Magnetic-Domain Structure of Cobalt Nanomagnets with Single-Notch and Y-Branch Geometries

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With continued trends for increasing data storage in modern electronic devices, the application of advanced techniques from nanotechnology offers the potential of significantly-improved magnetic data storage. Also, there is ongoing interest in utilizing specially-designed nanomagnetic structures for non-volatile logic applications. Motivated by these ideas, we have investigated the magnetic domain structure of two different types of magnetic nanostructure – a single "notch" in a rectangular bar, and a "Y-branch" junction formed by the intersection of two such bars. The Y-branch device is of interest as a potential "magnetic switch" in which the current flowing between its two branches may be switched in magnitude. In this presentation, we describe the results of magnetic-force microscopy measurements of the various nanostructures, and determine from a comparison of their characteristics how the geometry influences magnetic-domain structure. Using a novel magnetic-force microscope we apply a variable external magnetic field, at various angles relative to the structures, as a means to realize different magnetic domains. Our results show that the additional leg in the Y-branch structure gives rise to unique magnetic structures that are not observed in the single bars. This allows us to identify a new way of manipulating magnetism in nanostructures.

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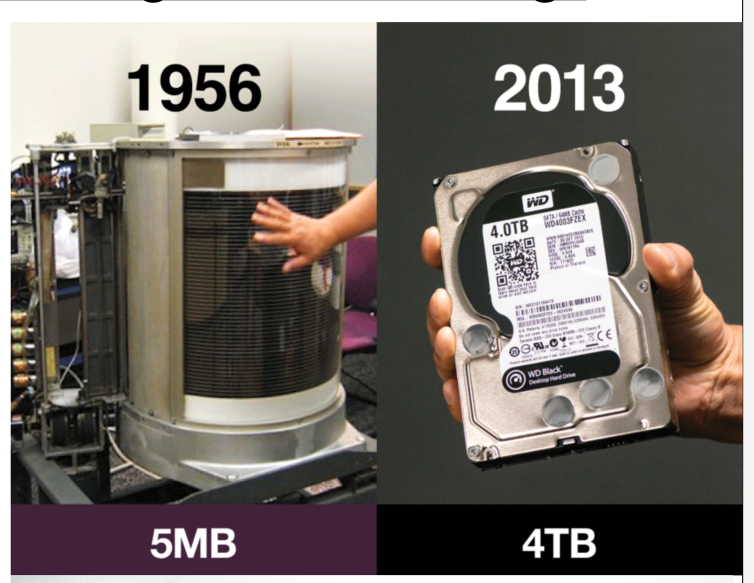
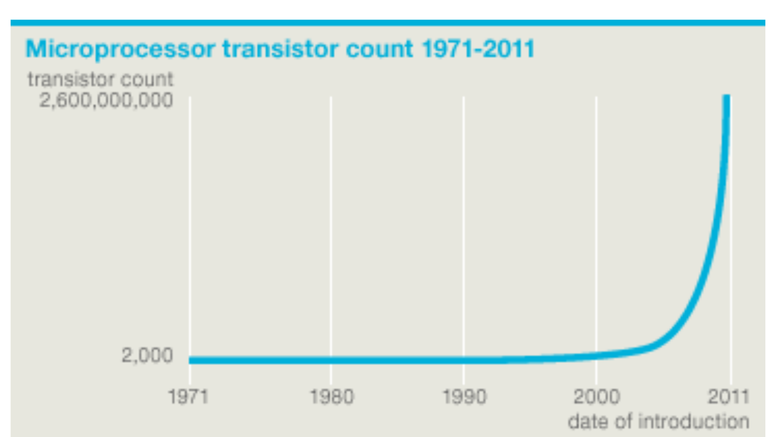
Introduction: The shrinking world of magnetic data storage

This picture shows how data storage has increased in capacity and decreased in size over the past 57 years.

