Asymmetric hysteresis loops of systems of bistable nanoscopic wires

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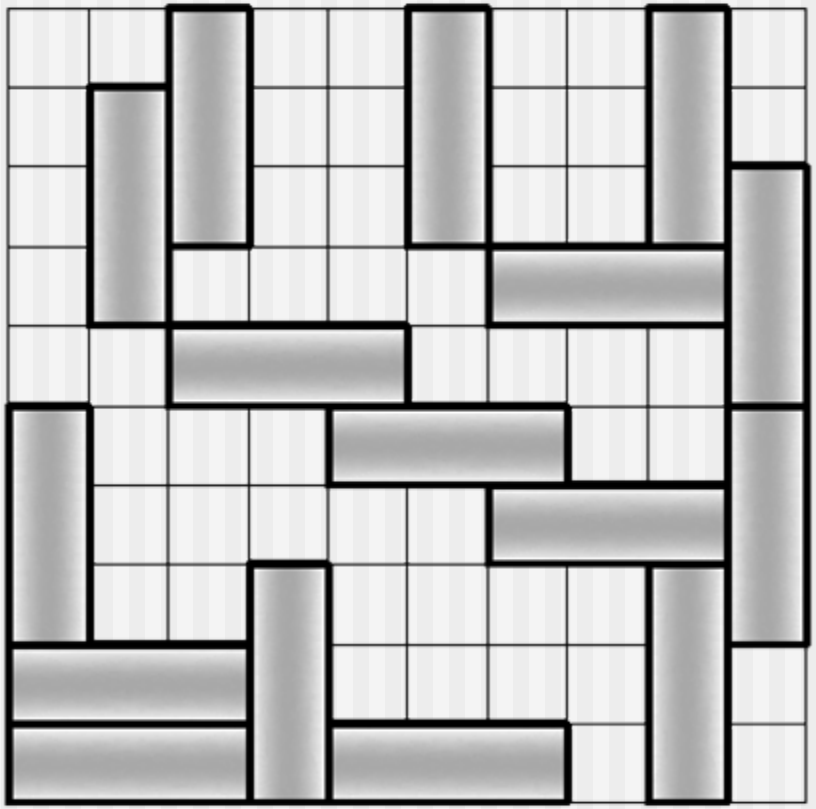
Outline

- The model
- Asymmetry - what it means?
- Asymmetric hysteresis loop for system
- „Be or not to be” … Gaussian?
- Possible application

One of typical configuration



System:

- Lattice: 10x10
- $N = 16$

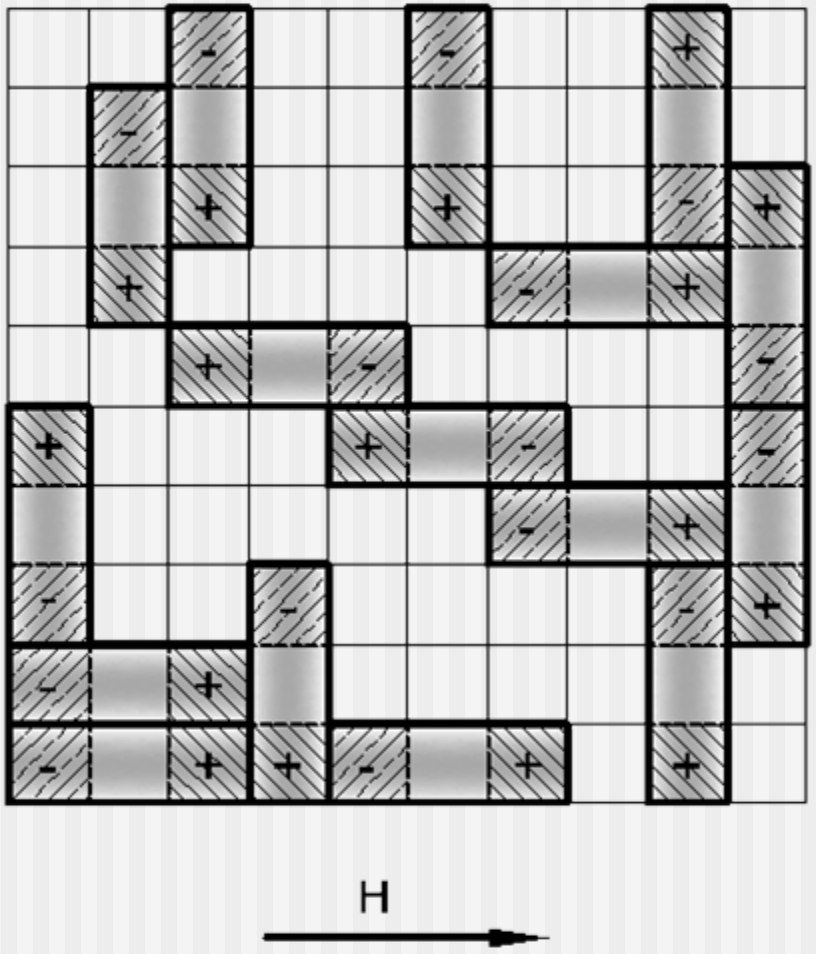
Wires:

- $D = 57$ nm
- $L = 115$ nm
- $M = 370$ emu/cm^3
- $H_s = 710$ Oe
- Gaussian H_s with: $u(H_s) = 5$ or 105 Oe

This system:

- $N_x = 7$
- $N_y = 9$

Interaction



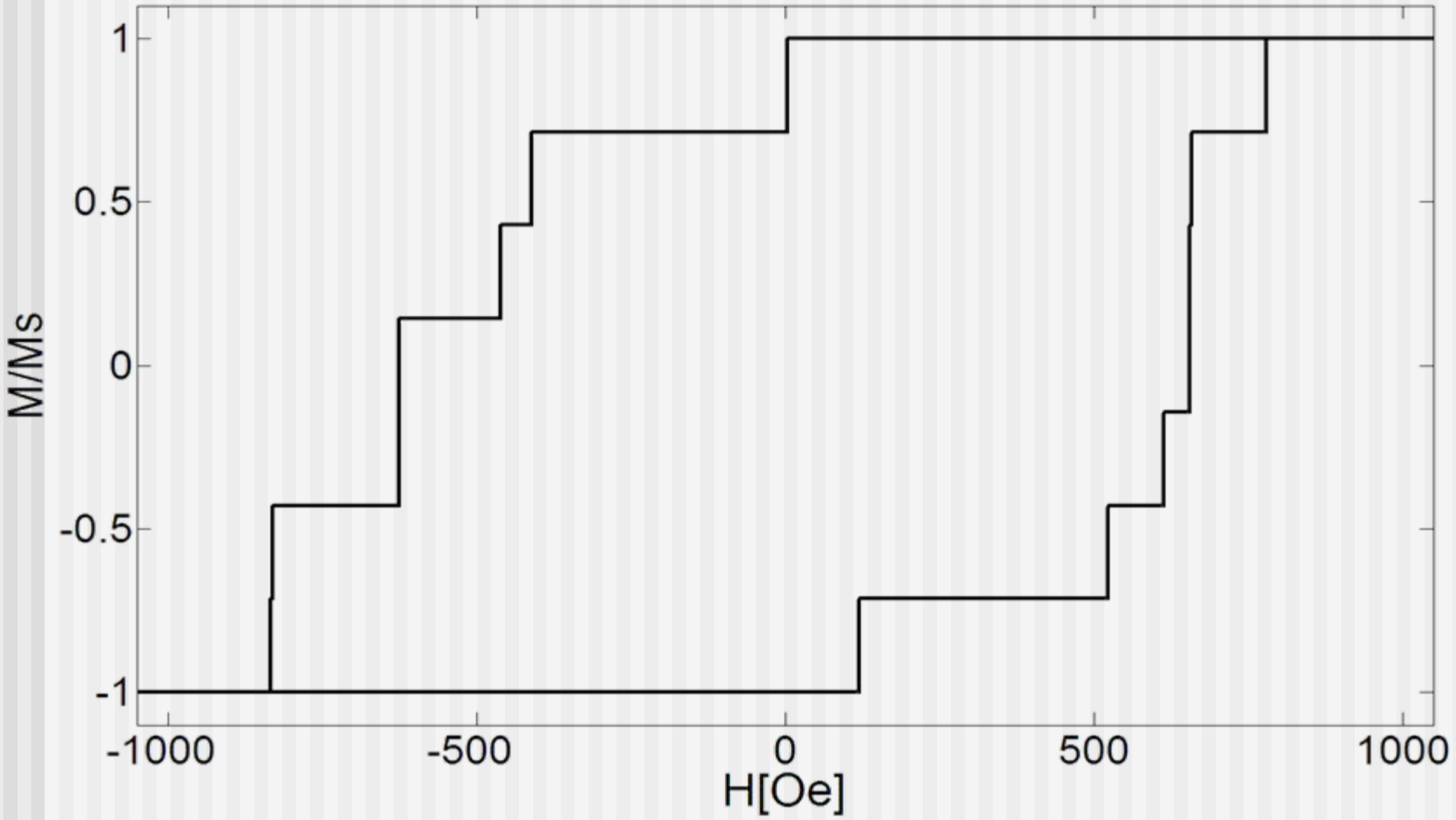
Three parts:

- With +*Q*
- Neutral
- With –*Q*

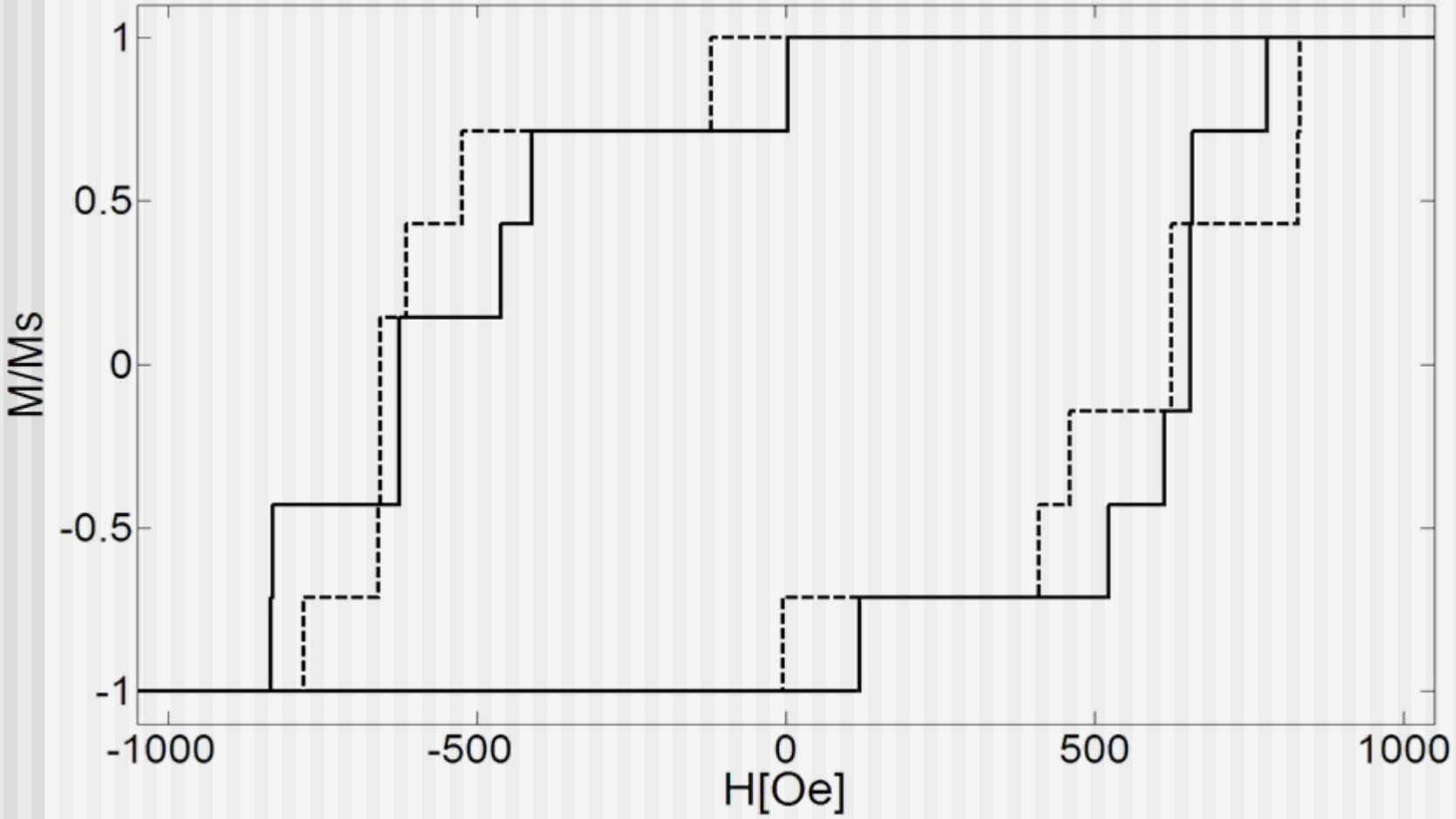
Absolute value of magnetic charge

$$Q = \pi^2 M D^2$$

Hysteresis loop and reversed loop



Hysteresis loop and reversed loop



Asymmetry

$$S1 = \int_{-H_m}^{H_m} (1 - M_d(H)/M_s)\,dH$$

$$S2 = \int_{-H_m}^{H_m} (M_a(H)/M_s + 1)\,dH$$

