NANOSPIN Summarizing MEETING, 11th-12th of July 2016

UNIWERSYTET IM. ADAMA MICKIEWICZA W POZNANIU

Nanomaterials Physics Division, Faculty of Physics

Static and dynamic properties and sample applications of periodically perforated thin film – magnonic crystals

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INNOVATIVE ECONOMY
NATIONAL COHESION STRATEGY

FNP Foundation for Polish Science

THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020

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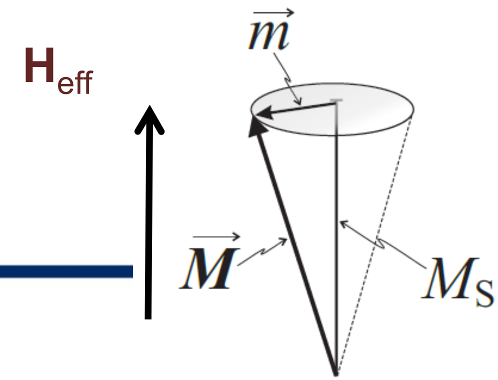
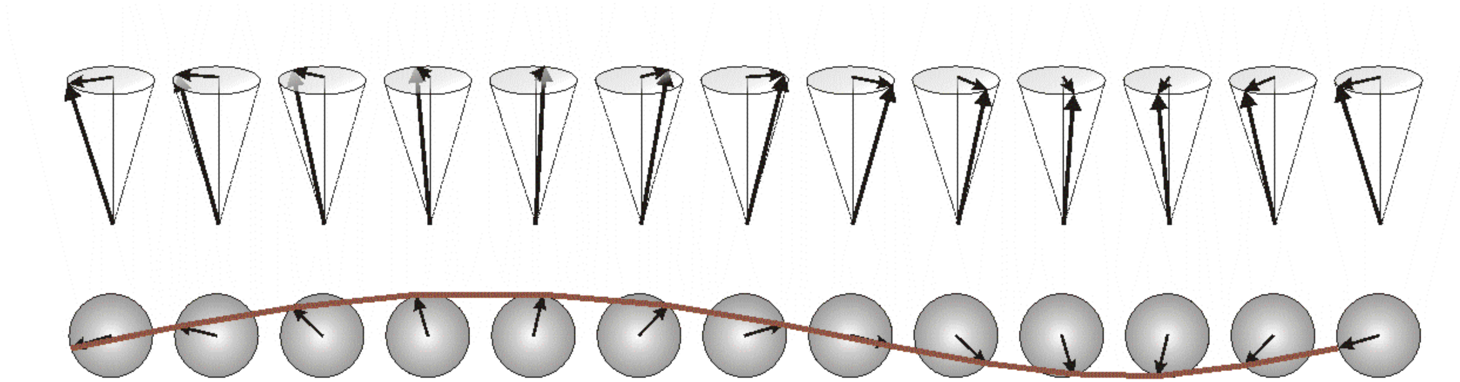
Outline

- Micromagnetic simulations
- Remagnetization process in patterned thin films
- Ferromagnetic resonance
- New technique of generation spin waves beams
- Summary

Spin waves





Landau-Lifshitz equations:

$$\frac{\partial \vec{m}}{dt} = \vec{\tau}_{LL}$$

$$\vec{\tau}_{LL} = \gamma_{LL}\frac{1}{1+\alpha^2}\left(\vec{m} \times \vec{H}_{eff} + \alpha\left(\vec{m} \times \left(\vec{m} \times \vec{H}_{eff}\right)\right)\right)$$

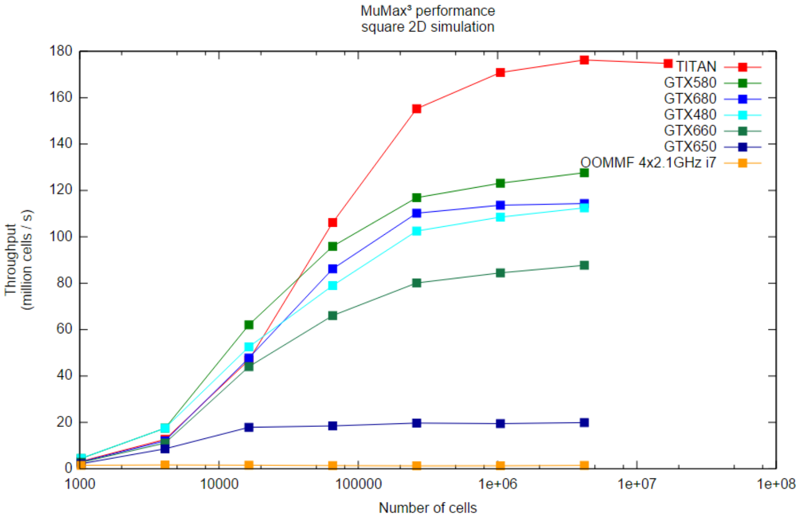
GPU / CPU

mumax^3

GPU-accelerated micromagnetism

The Object Oriented MicroMagnetic Framework (OOMMF) project at ITL/NIST

Micromagnetic simulations – performance comparison



http://mumax.github.io/

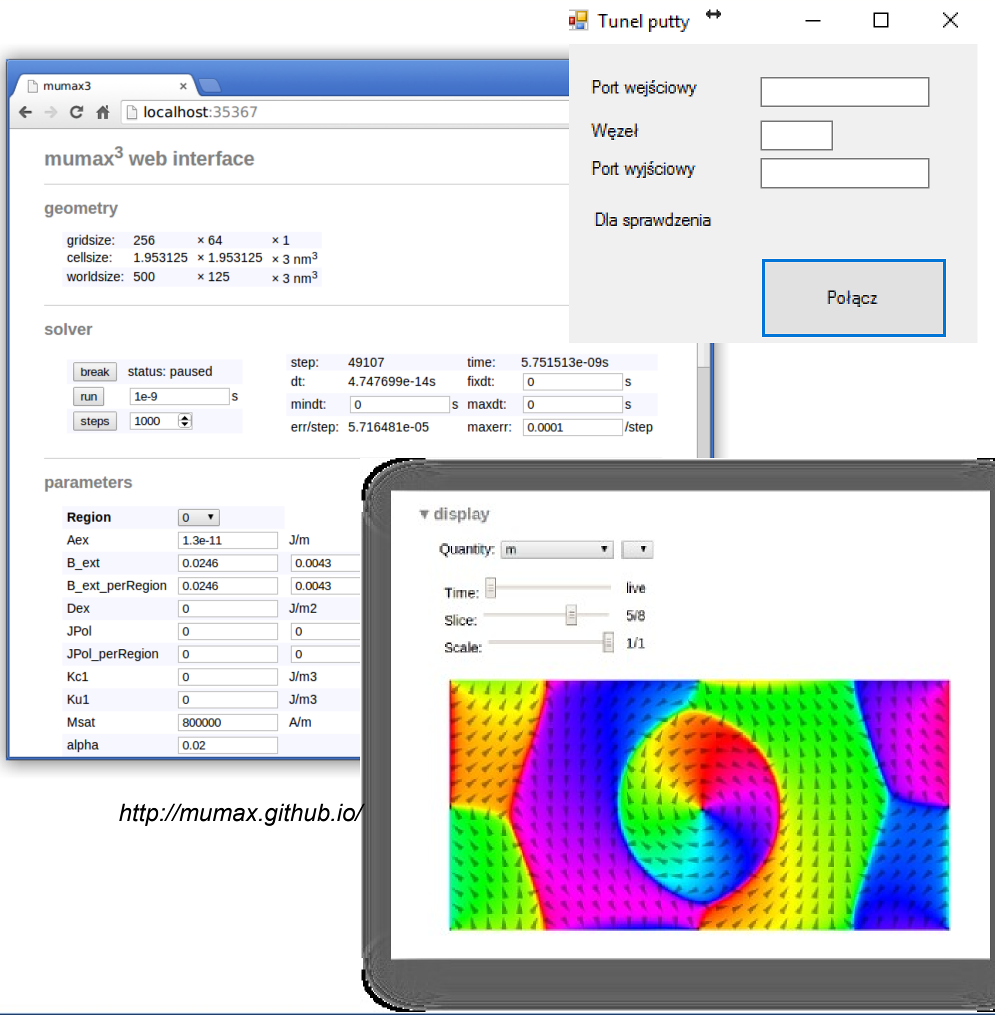
steps: 15387
time: 5.12373e-09 s
dt: 5.067e-13 s

