Angle-dependent magnetoresistance measurements of individual GaAs/(Ga,Mn)As core-shell nanowires at low temperature and high magnetic fields with *in-situ* double rotator

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Many interesting quantum phenomena require the relative rotation of a strong magnetic field at low (or even ultra-low) temperature with respect to a mesoscopic sample, be it semiconductors / nanomagnets with magnetic anistropies or superconductors with anisotropic gap structures. While readily available, commercial vector magnets (2D/3D) are usually significantly more expensive than single solenoids, despite delivering much smaller fields due to the limitations set by split coil magnets. Instead of rotating the field vector, the atto3DR - attocube's 3-dimensional rotator module - provides access to the full magnetic field (e.g. 9 T) in all directions relative to the sample surface, by rotating the sample *in-situ*. We discuss the key features of the setup, and show first measurement results at both 4 K: Magnetoresistance measurements on individual GaAs/(Ga,Mn)As core-shell nanowires have been conducted (similar to [2], see figure 1). The uniaxial magnetic anisotropy of a nanowire can be examined by performing measurements for different rotation planes. However, due to the random distribution of the nanowires on the substrate, the implementation of such an experiment is in general not straight forward. Using the convenience of a double rotator as the atto3DR, this is easily realizable in this setup (see figure 2). The module [3] consists of two piezo based 'slip-stick' rotators (with resistive encoders for full closed loop operation), which allow for arbitrary orientations of an external magnetic field vector and the sample plane. In addition, it features 20 measurement lines fully wired and a convenient leadless ceramic chip carrier (LCCC) mount for easy sample exchange.

References

[1] A. Rudolph, M. Soda, M. Kiessling, T. Wojtowicz, D. Schuh, W. Wegscheider, J. Zweck, C. Back, and E. Reiger, Nano Lett. 9, 3860–6 (2009).

[2] C. H. Butschkow, E. Reiger, S. Geißler, A. Rudolph, M. Soda, D. Schuh, G. Woltersdorf, W. Wegscheider, and D. Weiss, arXiv:1110.5507 (2011).

[3] www.attocube.com/attoCRYO/atto3DR.html

Figures

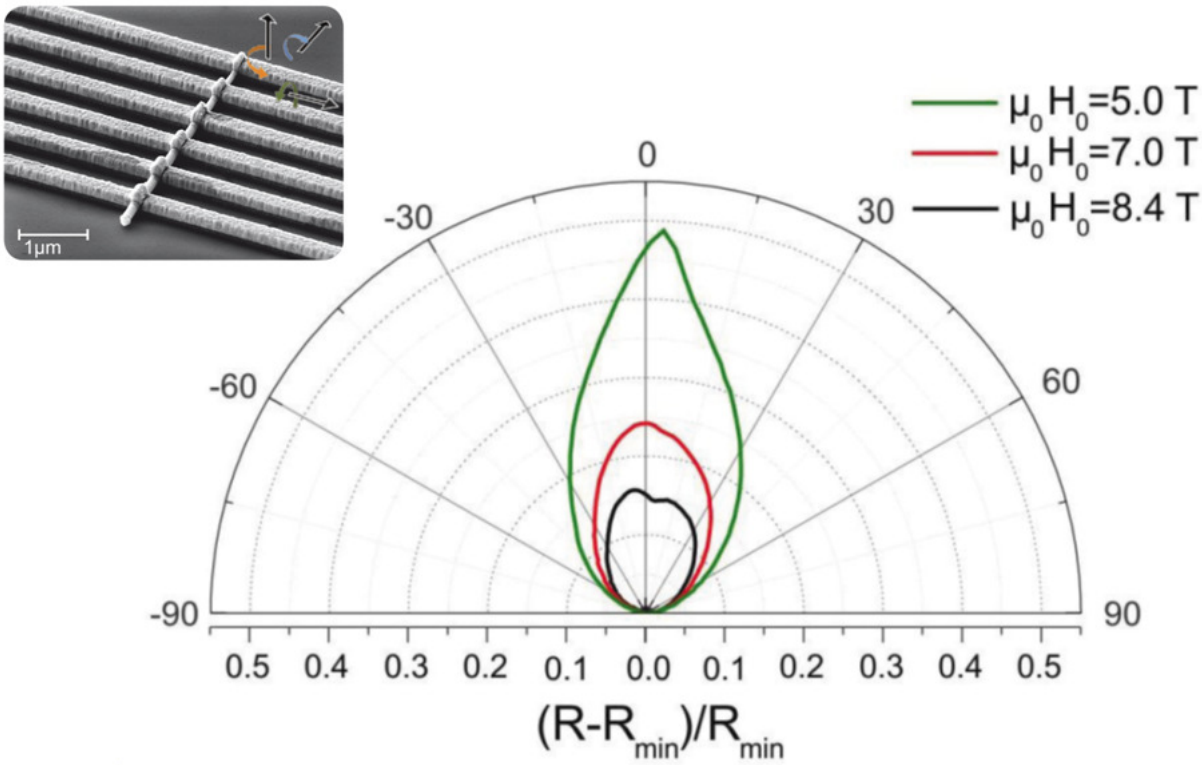

Figure 1: Normalized magnetoresistance as a function of the angle between externally applied magnetic field and the nanowire axis for various magnitudes of the external magnetic field. Inset (top left): Tilted scanning electron micrograph of a contacted nanowire. Black arrows indicate the sample coordinate system. Coloured arrows indicate the different rotational directions as used in the measurements (blue: transverse, orange: in-plane, green:perpendicular rotation).

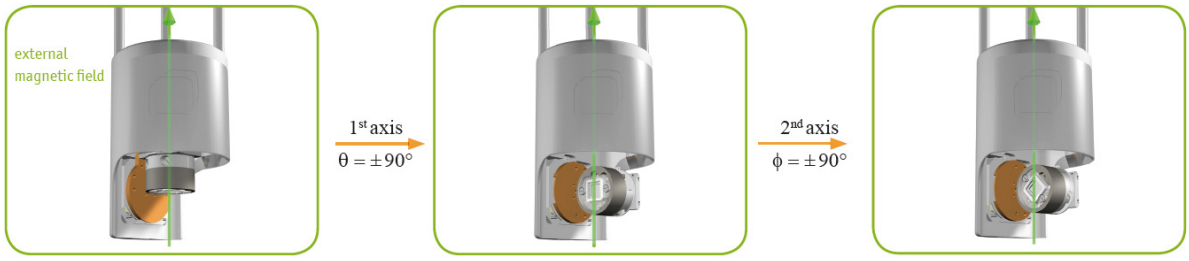

Figure 2: Working principle of the double rotator module and possible relative orientations between external magnetic field vector and sample surface.