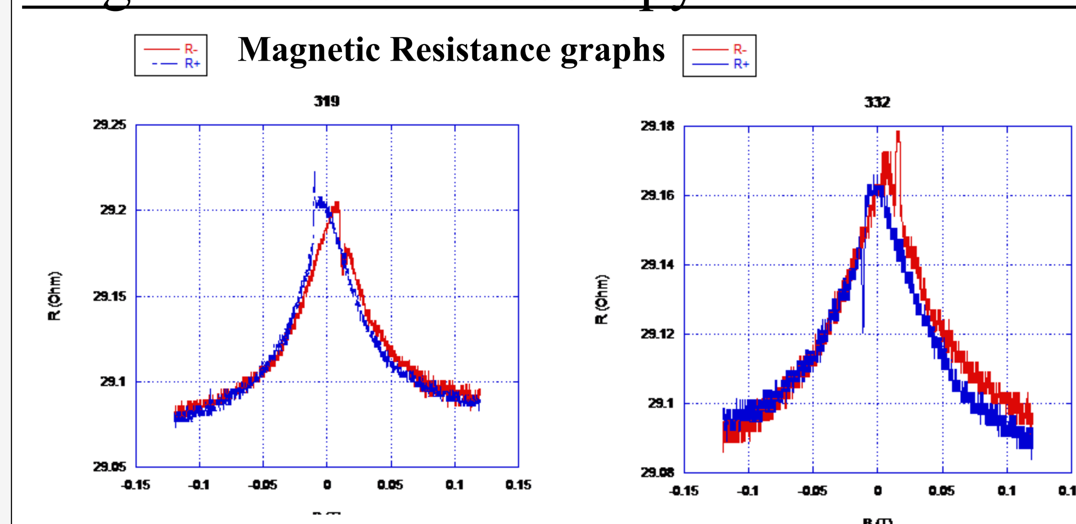


With Moore's law reaching its physical limits we need a new approach to continue our current trend, nanomagnets offer a suitable solution that will keep it going.

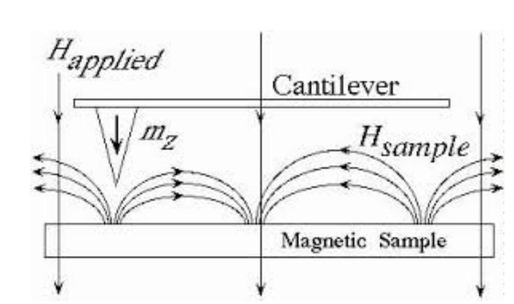


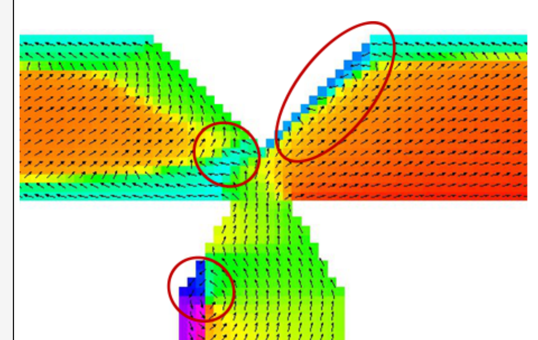
Moore's law: data density will doubled approximately every 18 months, this is the current definition of Moore's Law,

