

Title: Introduction to Spin Control in Lateral Quantum Dots and Micro-Magnets Characterization

Date: Jul 20, 2011 11:50 AM

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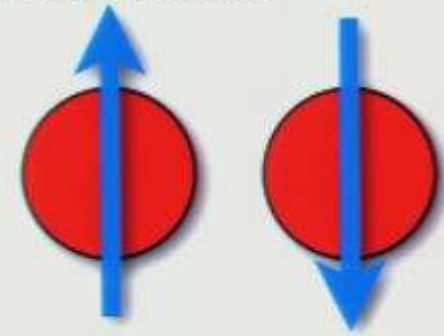
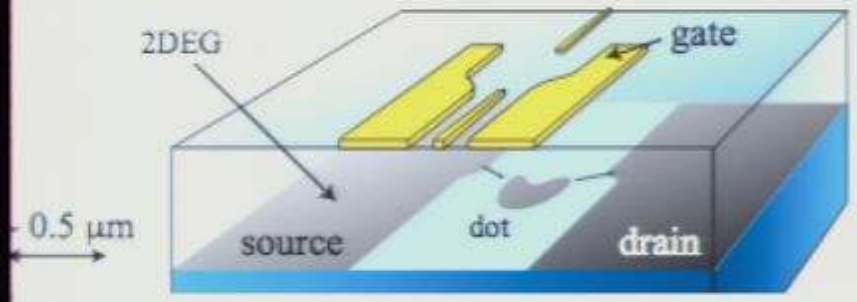
Abstract: Development of quantum computing promises, among other things, improvement of scientific computation performance. Indeed, a computer exploiting the properties of quantum mechanics would allow for computation power exponentially greater than a classic computer. We develop double lateral quantum dots with micro-magnets to control spin orientation of electrostatically confined electrons. In this talk, an introduction to the mechanisms used in the spin control will be given. Then, methods used to characterize the micro-magnets will be described. Finally, we will present the results obtained with Hall effect devices for the micro-magnets.

Spin qubits in lateral quantum dots

Goal: manipulate spin qubits in lateral quantum dots to encode information.

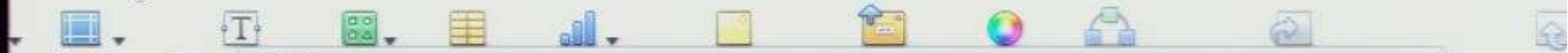
Qubit: electron electrostatically confined, spin up or down.

Can be manipulated with magnetic fields.



AlGaAs / GaAs heterostructure





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goal: manipulate

qubit: electron e

can be manipula



Keynote '09

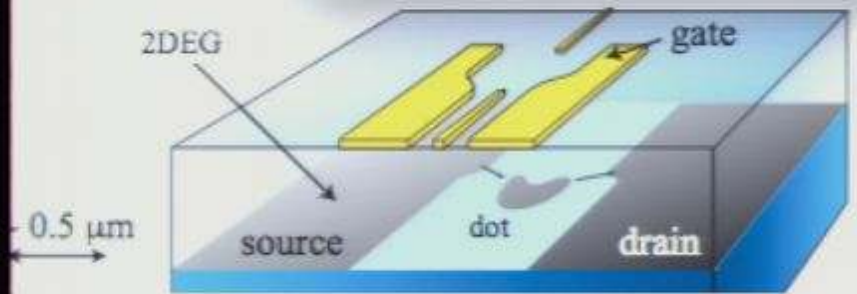
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AlGaAs / GaAs heterostructure



Diapos

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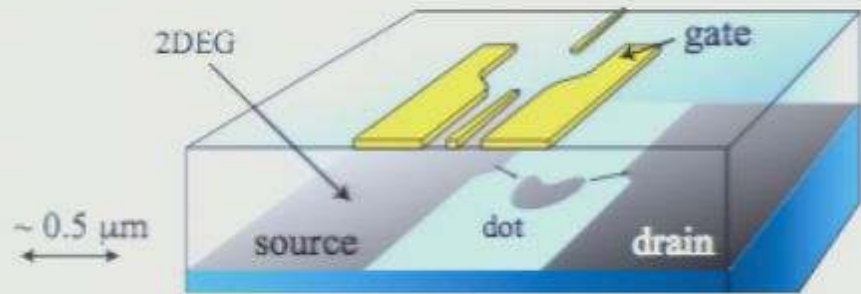
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AlGaAs

Diapos

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- 8

Introduction to spin in lateral quantum micro-magnets charac

Sophie Rochette
Département de Physiq
Université de Sherbrool



Introduction to spin control in lateral quantum dots and micro-magnets characterization

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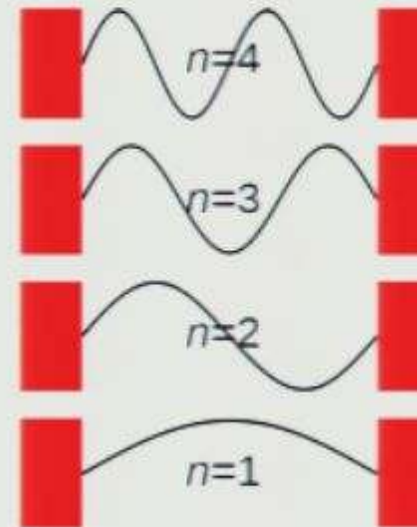
Women In Physics Canada
July 19-21, 2011
Institute for Quantum Computing

Overview

- * Quantum dots and qubits
- * Spin qubits in lateral quantum dots
- * Manipulating spin qubits with micro-magnets
- * Micro-magnets characterization methods (Hall effect)
- * Results of characterization
- * Conclusion

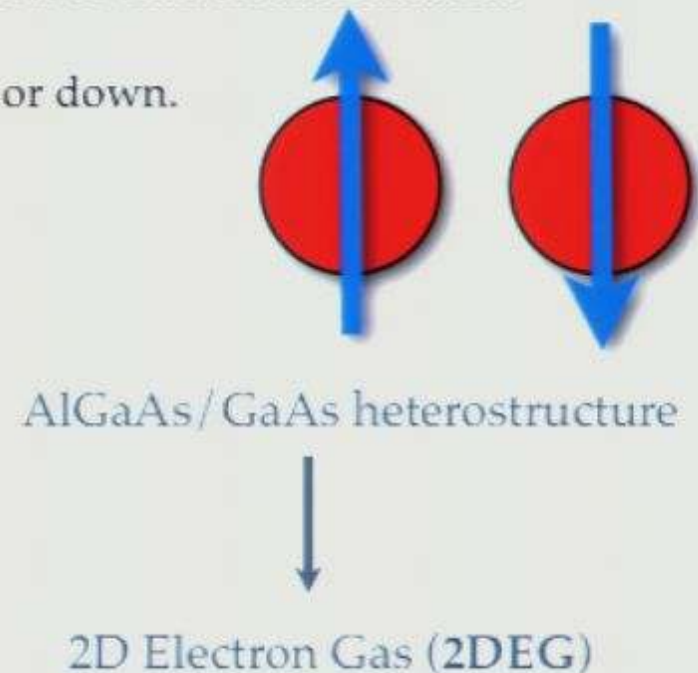
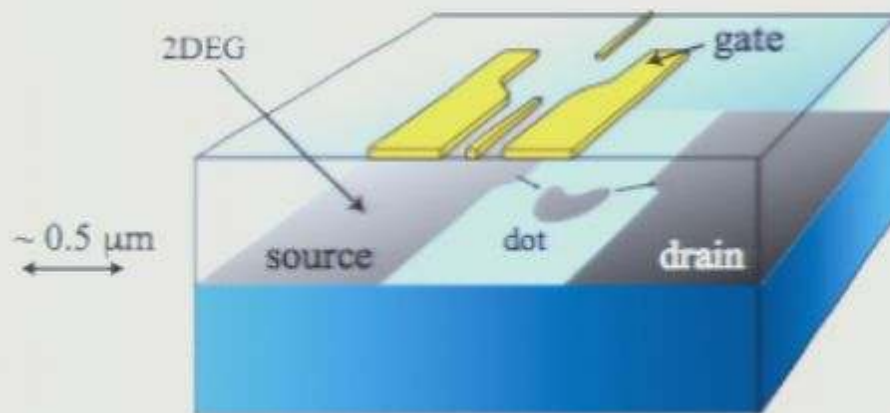
Quantum dots and qubits

