Reprogrammable micromagnetic transport

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The ability to selectively manipulate and transport superparamagnetic mircoparticles has far reaching potential in bioengineering. [1-3] Transport lines have been created using micronsized ferromagnetic islands that allow **programmable** transport. [1] By designing junctions in the transport lines, clockwise and counter clockwise rotation of the driving magnetic field either lead to the microparticles taking the turning or not. [1] Another approach has used trapped domain walls in zig-zag magnetic wires and notches in straight wires to direct microparticles. [2] A disadvantage of these techniques is that the particles are either manipulated all in the same way, or can only be transported one at a time along a predefined path. Recent work has seen the use of an electromagnetic needle to address and manipulate individual microparticles in arbitrary directions. [3]

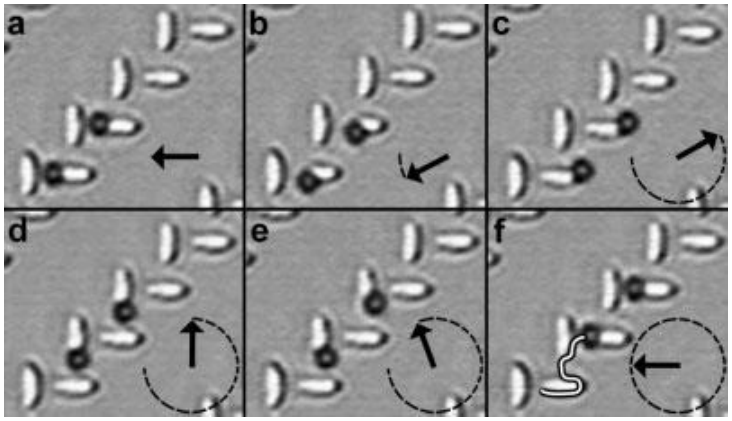

Figure 1 Transport of magnetic microparticles along a staircase pattern of permalloy elipses, showing the path the particle takes when the field is rotated clockwise. Figure from reference [1].

This project will aim to introduce reprogrammable elements into magnetic patterns for microparticle transport, allowing the same substrate to be used for different transport paths, depending on the state stored into it. One very useful element would be a distributor: an element which would determine which track to direct a particle onto. This could be a preprogrammed distributor, directing a particle onto a different track in a set order based on how many clock cycles of the driving field have been moved through. Another option would be a dynamically reprogrammable distributor, which either is reprogrammed using external influence or based on the number of particles distributed.

The research in this project will use micromagnetic simulations to model possible programmable elements. Candidate elements will then be fabricated using thin film deposition and lithography techniques and characterised using magnetic microscopy techniques, *e.g.* magnetic force microscopy, Lorentz transmission electron microscopy and magneto-optical Kerr effect microscopy. Interesting programmable elements will then be incorporated into transport lines, and the transport of superparamagnetic microparticles will be studied.

References

[1] Gunnarsson, K., Roy, P.E., Felton, S., Pihl, J., Svedlindh, P., Berner, S., Lidbaum, H., and Oscarsson, S., *Adv Mater*, **17** (2005) 1730
[2] Vieira, G., Chen, A., Henighan, T., Lucy, J., Yang, F.Y., Sooryakumar, R., *Phys Rev B*, **85** (2012) 174440
[3] Cenev, Z., Zhang, H., Sariola, V., Rahikkala, A., Liu, D., Santos, H.A., and Zhou, Q., *Adv Mater Technol,* **2017** (2017) 1700177