Magnetic Force Microscopy with external Magnetic field

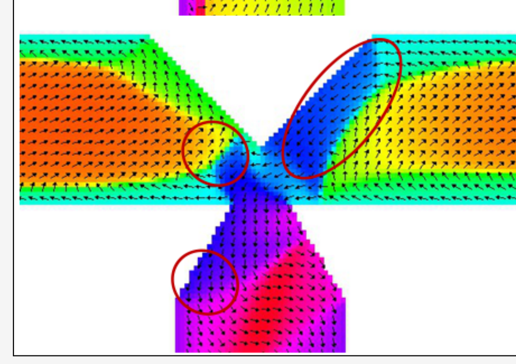


Magnetic Force Microscopy



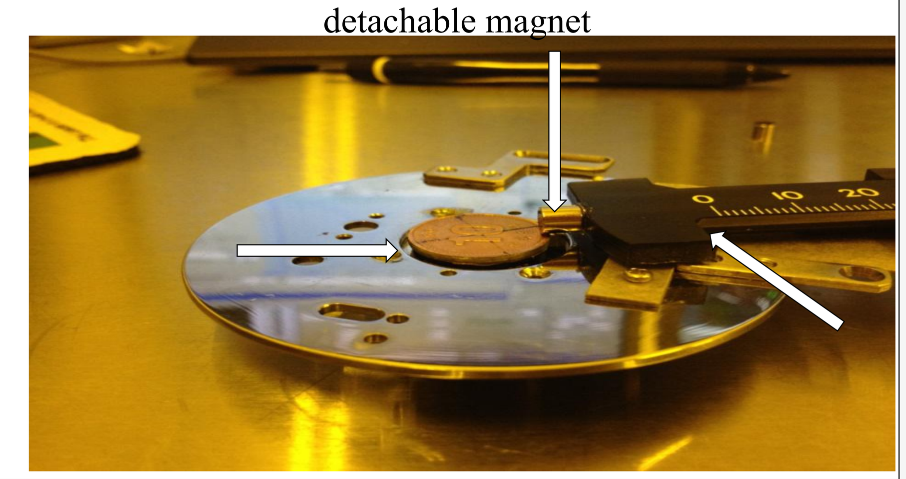


210 deg

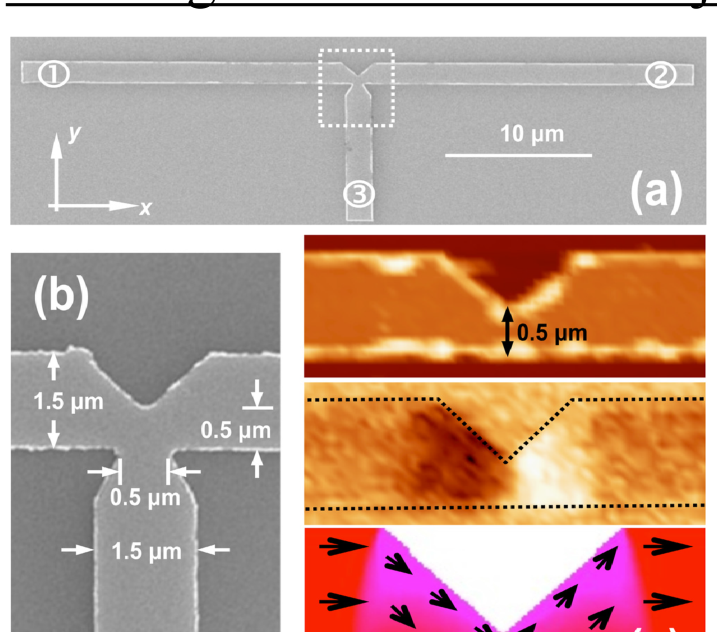


225 deg

MFM Stage with rotatable table and retractable arm with detachable magnet



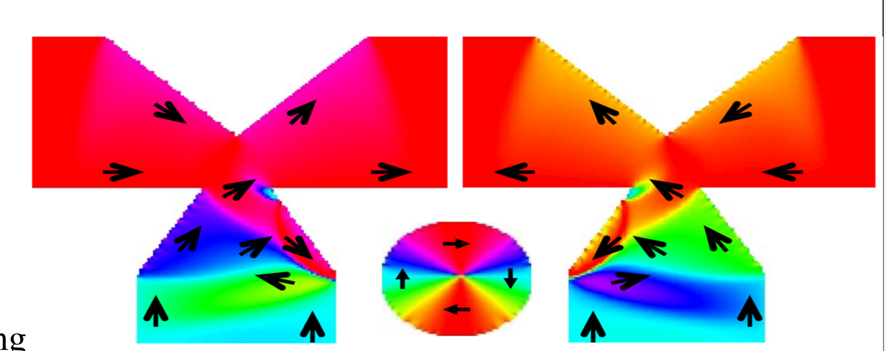
The magnetic Y-branch nanojunction

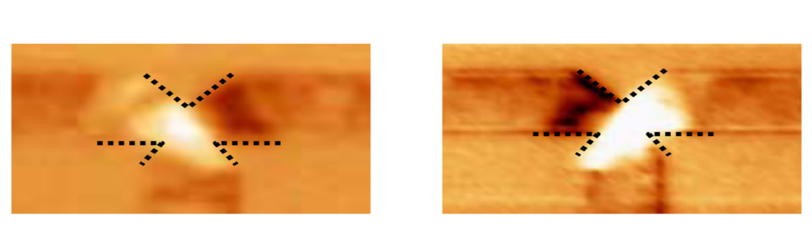


(a) Full image of a Y-branch nanojunction

(b) Close up image of the junction in a Y-branch nanojunction with dimensions.