- * What is a **quantum dot**?
 - * Few electrons, nanometer-scale confined system.
 - * Confinement \rightarrow quantum properties.
 - * Can be realized with electrons in semi-conductors.
 - * Excellent candidates for **qubits**.
- * What is a **qubit**?
 - * Basic constituent of quantum information.
 - * Bits: 0 or 1. Qubits: 0, 1, or any superposition.
 - * Uses **quantum properties**: superposition, entanglement, etc.



Spin qubits in lateral quantum dots

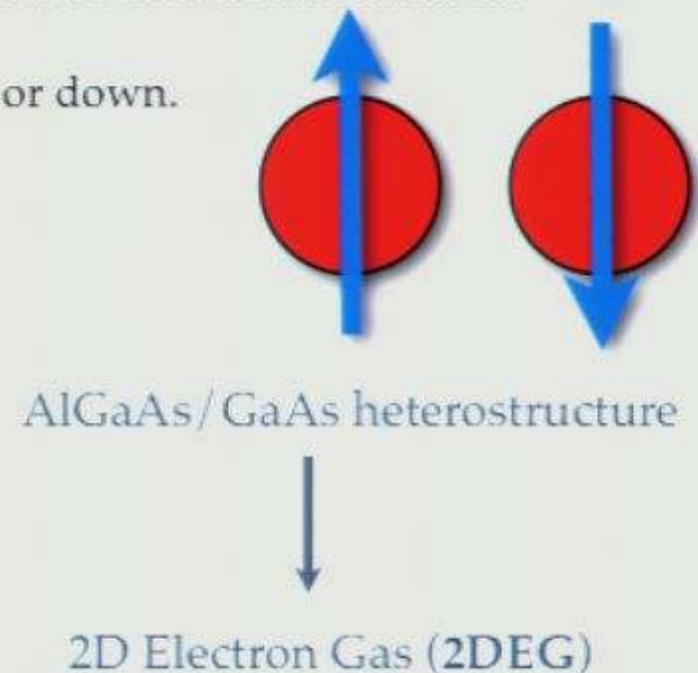
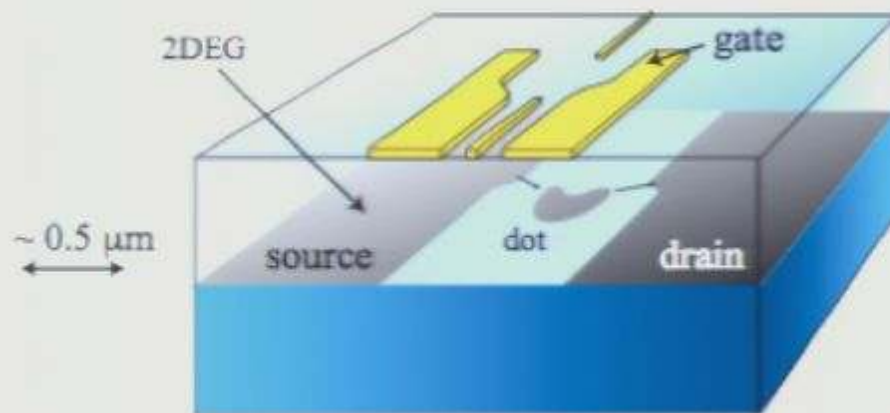
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- * Spin qubit: electron electrostatically confined, spin up or down.
- * Spin can be manipulated with magnetic fields.



- * The dot is shaped by applying negative biases on gates.
- * It is possible to isolate a **single** electron in the dot.

Spin qubits in lateral quantum dots

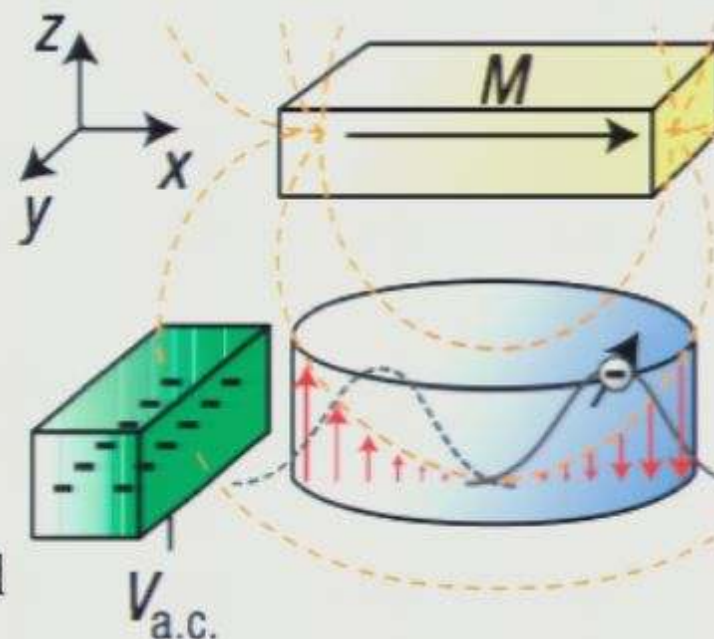
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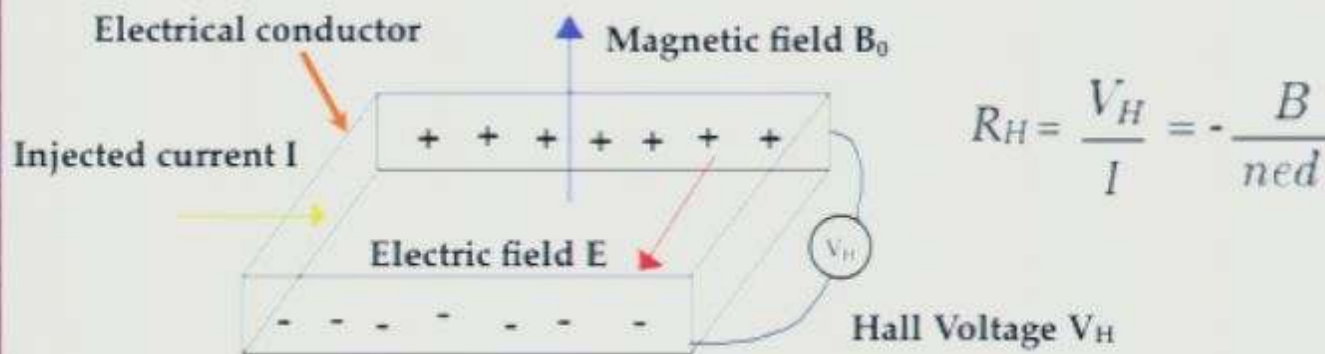
Manipulating spin qubits with micro-magnets

- * How can we effectively manipulate the spin?
- * Oscillating magnetic field is needed to manipulate the spin of the electron.
- * Usual methods for manipulating spin are too slow for our application.
- * We use a magnetic field gradient produced by a micro-magnet and AC potential applied on gates to produce an **effective oscillating magnetic field**.



