Magnetism and the effects of electric field

Marie Skłodowska-Curie Actions (MSCA) Innovative Training Networks (ITN) European Union's Horizon 2020

S. Roy[1], R. Pachat[1], A. Di Pietro[2], J. Shuai[3], M.G. Hafiz[3], A. Rajan[4], B. Bednarz[4], A. Pedrillo[5], P. Li[5], M. Fattouhi[6], S. Mozhikunnath Das[7], C. Balan[8], J. W. van der Jagt[9], M.A, Syskaki[4, 10] and G. Masciocchi[4, 11]

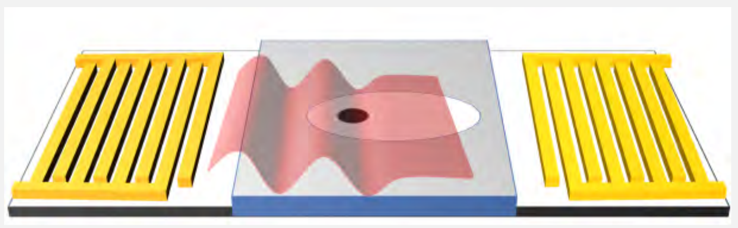
1 Université Paris Saclay, France (UPSaclay), 2 Istituto Nazionale di Ricerca Metrologica, Italy (INRIM), 3 University of Leeds, U.K. (LEEDS), 4 Johannes Gutenberg-Universitat Mainz , Germany (JGU), 5 Technische Universiteit Eindhoven, Netherlands (TU/e), 6 Universidad de Salamanca, Spain (USAL), 7 Aalto Korkeakoulusaatio SR, Finland (AALTO), 8 Centre National de la Recherche Scientifique, France (CNRS), 9 Spin-Ion Technologies, France (SPINION), 10 Singulus Technologies AG, Germany (SINGULUS), 11 Sensitec GMBH, Germany (SENSITEC)

In MagnEFi, a network of spintronics experts are linked by the ultimate goal of training the next generation workforce in E-field control of magnetism while the scientific goal is to move the field into the next level: integration. Innovative E-field control schemes based on Strain (**S**), Gating (**G**) and Light (**L**) will be thoroughly investigated and combined to produce a new class of enhanced multifunctional spintronics devices with **S**+**G**, **S**+**L** and **G**+**L** capabilities.

STRAIN

MagnEFi — UNIVERSITY OF LEEDS

Name: Jintao Shuai
Project: Interaction of surface acoustic waves and magnetic thin films
Country of origin: China
Host institution: University of Leeds
Host country: UK

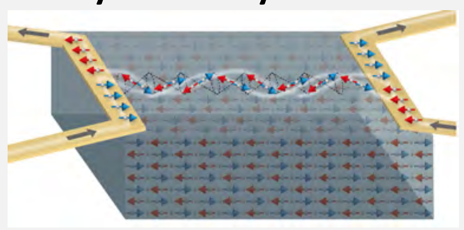


Project introduction

A promising route to low-power nanomagnetic data storage and computing devices is to apply a voltage to a piezoelectric material that exerts strain on an adjacent magnetic thin film and manipulates its properties via magnetoelasticity. Using a time-varying strain, such as that provided by surface acoustic waves has the potential for focusing on interference to manipulate magnetic spin structures. This project will study the interaction of the surface acoustic waves with magnetic multilayer films such as Co/Pt.

MagnEFi — JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Name: Adithya Rajan
Project: Influence of dynamic strain on antiferromagnetic ordering
Country of origin: India
Host institution: Johannes Gutenberg University Mainz
Host country: Germany

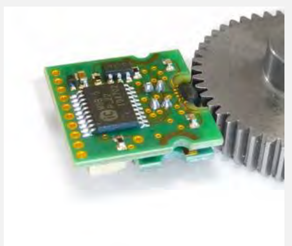


Project introduction

Lower power operation is enabled by electric fields that can manipulate antiferromagnets by strain and charge doping, which is particularly apt for antiferromagnets that intrinsically cannot be manipulated by conventional magnetic fields. We will study the effects of electric fields on the antiferromagnetic order parameter and explore the ultra-fast dynamics resulting from the antiferromagnetic order. Ultimately, we will gauge if coherent spin dynamics can be used for novel wave-based logic device concepts.