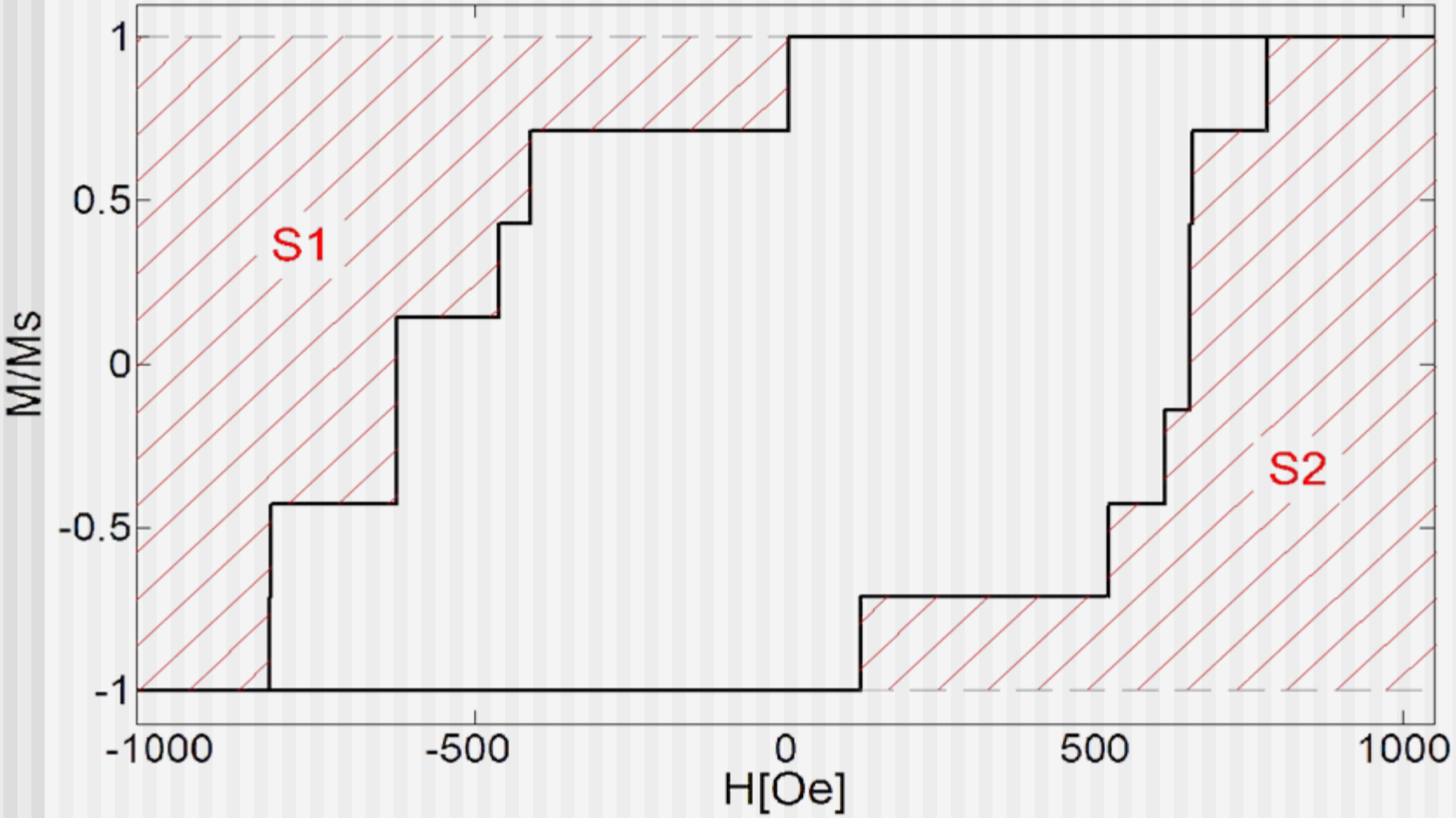
$$A = S1 - S2$$

$M_a(H)$ – curve for ascending magnetic field

$M_d(H)$ – curve for descending magnetic field

H_m – maximal applied field

Asymmetry



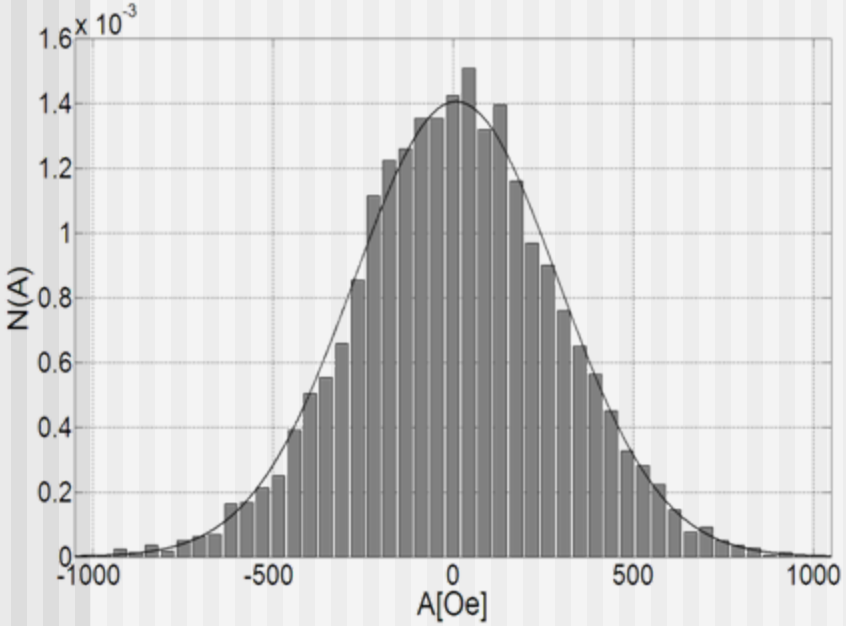
Sources of A

- Spatial distribution of the wires
- Distribution of the switching field of the wires