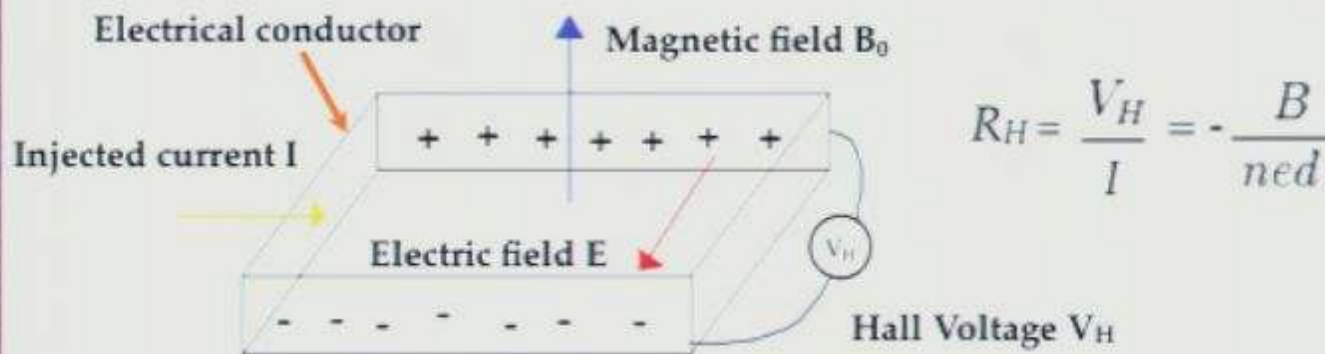
Characterization of micro-magnets: Hall effect

- * Goal of the characterization process: determine the **magnetization** of the micro-magnets.
- * **Hall effect:** apparition of a voltage perpendicular to the injected current in the presence of a magnetic field.



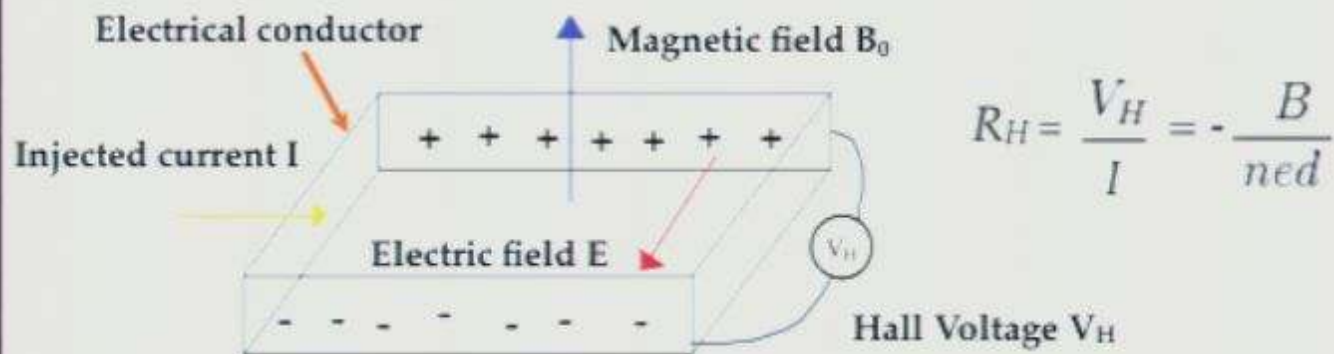
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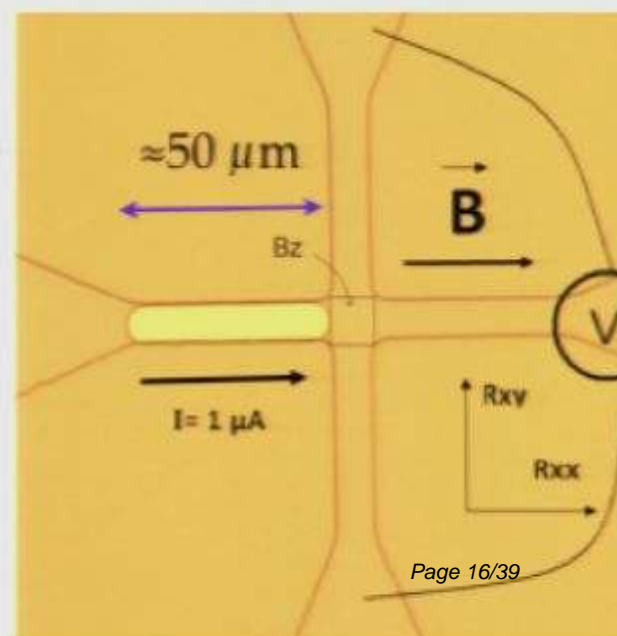
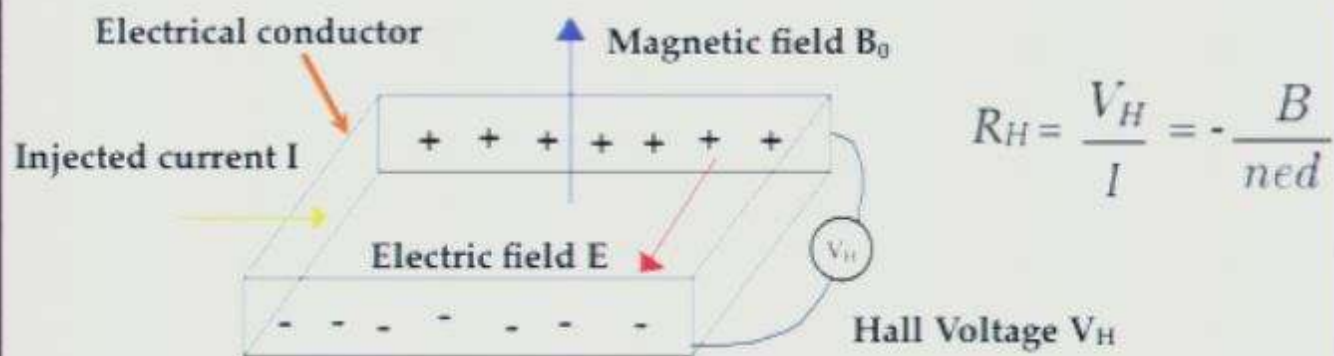
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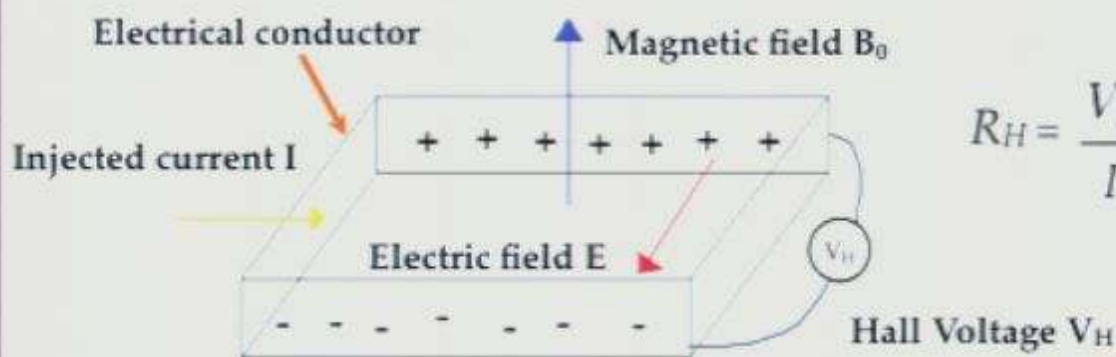