MagnEFi — SENSITEC

Name: Giovanni Masciocchi
Project: Control of strain in magnetoresistive elements and its utilization
Country of origin: Italy
Host institution: Sensitec GMBH
Host country: Germany



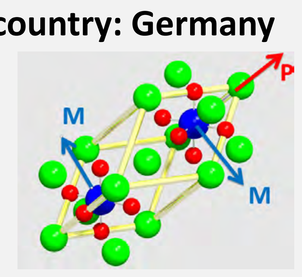
Project introduction

Magnetoresistive sensors consist of magnetic thin films and micro- to nanostructures. It is important to understand the behaviour of magnetic domain walls in these structures, to optimize the performance of the sensors. In this project, the influence of strain on MR sensors will be studied via two aspects: The conventional approach of minimizing the sensitivity of the sensor to strain by means of design and choice of materials will be pursued, and the utilization of strain to realise new or improved functionalities will be a goal.

GATING

MagnEFi — JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Name: Beatrice Bednarz
Project: Ferroelectric gating of the antiferromagnet/ferromagnet coupling
Country of origin: Netherlands
Host institution: Johannes Gutenberg University Mainz
Host country: Germany

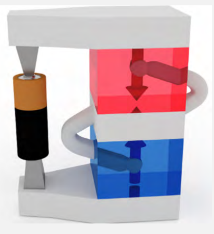


Project introduction

The project aims to couple room temperature multiferroic antiferromagnets to double perovskites which will make it possible to couple the ferrimagnetic moment to the electric field. In addition to the magnetic exchange coupling effect, the charge of the ferroelectric will act on the magnetic layer and modify magnetic interface effects such as the existence of perpendicular magnetic anisotropy or DMI. This can lead to new device architectures where magnetism is manipulated by electric fields.

MagnEFi — TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Name: Adrien Petrillo
Project: E-field gating of interlayer exchange coupling
Country of origin: Belguim
Host institution: Eindhoven University of Technology
Host country: The Netherlands

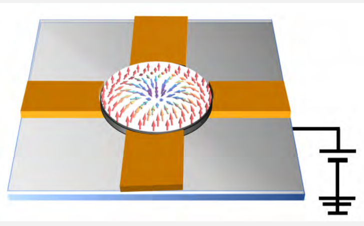


Project introduction

We aim to achieve electric field control features in perpendicularly magnetized systems by manipulating spin-dependent quantum well states: the so-called RKKY interlayer exchange coupling. We will explore the possibility of carefully tuning this interlayer exchange coupling using advanced multilayer engineering using direct gating and ionic liquids. We will study the complex magnetization switching behaviour of nano-magnetic devices under this combined mechanism.

MagnEFi — UNIVERSITY OF LEEDS

Name: Md Golam Hafiz
Project: E-field gating of magnetic multilayers with structural inversion asymmetry
Country of origin: Bangladesh
Host institution: University of Leeds
Host country: UK



Project introduction

In this project we shall deposit dielectric layers on magnetic multilayers that support skyrmions in order to be able to apply a gate voltage. This project builds on the internationally leading work on thin film skyrmions in the School of Physics and Astronomy at Leeds. The films will be prepared in the new Royce multi-deposition system. Lithographic techniques will be used to define micro- and nanoscale devices, and magneto-transport and magnetic imaging techniques will be used to characterise them.