Performance comparison for different GPU's

Karta graficzna	Czas symulacji	Liczba procesorów	Częstotliwość rdzeni (boost)	Wydajność	Przewidywany czas symulacji	Średnia cena w dniu premiery
TITAN X	16	3072	1075	0.9	16.67	5200
TI BLACK	19	2880	980	0.77	19.52	4700
TI 980	**15**	**2816**	**1304**	**1**	**15**	**3675**
GF 860 M	78	640	1029	0.20	83.64	
Tesla 2050	45	448	1150	0.14	106.91	8000

Micromagnetic simulations - interface

```
D := 430e-9 // circle radius
A := 620e-09 // lattice constant
Ncells := 256
cellS := A/Ncells
print()
Nx := Ncells
Ny := Ncells
Nz := 1
cx := cellS
cy := cellS
cz := 10e-09

setgridsize(Nx, Ny, Nz)
setcellsize(cx, cy, cz)

circ0 := (circle(430e-9)) // D - diameter
circ1 := (circ0.repeat(A, A, 0)).sub(circ0)
g := circ0.add(circ1)
setgeom(g)

EdgeSmooth=0
DefRegion(1, circ0 )
DefRegion(2, circ1 )
SetPBC(8, 8, 0)

A_Py := 1.3e-11
Ms_Py := 0.8e+06


Aex = A_Py
Msat = Ms_Py
B0 := 0.1630

//phi:=45*pi/180
phi:=0*pi/180
cInit := 5  // initial multiplier of external field
alpha = 0.001

m=uniform(cos(phi),sin(phi),0)
B_ext = vector(cInit*B0*cos(phi),cInit*B0*sin(phi),0)

MaxDt = 1e-10
MinDt = 1e-15
// S T A B I L I Z A T I O N
t = 0
relax()
// Zmniejszanie pola
t = 0
```



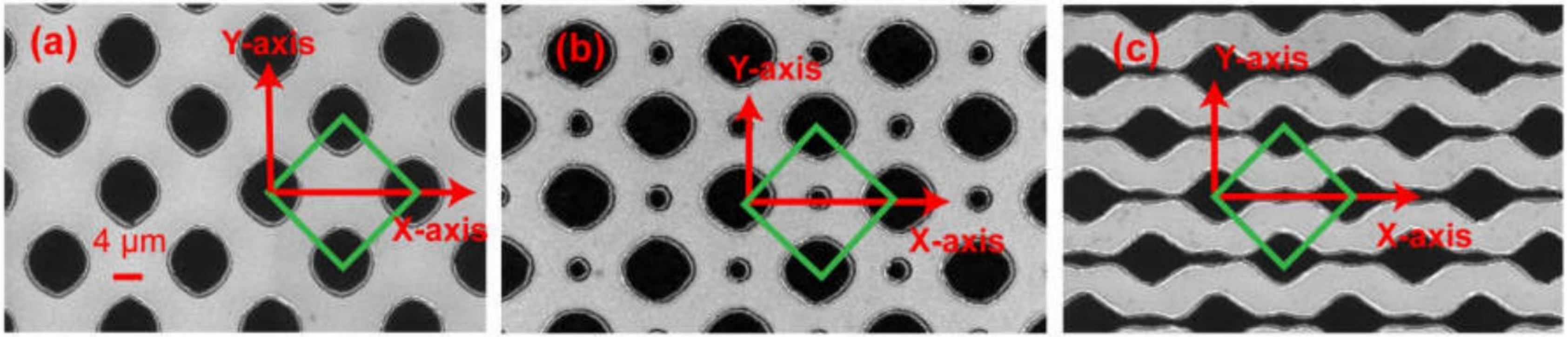
http://mumax.github.io/

Static properties of periodically perforated magnetic thin films

Samples of Py thin film

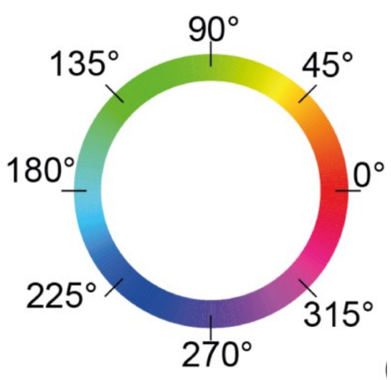
Experiment

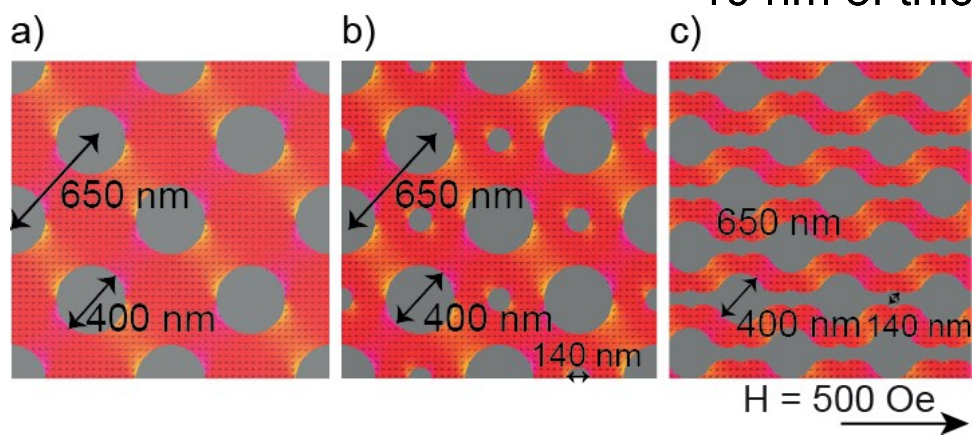
Square ADL | Bi-component ADL | Wavelike