(c) topography, MFM, and OOMMF simulation of the magnetization image of a Single-bar nanomagnet (without the Y-branch).





(a) OOMMF simulation of the magnetization of Y-branch nanojunction computed after returning to zero magnetic field from +0.1 T (left) and -0.1 T (right)
(b) MFM image of image above (a)

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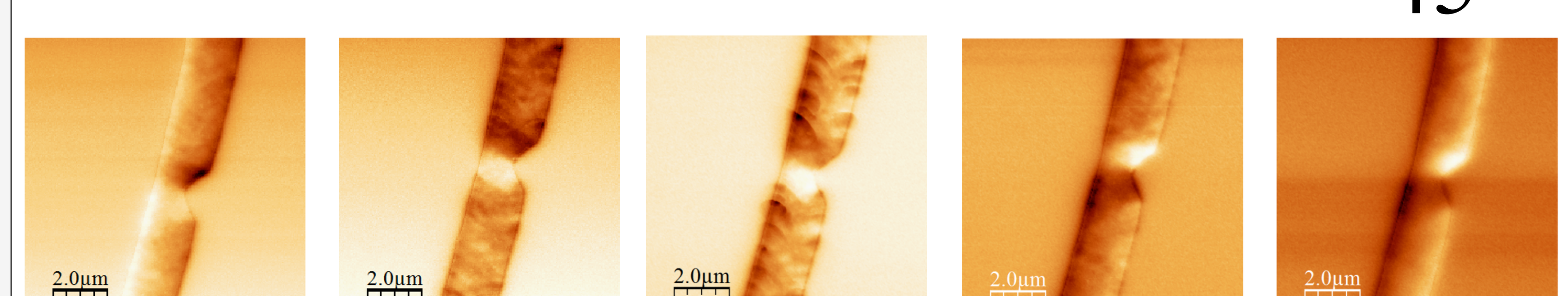
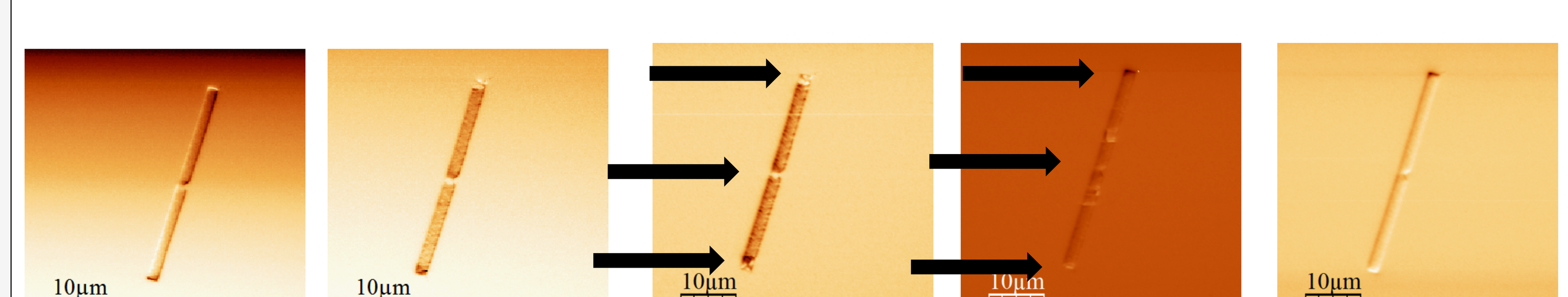
Results: Geometry influences magnetic-domain