LIGHT

MagnEFi — TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Name: Pingzhi Li
Project: All-optical magnetic switching and photonic circuit integration
Country of origin: China
Host institution: Eindhoven University of Technology
Host country: The Netherlands

Project introduction

We will use deterministic all-optical switching by single femtosecond laser pulses to reverse the magnetic state of ferromagnetic systems that are relevant for state-of-the art spintronics. First we will engineer layered structures that display strong DMI and SOT and demonstrate all-optical control and current-induced domain wall motion in one device. We will also perform experiments on all-optical switching of one of the two magnetic layers in a MTJ, and measure induced electrical effects either directly or indirectly.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 860060 "Magnetism and the effect of Electric Field" (MagnEFi).

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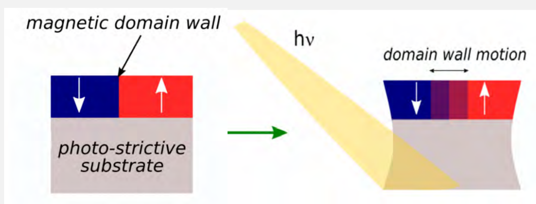
INTEGRATION

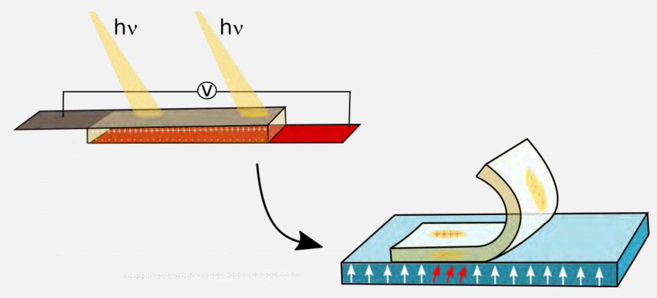
Name: Subhajit Roy
Project: Photo-induced strain control of magnetic domain wall motion in nanostructures
Country of origin: India
Host institution: University Paris Saclay
Host country: France



Project introduction

This project focuses on the manipulation of magnetic domain wall motion by applying mechanical strain and light. The ultimate goal will be to understand and optimise these two effects separately and to potentiate the device functionality by exploring the combined effects on magnetic domain wall motion and magnetisation switching.

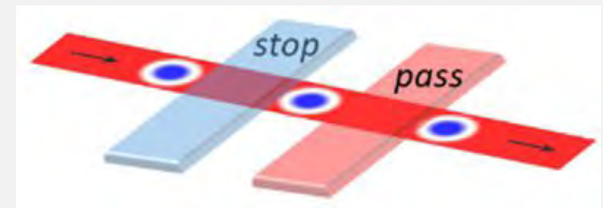
Name: Rohit Pachat
Project: Photo-active ionic gating
Country of origin: India
Host institution: University Paris Saclay
Host country: France



Project introduction

This project will explore E-field gating of magnetic domain wall motion using parallel arrays of bipolar and non-volatile gates defined by light-controlled ionics. By appropriately choosing the light exposure pattern and/or the gate contact geometry, arrays of non-volatile gates will be created across extended areas with both positive and negative charges.

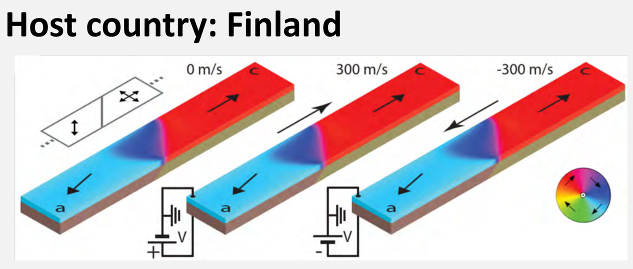
Name: Cristina Balan
Project: Combined gating and optical control of skyrmion-bubbles
Country of origin: Romania
Host institution: Centre National des Etudes Scientifiques
Host country: France



Project introduction

The objective of this project is threefold. First, skyrmions will be stable at room temperature and mobile under current in our material. Second, skyrmions will be injected in a narrow strip by current; local sub-micrometric local gates will serve to nucleate, annihilate and control their position. Thirdly, we will nucleate domain walls and skyrmions with ultrafast light pulses.