Micromagnetic simulations

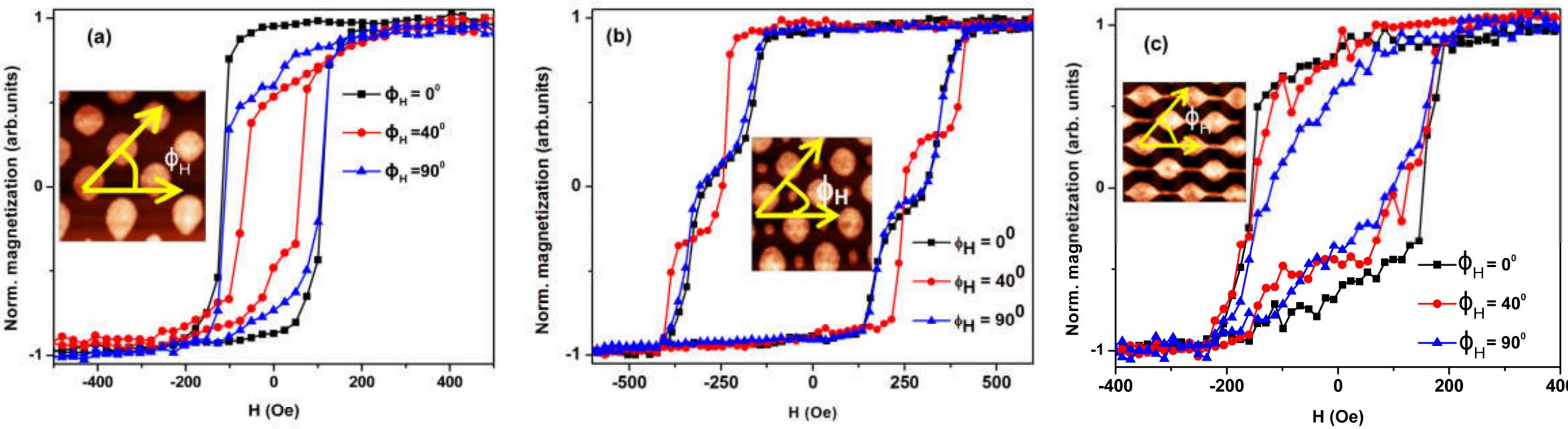
10 nm of thickness





Reversal mechanism in periodic Py nanostructures

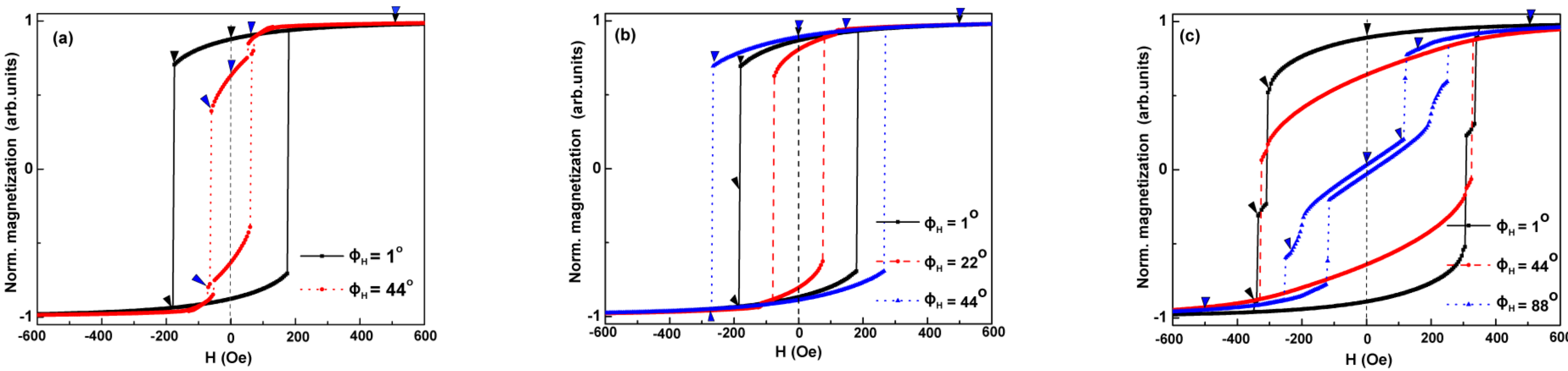
Magnetization reversal mechanism was studied through Kerr microscopy (LMOKE).

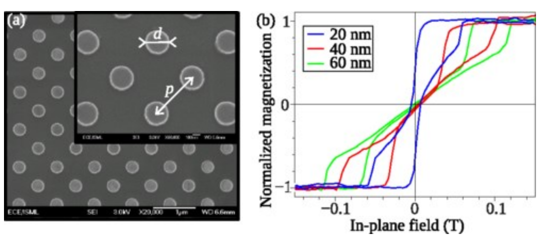


N. Tahir, et. al. submitted 2016

Micromagnetic simulations

Hysteresis loops obtained from micromagnetic simulations at different in-plane angles

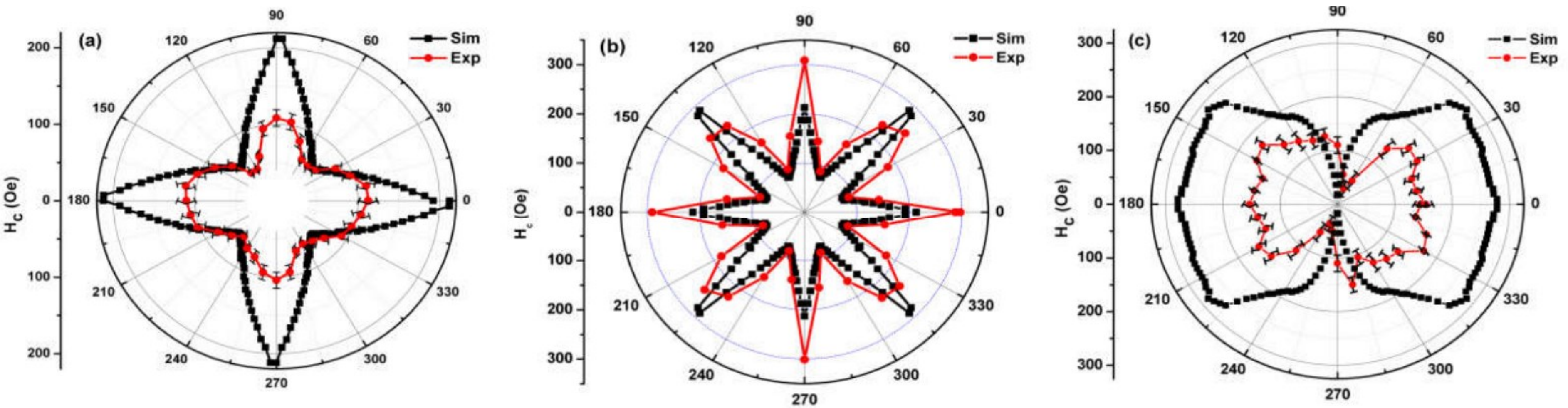




R. V. Verba, et. al, Phys. Rev. B **93** (2016)

Easy and hard axes

Polar plot showing comparison of simulated and experimental (from LMOKE) H_c field in dependence on the external magnetic field orientation.

