 mT (Fig 3, Fig 4). DW propagation speeds are in the 100 m/s range. The field spike resulting from the passing, fast-moving wall switches the adjacent nanomagnets one by one into an excited state. Finally the magnets relax into their computational ground state (Fig 5). The antiferromagnetically ordered nanomagnet chain is often referred as 'nanomagnet wire' in the NML literature and can be considered as the simplest NML device [2].

DISCUSSIONS

Domain-wall wall assisted switching can dramatically improve the already attractive dissipation characteristics of NML devices. Work is in progress to investigate domain wall clocking of logic gates and to better control the distribution field emanating from domain walls.

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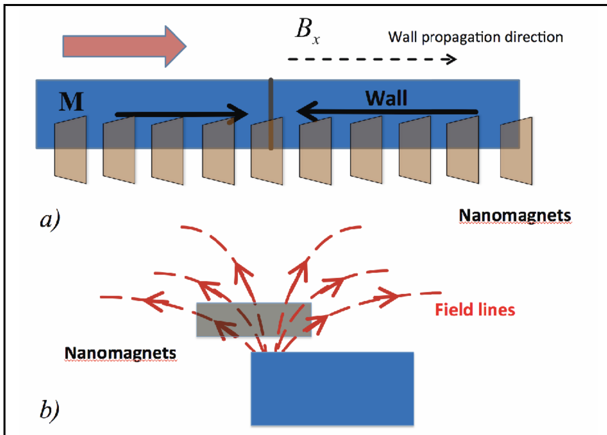

Fig 1. Schematics of a geometry for domain-wall assisted switching. Panels (a) and (b) are the top and side views, respectively. Dots are placed where the *z* component of the field is strongest.

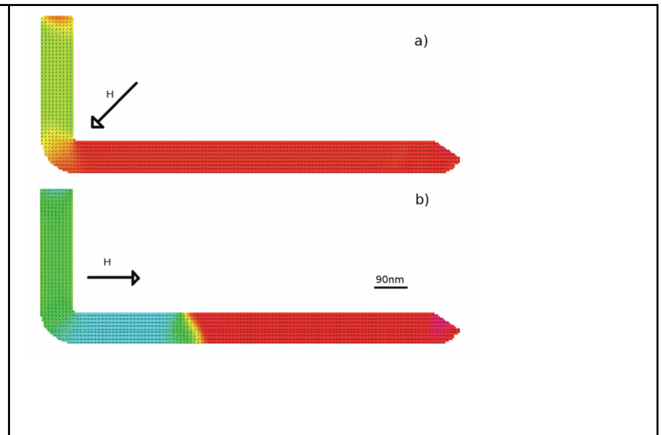

Fig 2. The field sequence for intiating and displacing domain walls. The domain wall is first created in the corner of an L-shaped DWC (a). Afterwards a relatively weak field can propagate it (b).

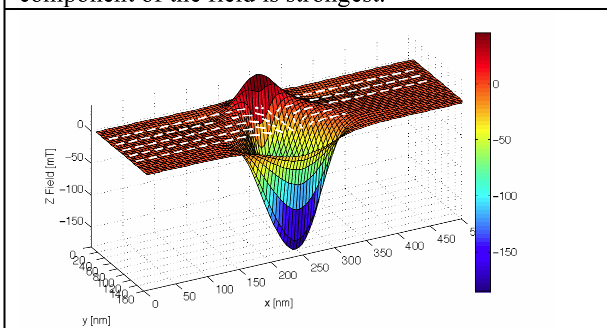

Fig 3. The *z*-component of the magnetic field in a plane 10 nm from the surface of the DWC. This field is clocking the dots.

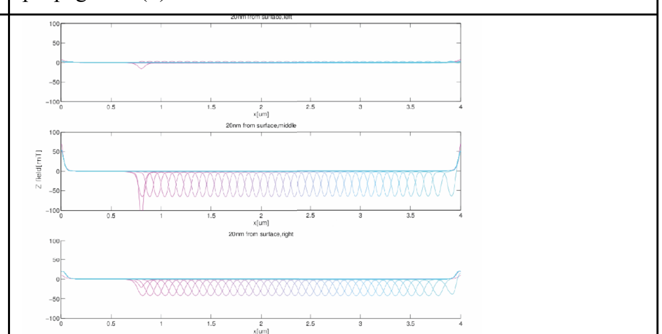

Fig 4. Snapshots of the field distribution 20 nm from the DWC. The shape of the field pulse does not change as the wall propagates along the DWC.

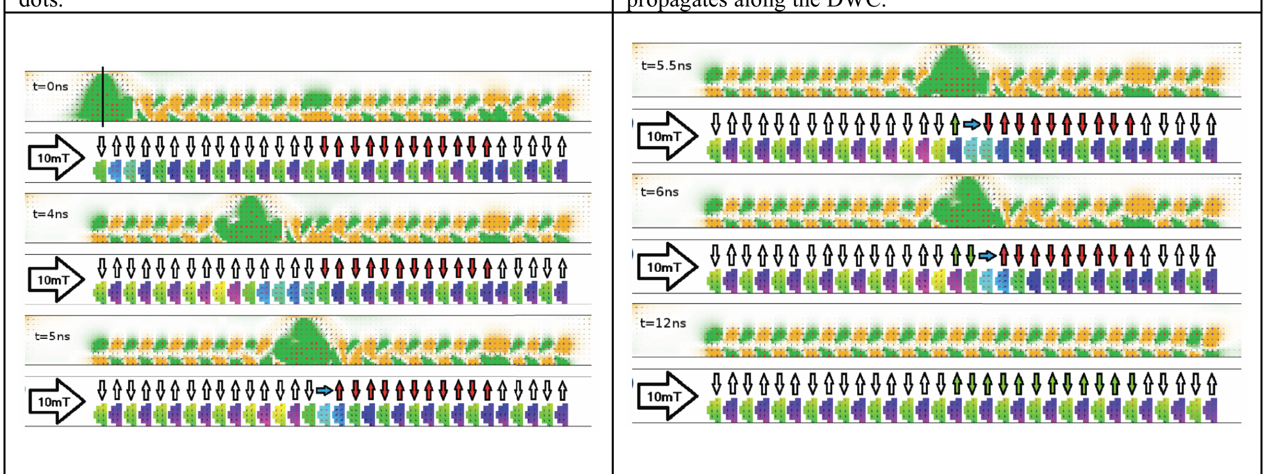

Fig 5. Snapshots showing domain-wall clocking at work. Each snapshot shows the field distribution (top panel) and the corresponding nanomagnet state (bottom panel with arrow). The passing domain wall puts the nanomagents into a metastable state and they relax into an ordered state afterwards.