Hall effect device

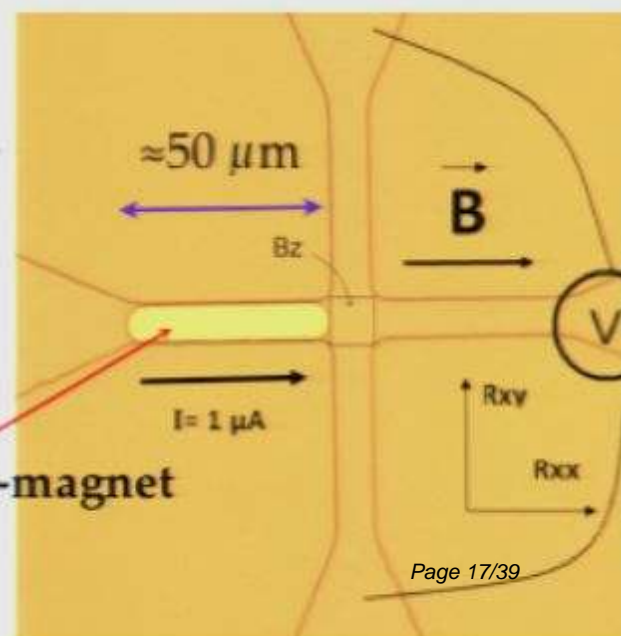


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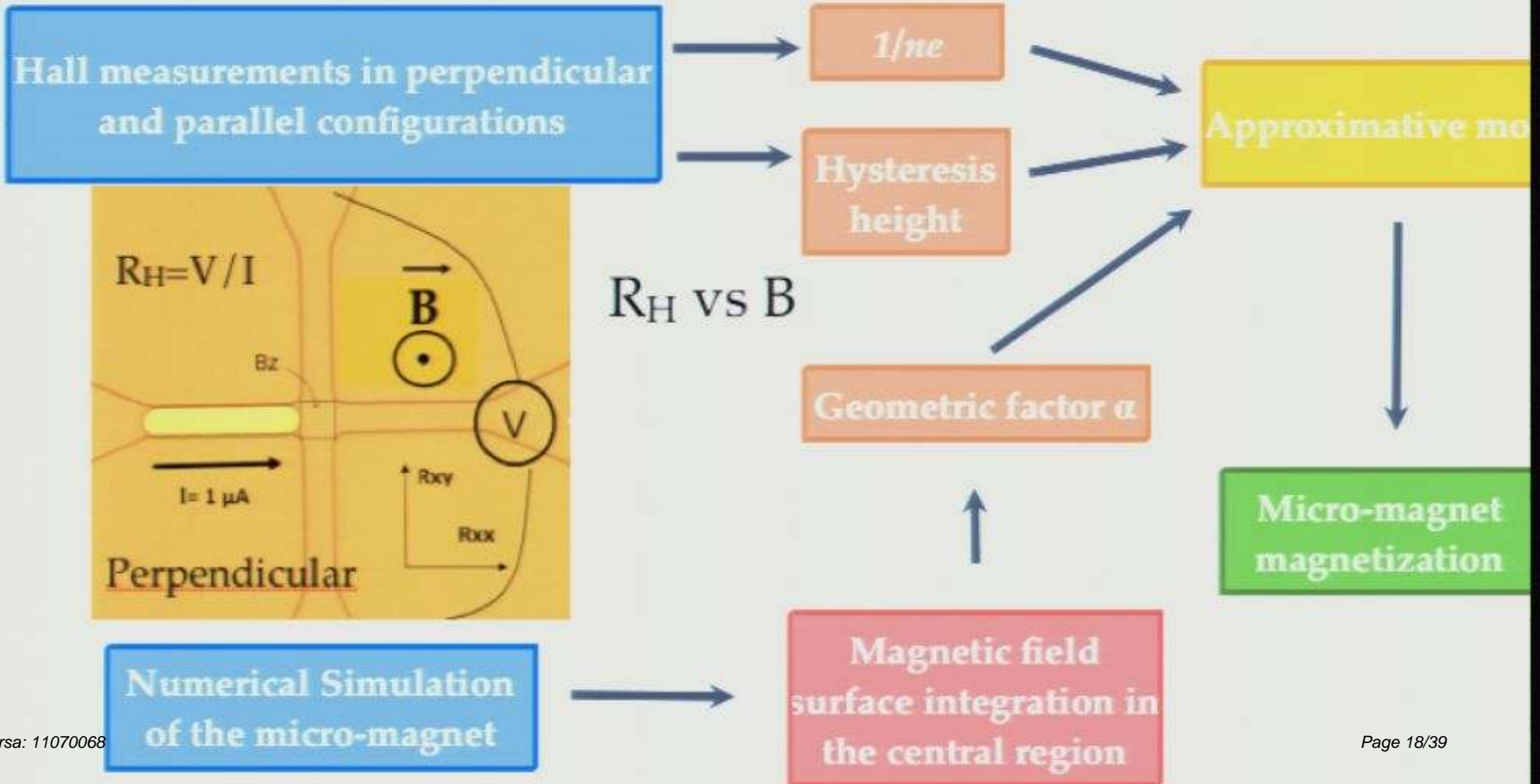
$$R_H = \frac{V_H}{I} = -\frac{B}{ned}$$