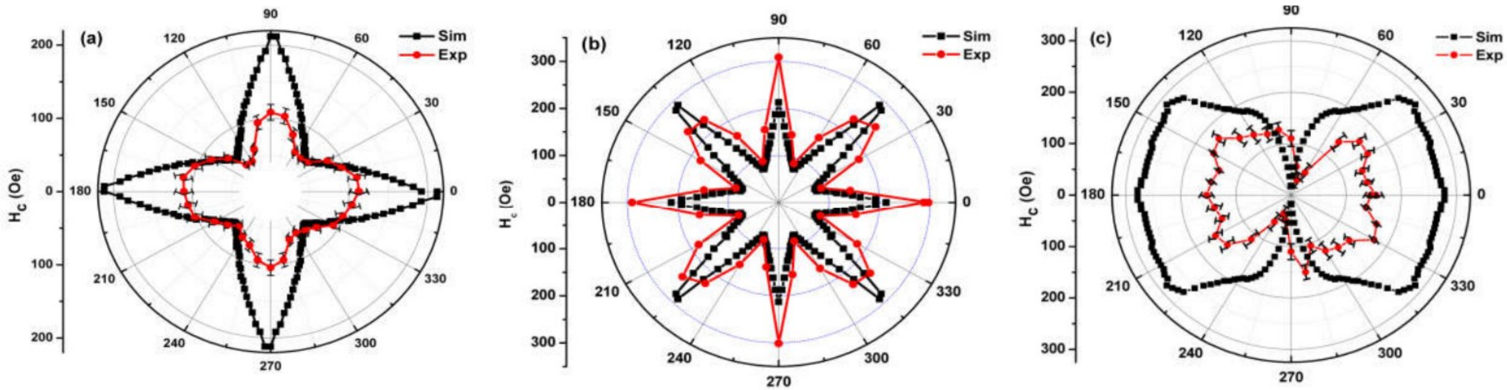


Black lines – simulation, red lines – experimental.

N. Tahir, et. al. submitted 2016

Easy and hard axes

Polar plot showing comparison of simulated and experimental (from LMOKE) H_c field in dependence on the external magnetic field orientation.



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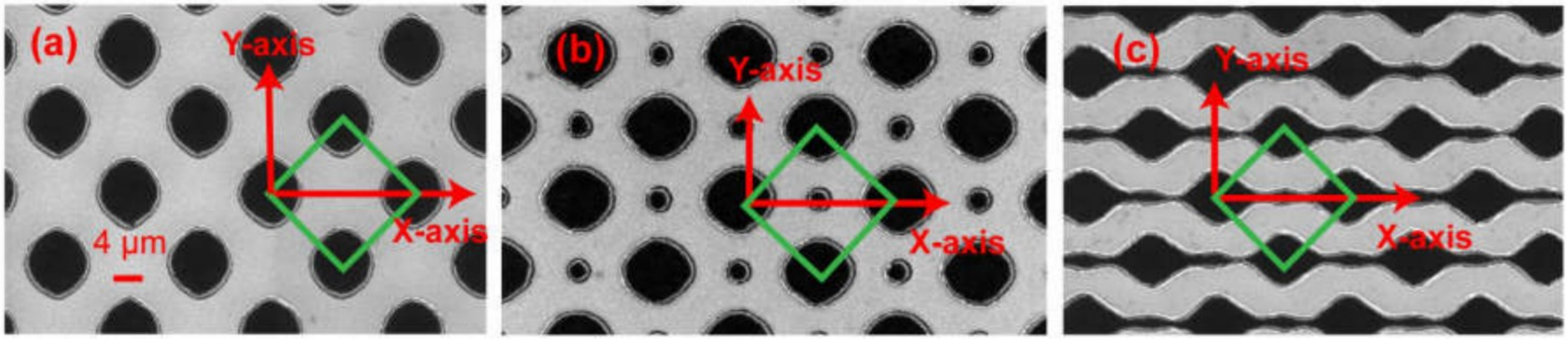
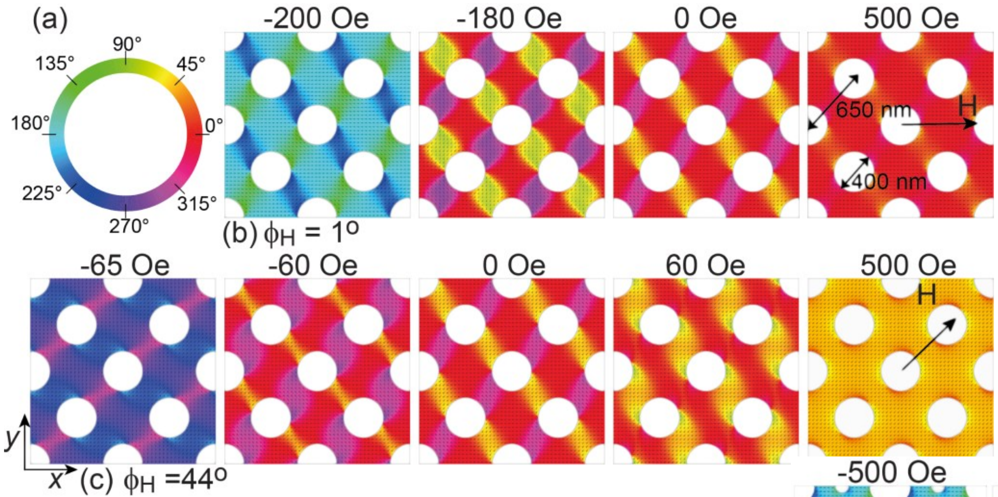
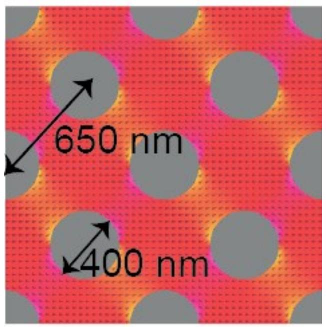


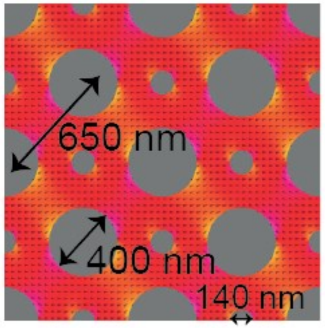
Magnetization distribution obtained from micromagnetic simulations for SquareADL