Name: Sreeveni Mozhikunnath Das
Project: Ferroelectric strain coupling and gating integration devices for magnetic domain wall motion control
Country of origin: India
Host institution: Aalto University
Host country: Finland

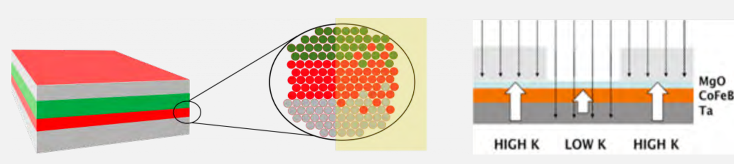


Project introduction

This project explores electric-field-driven magnetic domain wall motion in nano-structure materials. The driving mechanism is based on strain transfer from a ferroelectric layer and gating of a dielectric or solid-state ionic conductor. Combinations of these effects will be explored to deliver new functionalities.

MATERIALS

Name: Gyan van der Jagt
Project: Interface engineering by He+ ion irradiation
Country of origin: Netherlands
Host institution: Spin-Ion Technologies
Host country: France



Project introduction

This project will study a new concept of scalable and low power E-Field gating domain wall devices based on realizing modulation of magnetic properties by using ion irradiation. The magnetic properties in magnetic thin films will be tailored using ion irradiation induced interface engineering.

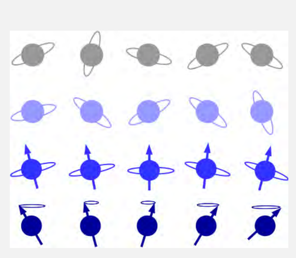
Name: Mandy Syskaki
Project: Advanced Materials Deposition
Country of origin: Greece
Host institution: Singulus Technologies AG
Host country: Germany

Project introduction

In this project, we will develop and deposit high quality material stacks for experiments of electric field manipulation. In particular, high-k dielectrics and ionic conductors can be used to continuously tune the magnetic properties such as anisotropies, the strength of the exchange interactions leading to a control of the spin structures including the Curie temperature, etc.

THEORY

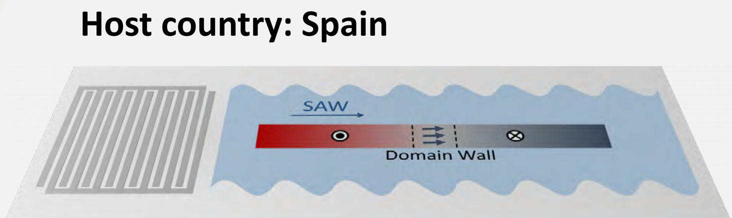
Name: Adriano di Pietro
Project: Modelling the impact of E-fields on magnetic interface phenomena
Country of origin: Germany
Host institution: Istituto Nazionale di Ricerca Metrologica
Host country: Italy



Project introduction

This project aims to understand the role of electrical fields in changing the properties of the magnetic layer considering the effect of gate-induced charge accumulation and of optical effects in the case of all-optical control of magnetization and photo-induced strain. Theoretical analysis and simulations will consider these effects on the motion of domain walls and of skyrmion-bubbles.

Name: Mouad Fattouhi
Project: Modelling magnetization dynamics in piezoelectric/magnetic devices
Country of origin: Morocco/France
Host institution: University of Salamanca
Host country: Spain



Project introduction

This project aims to study the effect of strain on the magnetic properties of different materials, nanostructures and devices. The work to be carried out is theoretical and computational. It will also require visiting network partners' labs to become familiar with experimental techniques, help in the interpretation of the data and in the design of new devices.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No. 860060 "Magnetism and the effect of Electric Field" (MagnEFi).

MARIE CURIE ACTIONS

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