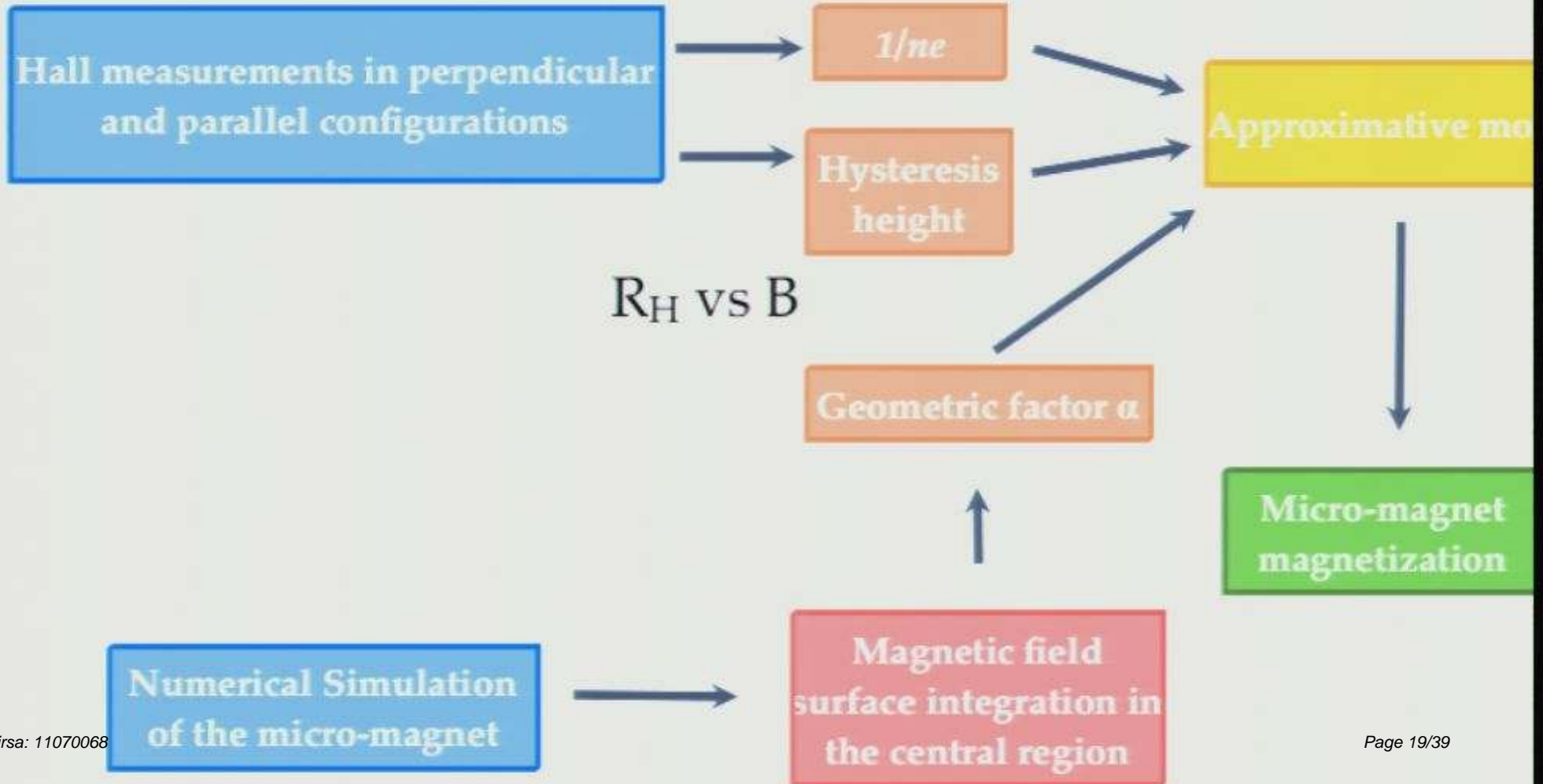
Hall effect device



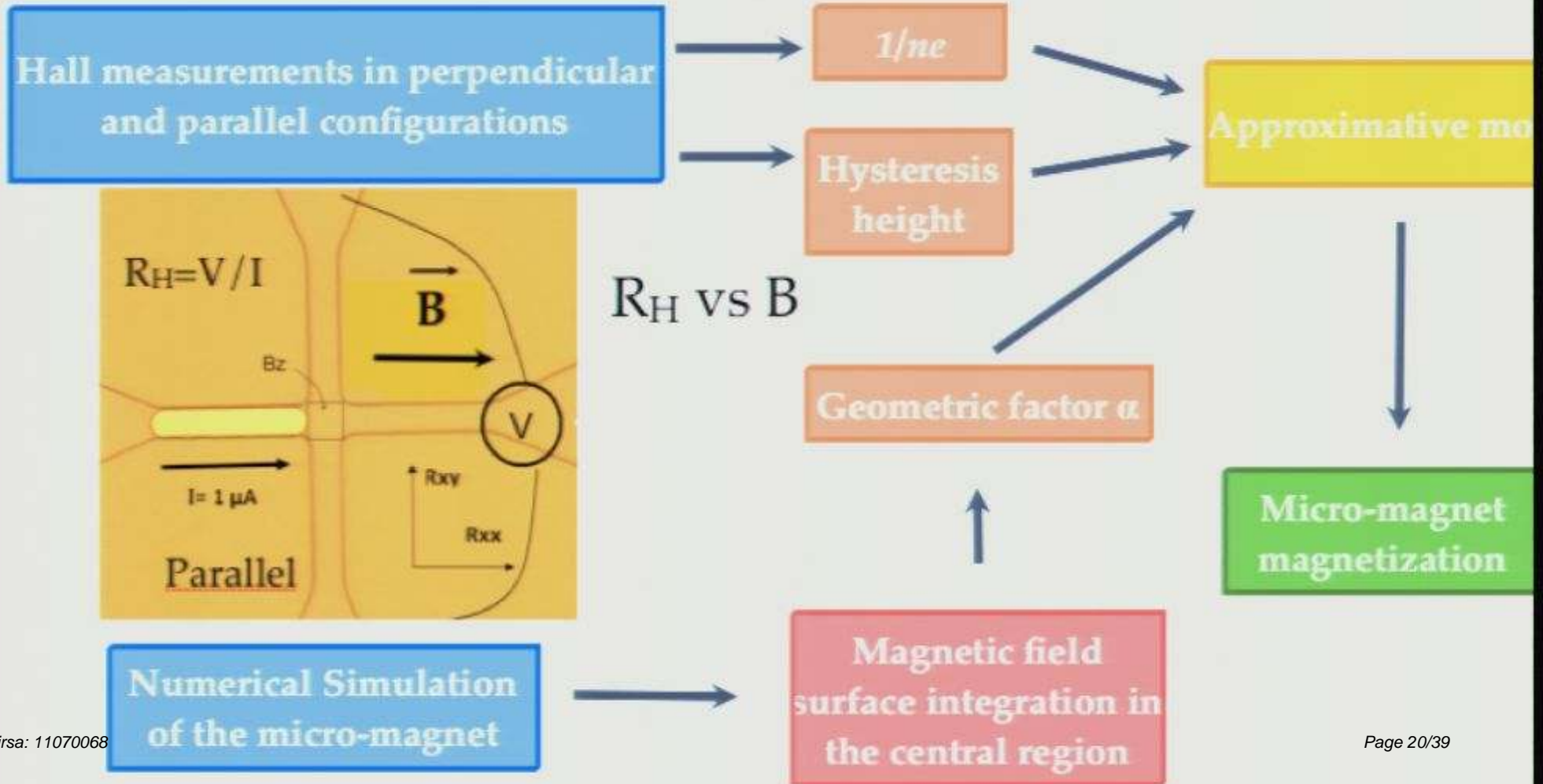
Characterization steps



Characterization steps



Characterization steps



Characterization results

Characterization results

- ✦ Measurements in perpendicular configuration.