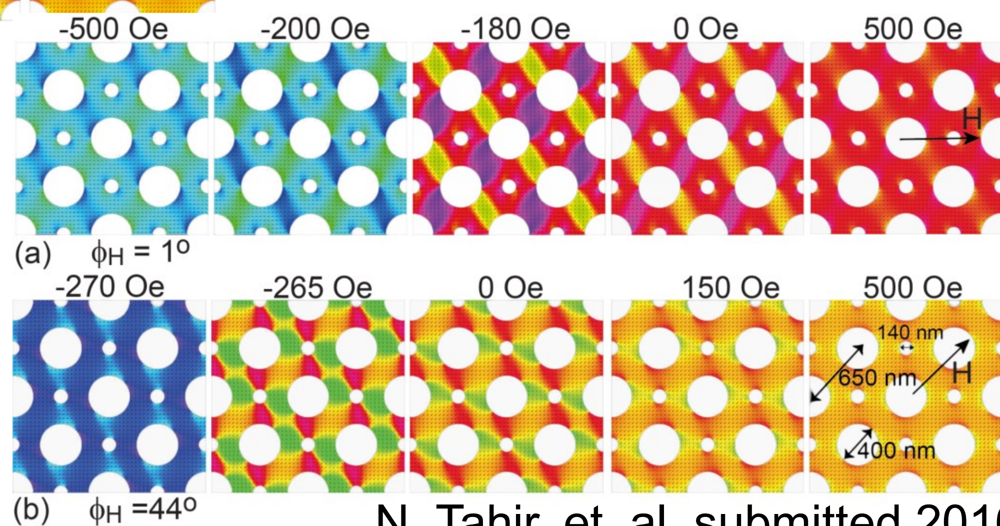


a)



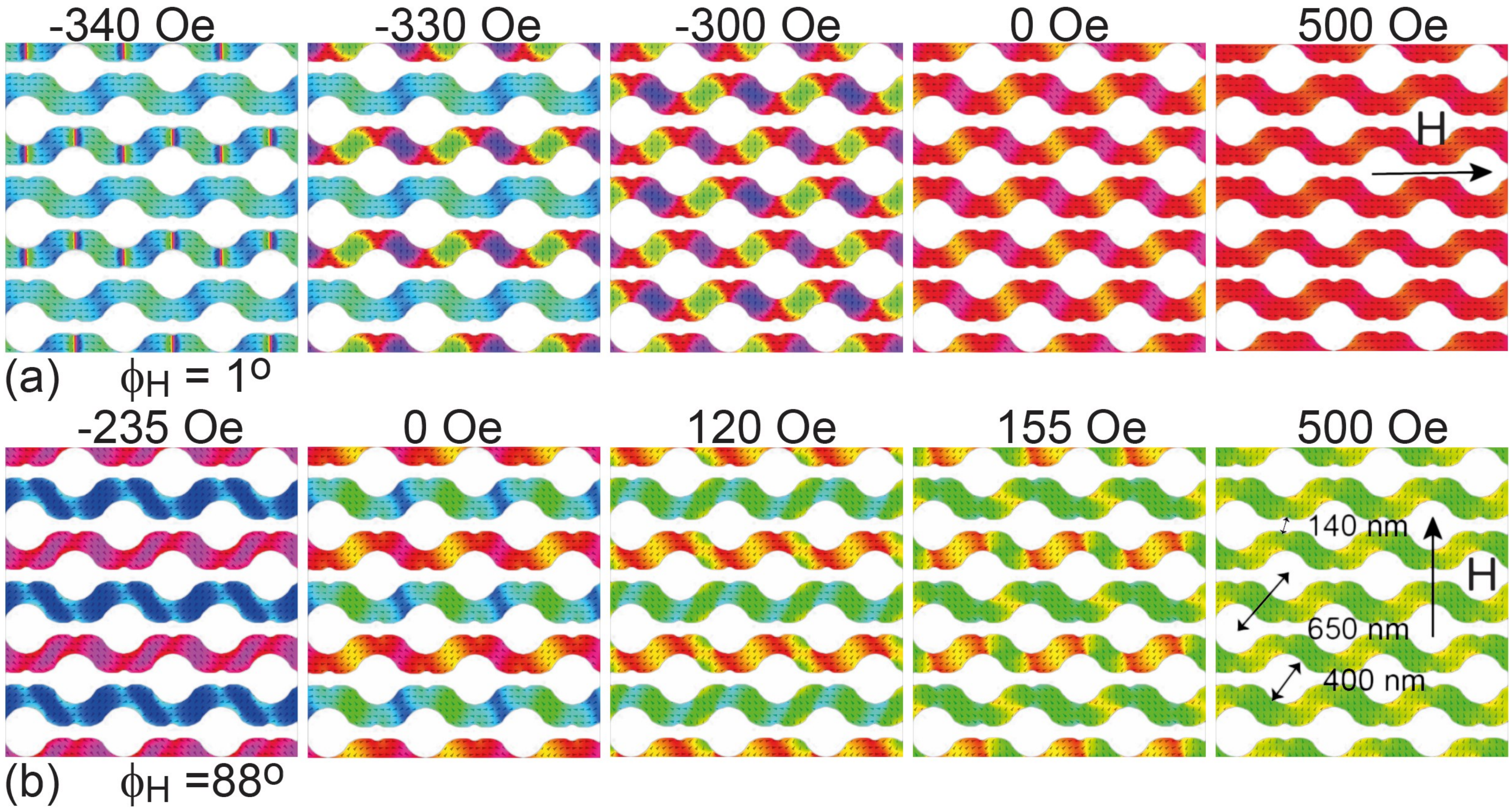
b)