Single-notch bar 45°

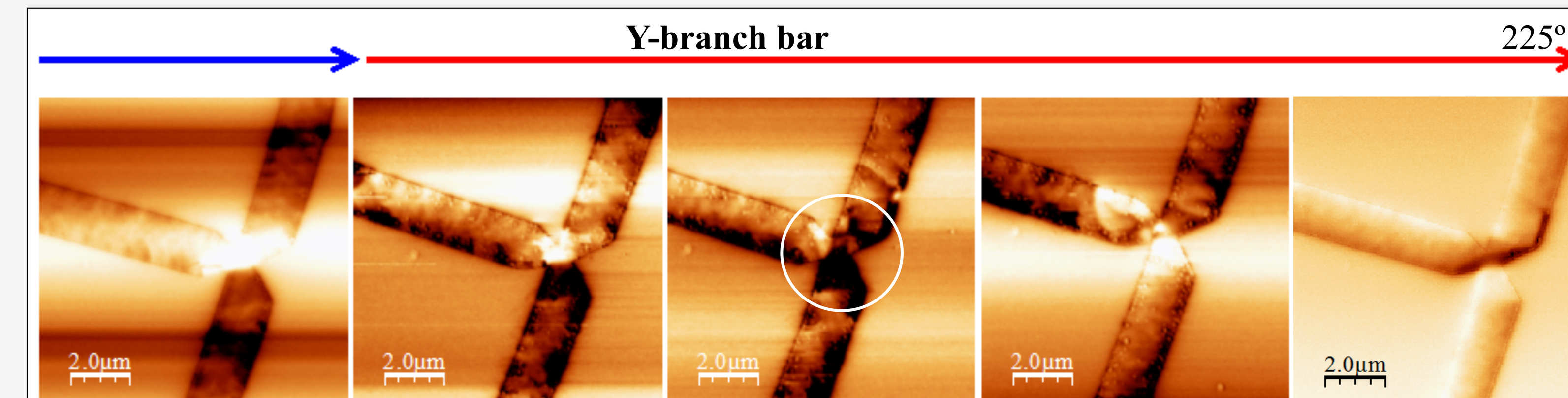


N 27 mm 20 mT~ | N 0 mm 0 mT~ | S 22 mm 4 mT~ | S 24 mm 7.8 mT~ | S 27 mm 20 mT~

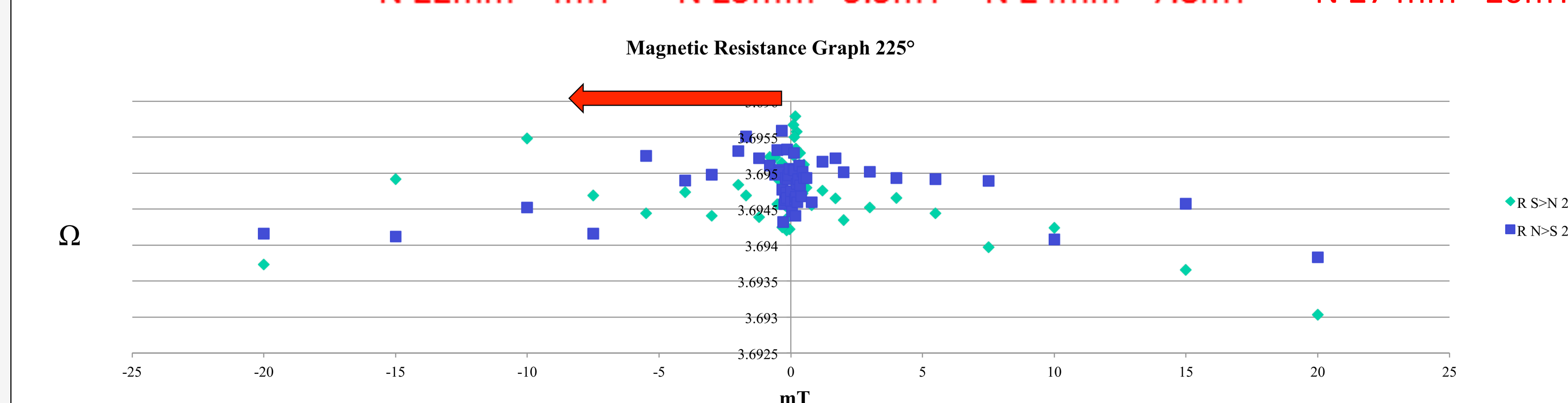


Single-notch bar magnetic resistance graphs shows no spikes or dips unlike Y-branch bar magnetic resistance graphs