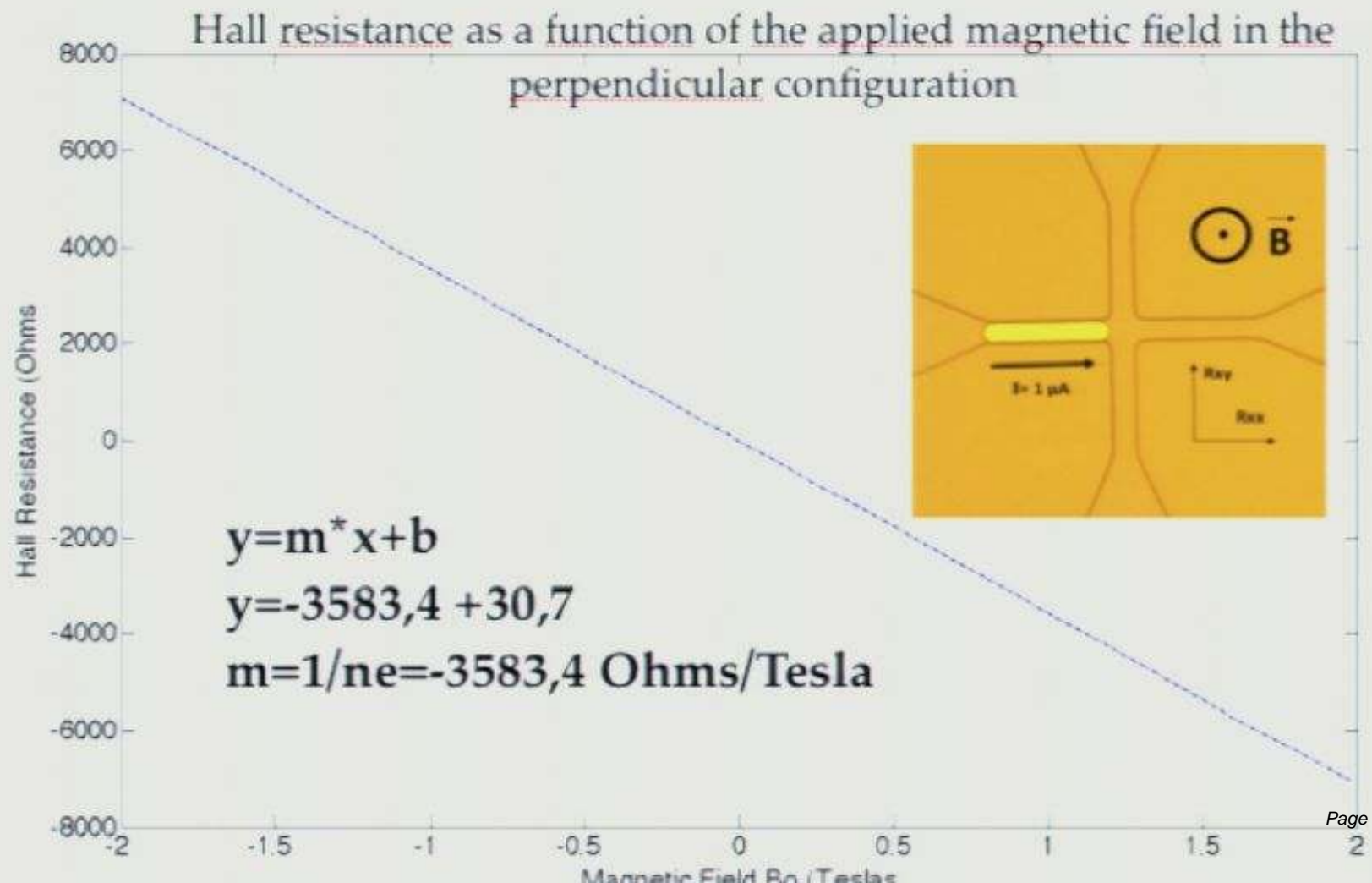
Characterization results

- * Measurements in perpendicular configuration.
- * The magnetization of the micro-magnet is weak in this configuration.

Characterization results

- ✦ Measurements in perpendicular configuration.
- ✦ The magnetization of the micro-magnet is weak in this configuration.
- ✦ The slope of R_H vs B gives us the charge carriers density.

Characterization results



Characterization results

Characterization results

- ✦ Measurements in parallel configuration.

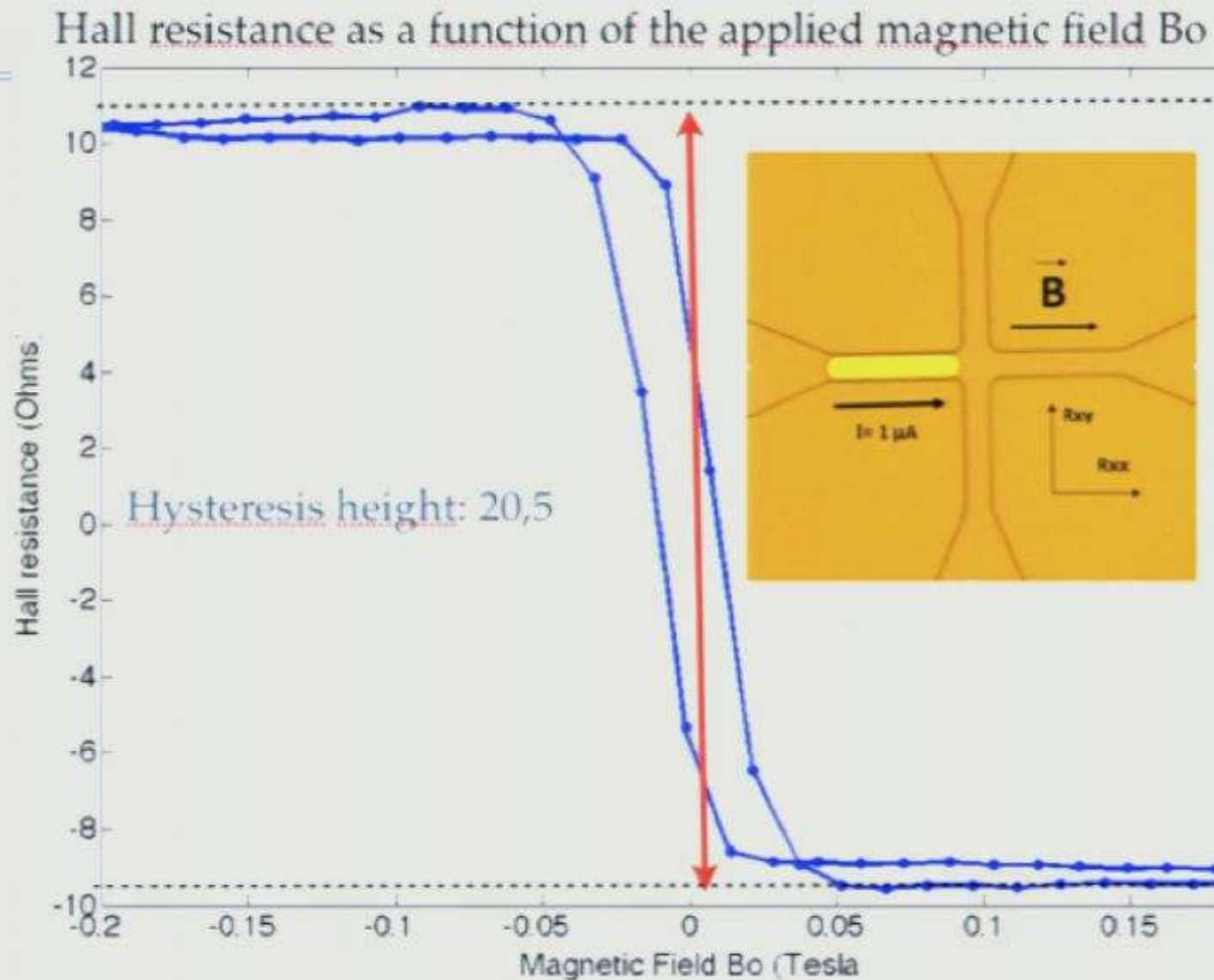
Characterization results

- ✦ Measurements in parallel configuration.
- ✦ The magnetization of the micro-magnet is strong in this configuration. The micro-magnet produces a magnetic field entering the central region of the cross.

Characterization results

- ✦ Measurements in parallel configuration.
- ✦ The magnetization of the micro-magnet is strong in this configuration. The micro-magnet produces a magnetic field entering the central region of the cross.
- ✦ The plot of R_H vs B shows an hysteresis because of the micro-magnet magnetization

Characterization results

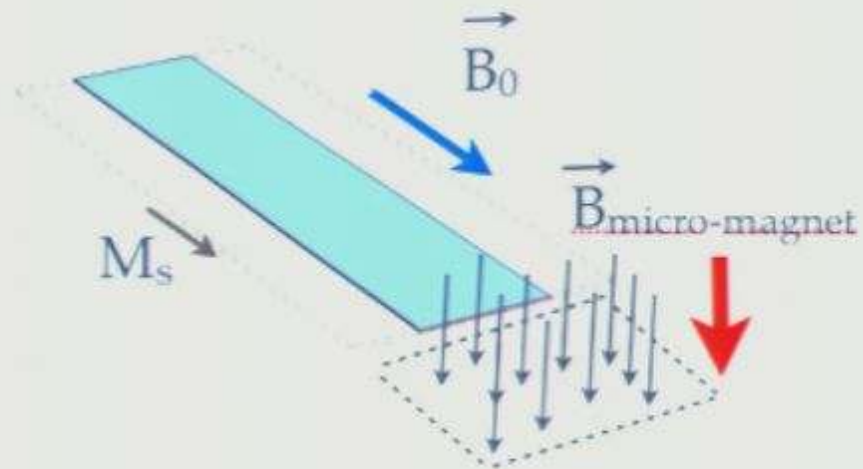


Characterization results

- ✦ We simulate a magnetic object with dimensions=micro-magnet.