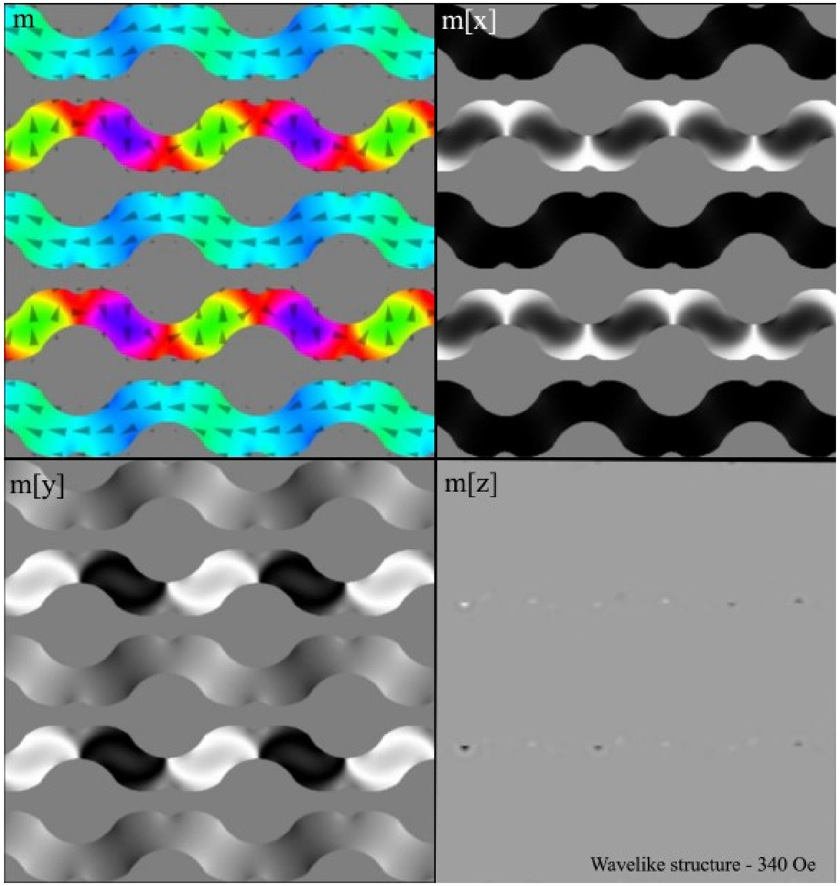


N. Tahir, et. al. submitted 2016

Magnetization distribution obtained from micromagnetic simulations for WaveLike



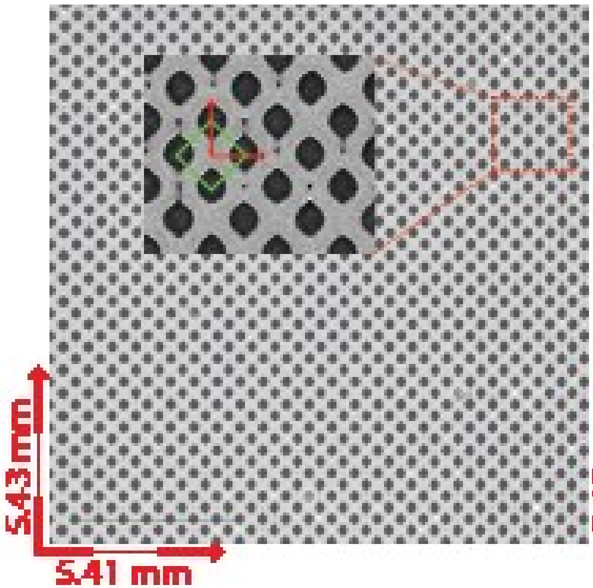
360 domainwalls creating



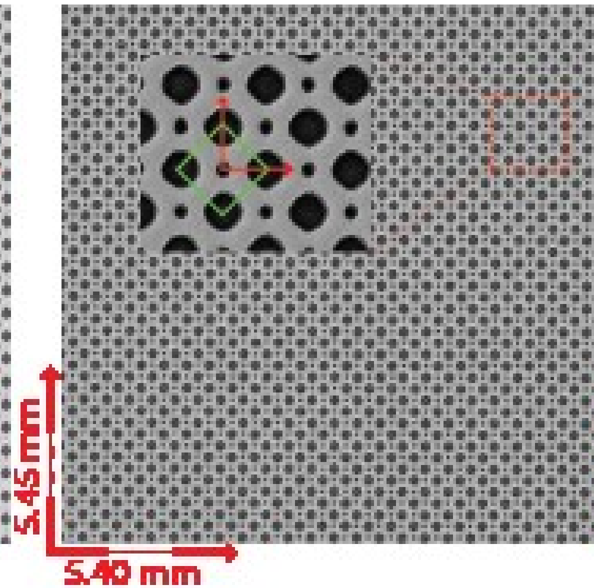
N. Tahir, et. al submitted 2016

Dynamic properties of magnonic crystals

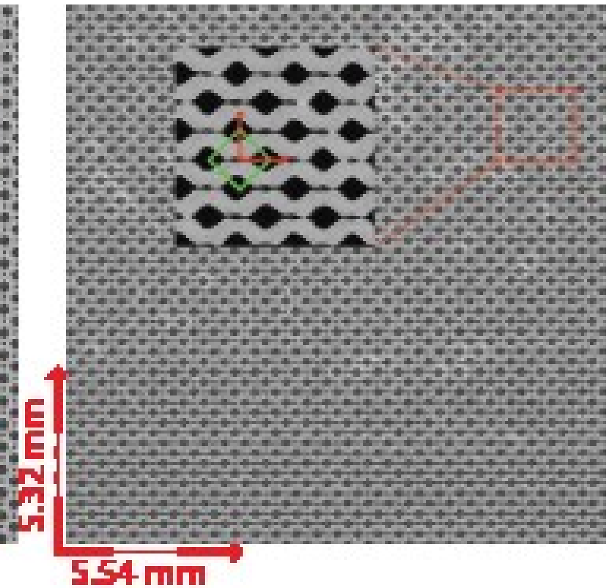
SEM images of the three investigated samples