- Distribution of directions of magnetic moments of the wires perpendicular to H.

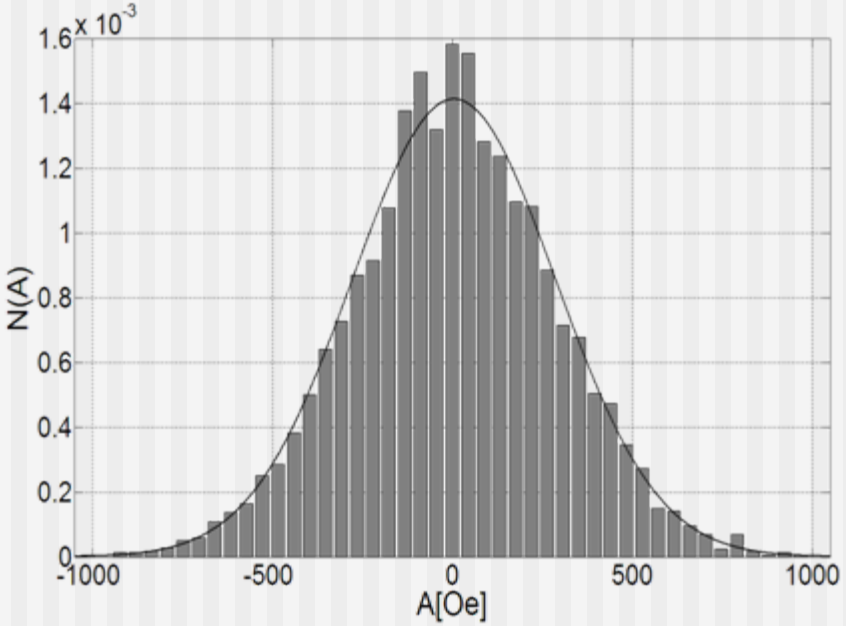
Three cases:

I. Different spatial systems with
   $u\,(H_s) = 5$ Oe
II. Different spatial systems with
   $u\,(H_s) = 105$ Oe
III. One spatial system with
   $u\,(H_s) = 105$ Oe