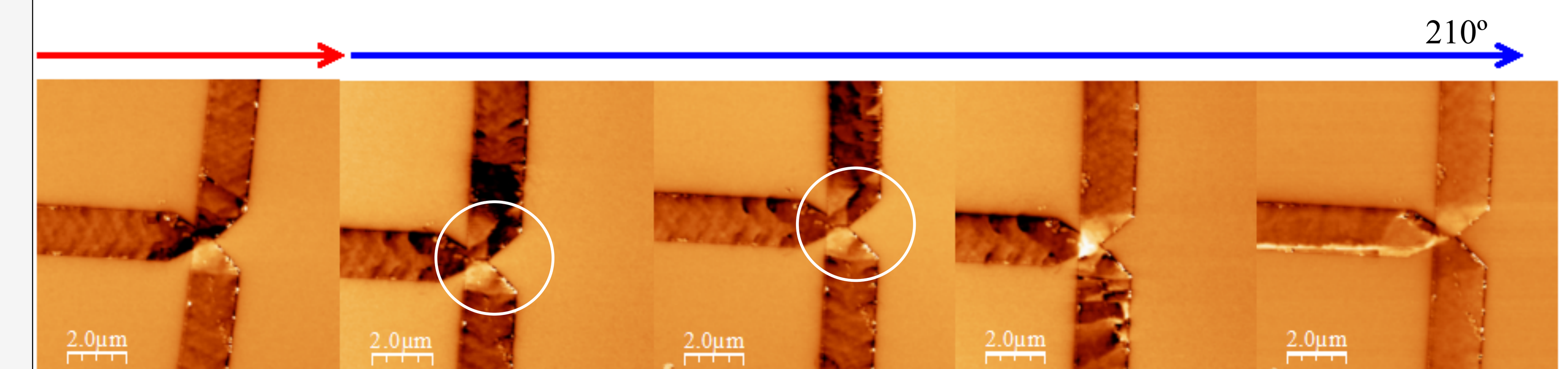
Y-branch bar 225º



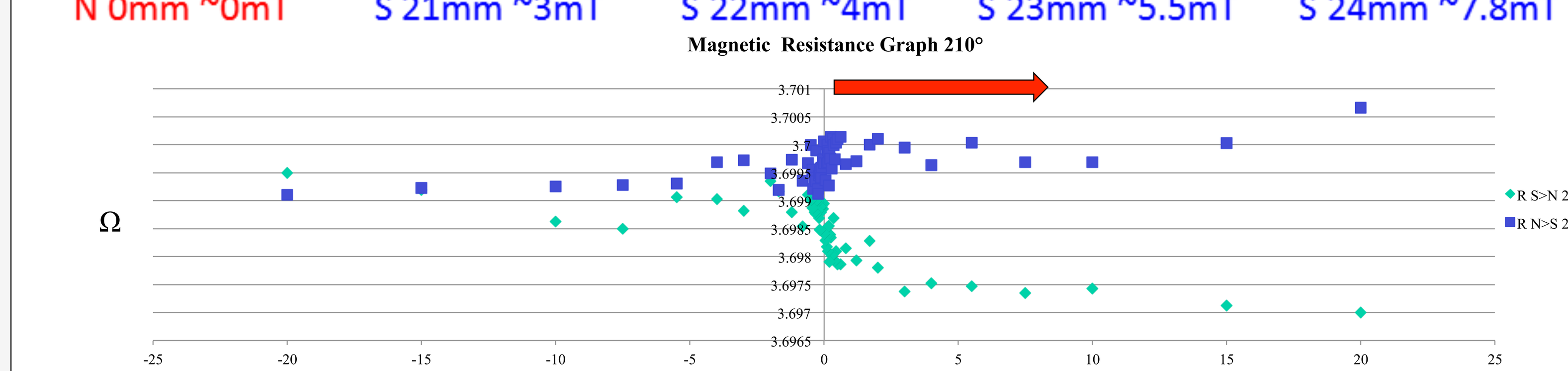
S 0.0 mm ~0mT | N 22mm ~4mT | N 23mm ~5.5mT | N 24mm ~7.8mT | N 27 mm ~20mT



210º



N 0mm ~0mT | S 21mm ~3mT | S 22mm ~4mT | S 23mm ~5.5mT | S 24mm ~7.8mT



Discussion & Conclusion

Our results show that the additional leg in the Y-branch structure gives rise to unique magnetic structures that are not observed in the single bars

Spikes in magnetic resistance graph seem to be caused by the vortexes

This allows us to identify a new way of manipulating magnetism in nanostructures.

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