SquareADL



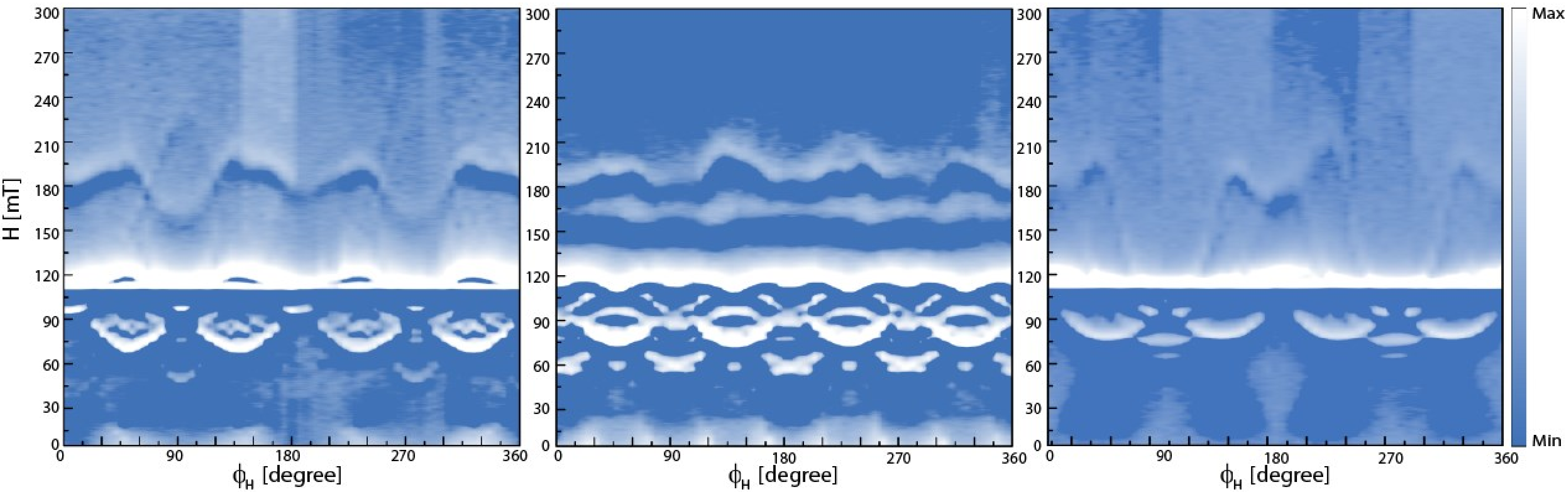
Bi-componentADL



Wavelike

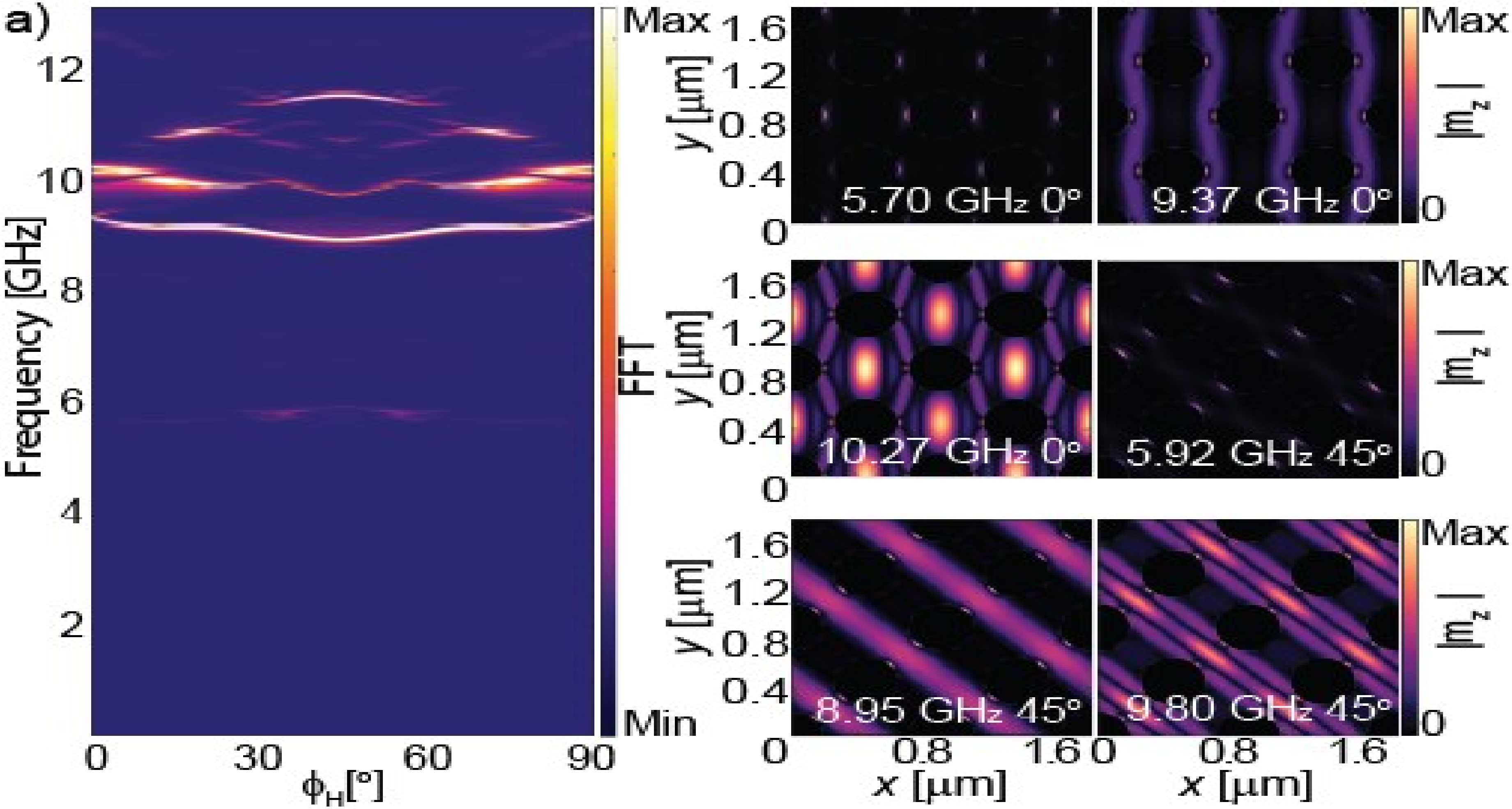
FMR spectra in dependence on the in-plane angle of the magnetic field.

Experimental FMR results



M. Zelent, et. al. in final preparation (2016)

Modes visualization



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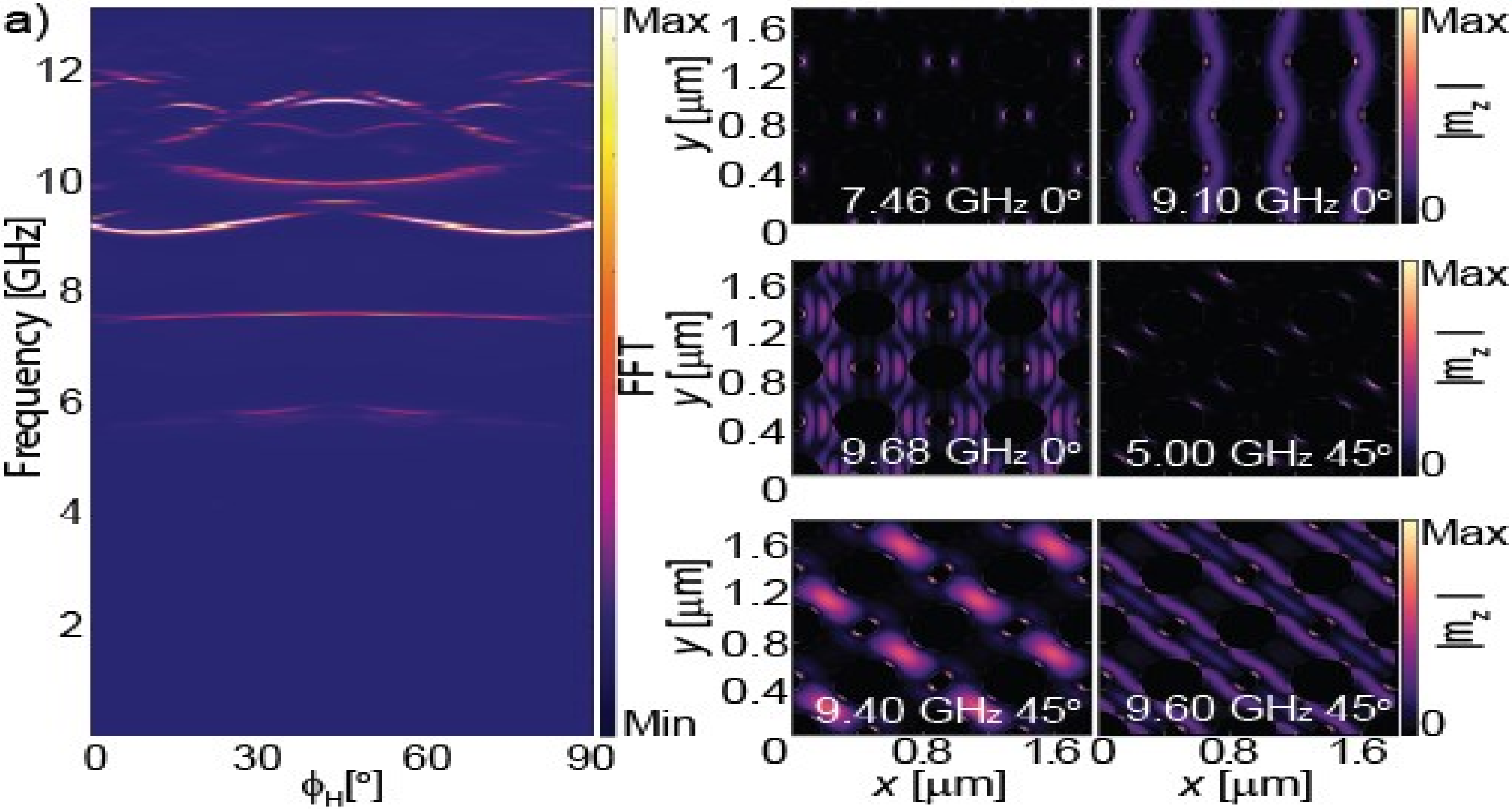