Asymmetry distributions for systems I and II ($5x10^3$ systems)

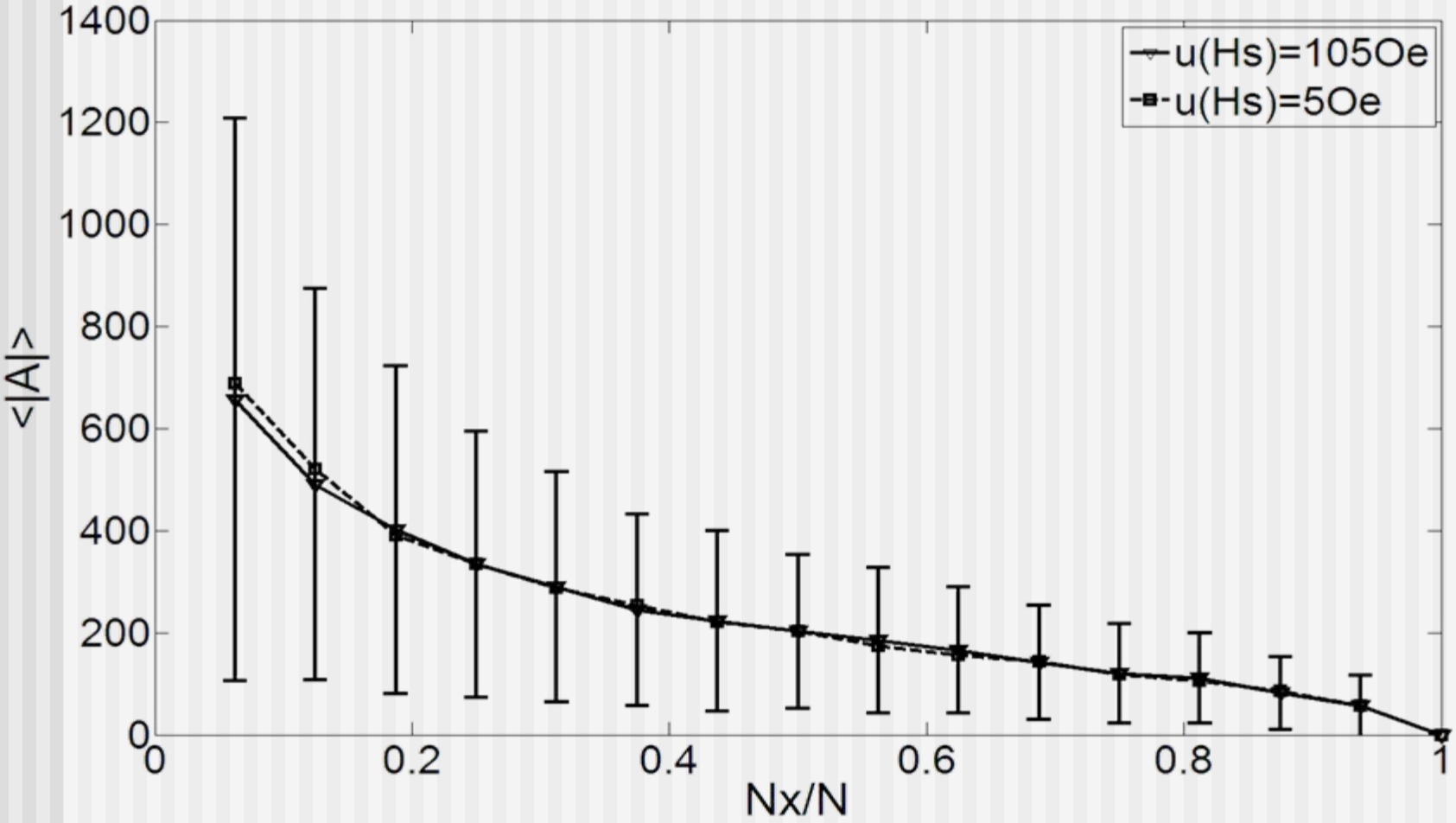


$u(H_s) = 5$ Oe
$\mu = 9.47$ Oe
$\sigma = 284.08$ Oe

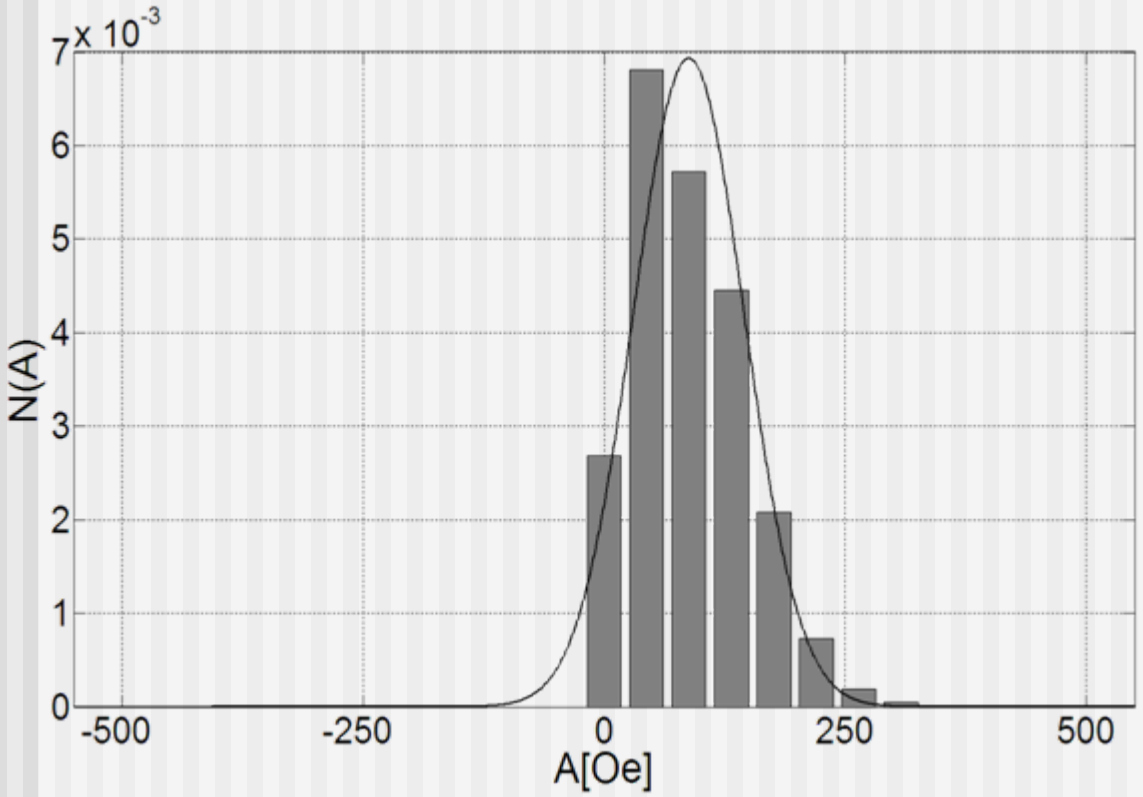


$u(H_s) = 105$ Oe
$\mu = 4.97$ Oe
$\sigma = 282.39$ Oe

Mean value of absolute value of the asymmetry A (for 10^3 systems)



The asymmetry distribution for system III ($5x10^3$ systems)



$u(H_s)$ = 105 Oe
μ = 87.80 Oe
σ = 57.54 Oe

μ and σ for distributions of A

System No.	μ [Oe]	σ [Oe]
I. Differ.: $u(H_s)$ =5Oe	9.47	284.08
II. Differ.: $u(H_s)$ =105 Oe	4.97	282.39
III. The same: $u(H_s)$ =105 Oe	87.80	57.54

Possible applications

- The number of state perpendicular to switching field

$$2^{N-N_x}$$

- Each state characterized by its own hysteresis loop (specific shape, in most cases asymmetric)
- For example: magnetic coding

Magnetic coding

One magnetic state

⇒ check: verified

⇒ apply field impulse at given point and given intensity

⇒ modified system – new loop shape

⇒ check: is it proper or not ?

⇒ …

Sequential verification of the magnetic state of the system

- Compared to: password within a password within a password etc.

Possible applications – comments

- If not a lot of wire in the system – number of their spatial configurations is high enough to have a lot of sequences of the shapes of M(H).
- We expect: improper signal can modify the state of system as to disable its recurrence (potential safety applications)

Summary

- Different curves for descending and ascending magnetic field – due to the wires perpendicular to the applied field
- A is determined mostly by the differences in spatial configurations
- Potential safety applications

Thank you for your attention