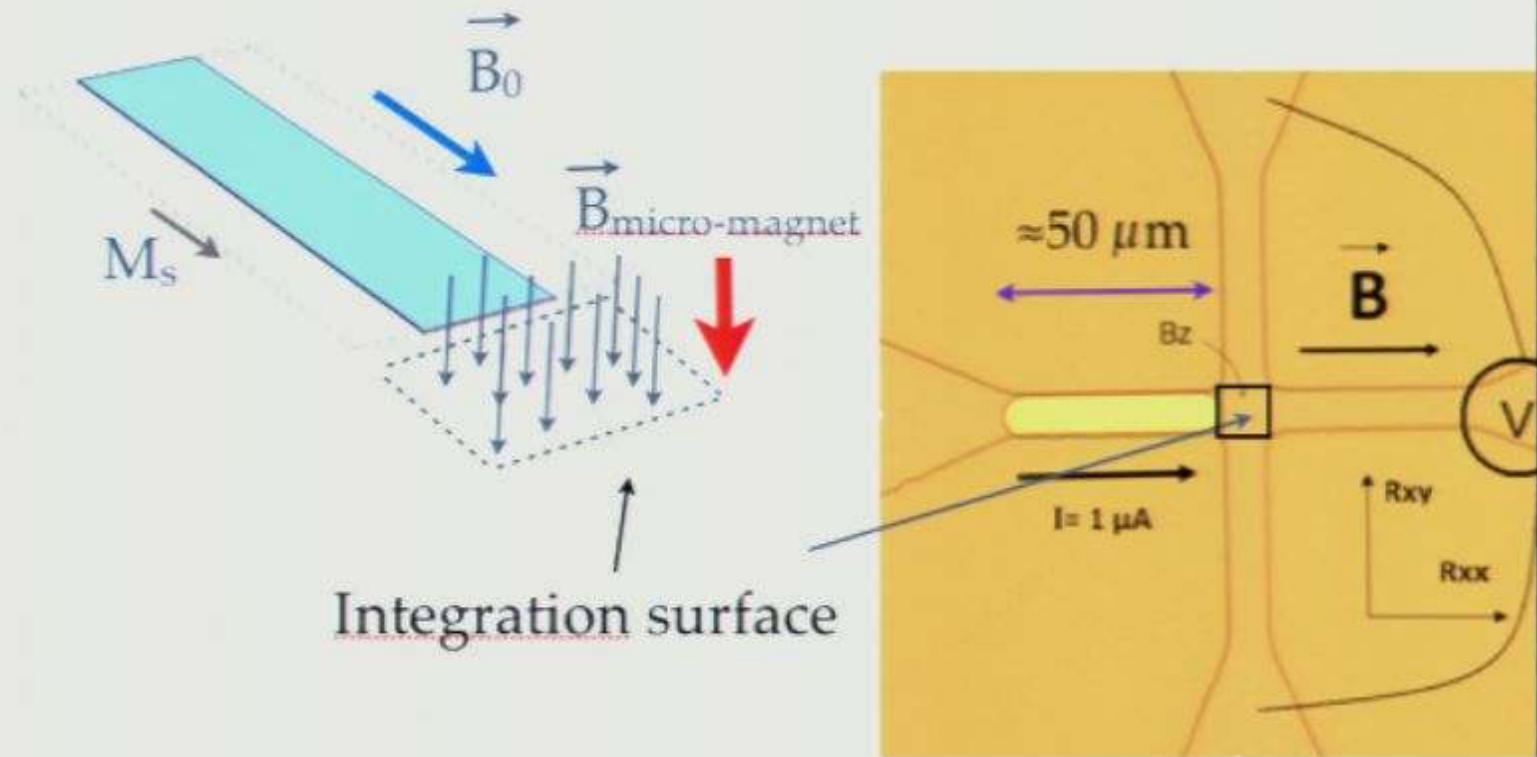
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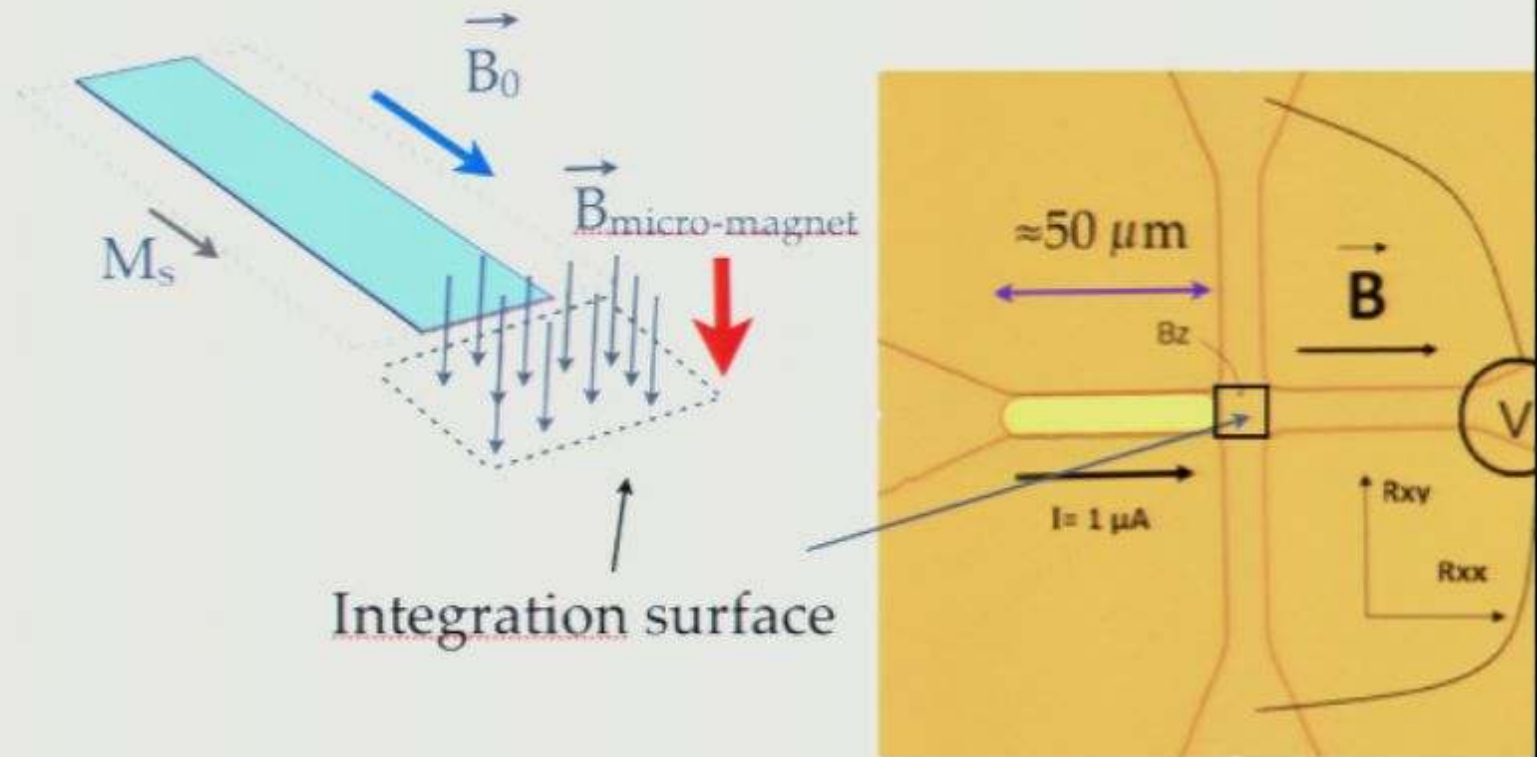
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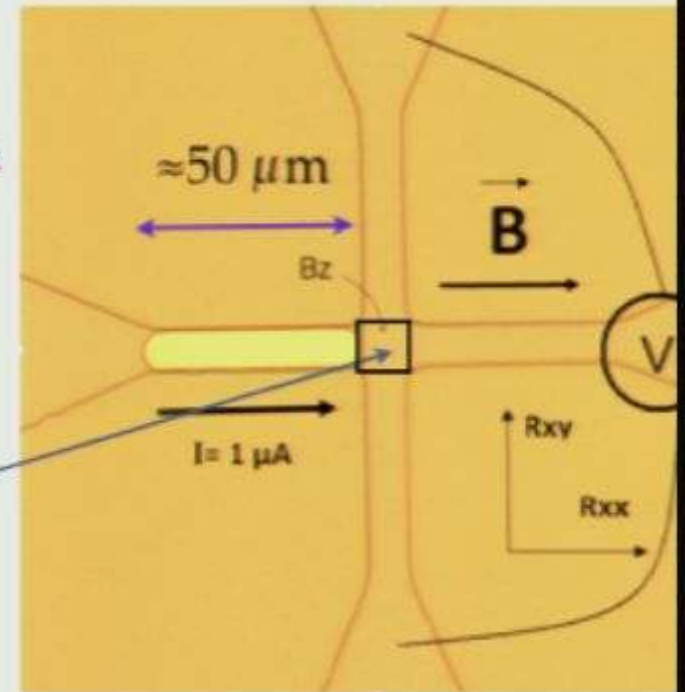
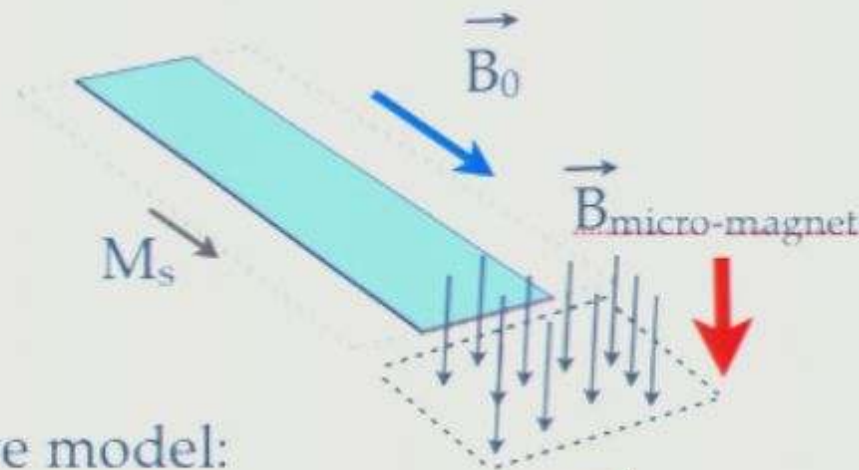