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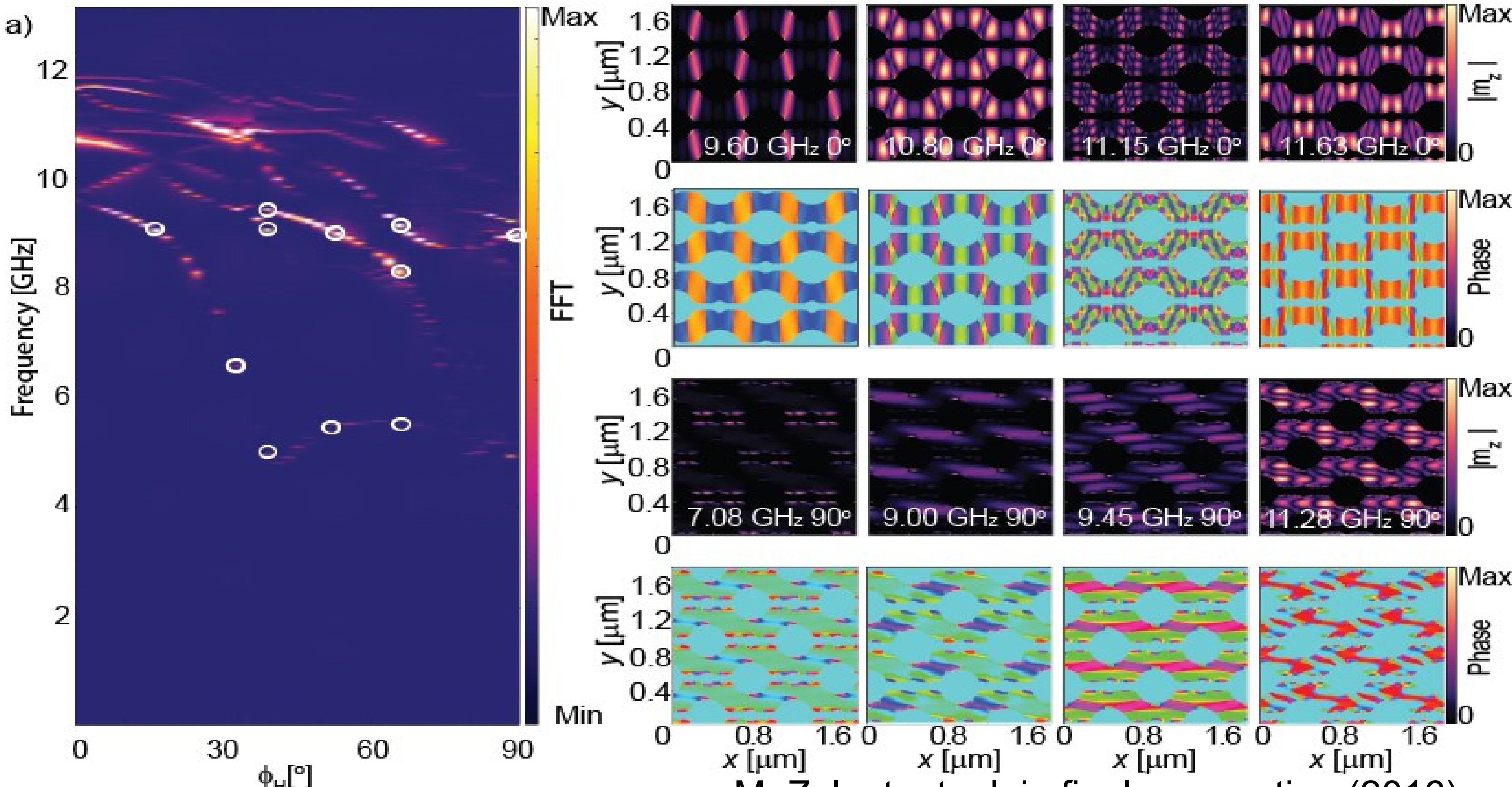
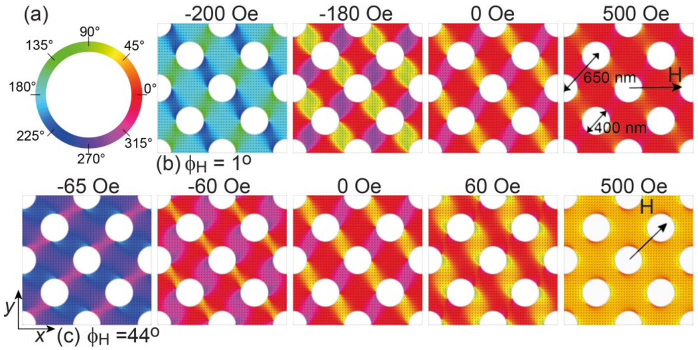
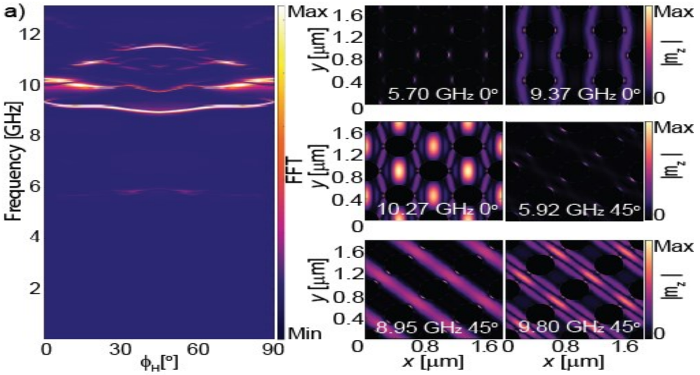


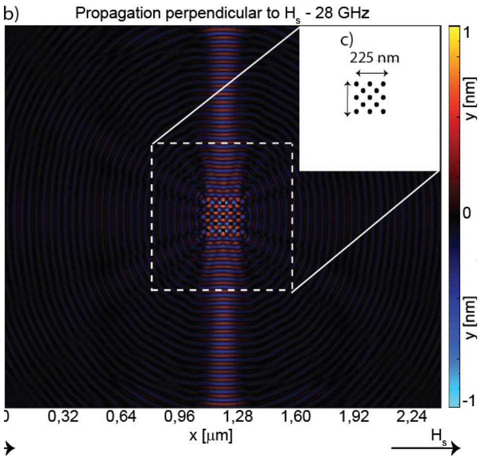
M. Zelent, et. al. in final preparation (2016)

Sample applications of magnonic crystals

Summary







New ideas

Founding

The presented research has received support from:

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THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION HORIZON 2020

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Thank you for attention

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