$$\alpha(W) = \frac{1}{A\mu_0 M_s} \iint_{\perp} \mathbf{B}(x, y, z = -d; M_s, W) \cdot d\mathbf{A}$$

d : distance micro-magnet to 2D plane
 W : micro-magnet dimensions

Characterization results

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Approximative model:

$$\frac{\Delta R_H}{2} \approx \frac{\alpha}{en_s} \mu_0 M_s$$

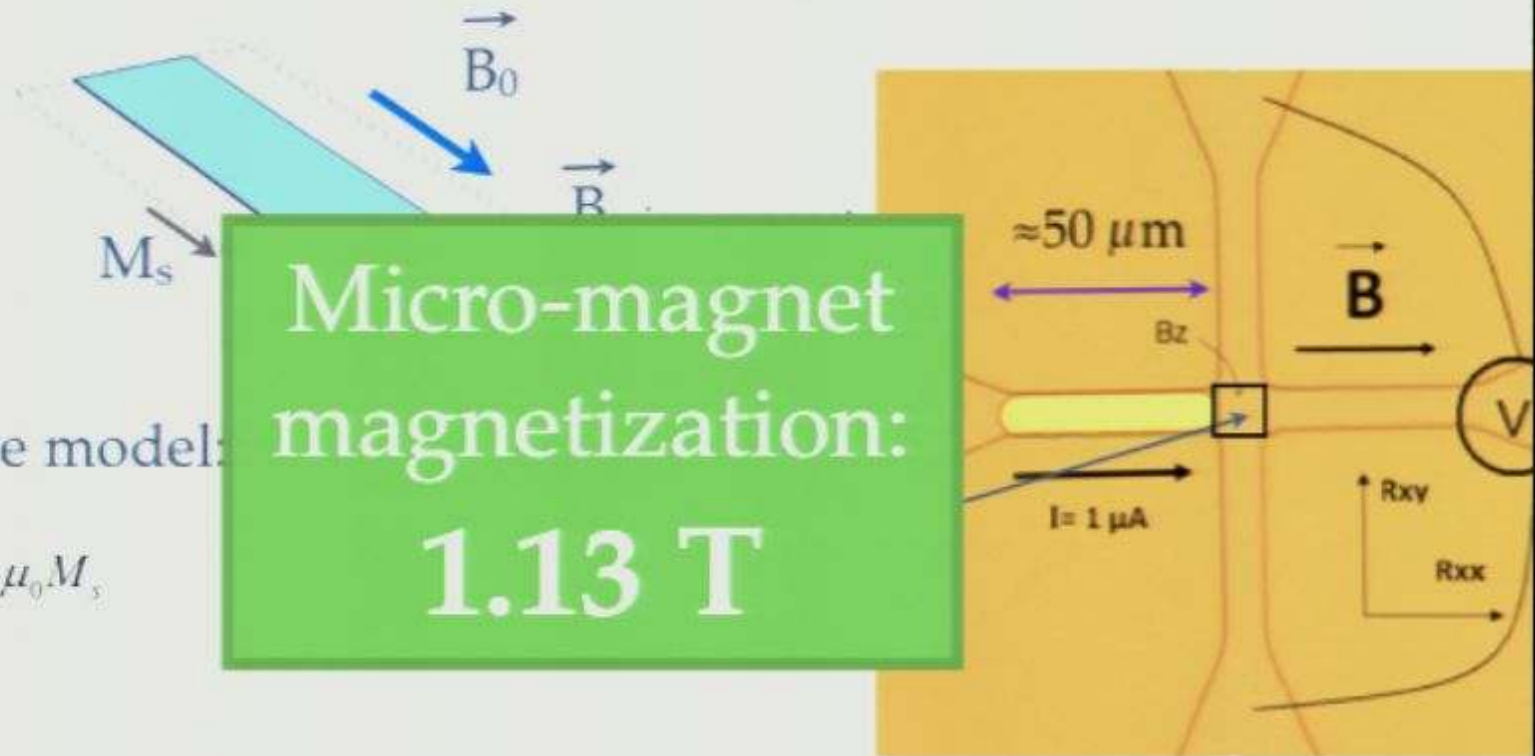
Integration surface

$$\alpha(W) = \frac{1}{A\mu_0 M_s} \iint_A \mathbf{B}(x, y, z = -d; M_s, W) \cdot d\mathbf{A}$$

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Characterization results

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Micro-magnet magnetization:
1.13 T

Approximative model:

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d: distance micro-magnet to 2D plane
W: micro-magnet dimensions

Thank you

Conclusion

- * We fabricated Hall effect devices to determine the magnetization of micro-magnets of cobalt.
- * Those micro-magnets are to be used to manipulate spin qubits in lateral double quantum dots.
- * We obtained the magnetization: 1.13 T. The reference value for cobalt saturation magnetization is 1.8 T.
- * The result will be improved by using more precise dimensions for simulation and a smaller integration surface.

Thank you