Magnetism and the effects of electric field

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

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MagnEFi
MAGNETISM AND THE EFFECTS OF ELECTRIC FIELD

BACKGROUND

Magnetic Random Access Memory (MRAM) technologies have moved from a magnetic-field based to an electrical-current based magnetisation switching scheme using the spin transfer torque (STT) effect. This has improved performance leading to the recent commercialisation of the STT-MRAM. However, there is a long way ahead in terms of energy efficiency, where efforts are mostly centred around reducing the currents needed to switch magnetic states [1]. In this context, electric (E) field control of magnetism has been identified as one of the most promising routes to ultra-low power GreenIT [2]. E-fields can induce a reversible and local modulation of magnetic properties, for example, high and low anisotropy states when E-fields are on and off, respectively. In the low anisotropy state the switching current needed during the writing process could be drastically reduced, while switching back to a high anisotropy state guarantees a high thermal stability for long term storage. These perspectives for improving energy efficiency could have a large impact on mobile devices where power consumption is becoming increasingly dominated by volatile memory, logic and sensing components (magnetic field sensors)[3]. Therefore, E-field control of magnetism is nowadays being intensely investigated.

OBJECTIVES

In this project, European experts have assembled to provide enhanced training and education to early-stage researchers (ESRs) on the topic of electric field effects on nanoscale magnetic structures. The goal is to have a significant scientific impact in terms of the design and performance of multi functional spintronics devices. Research in this area is expected ultimately to lead to ultralow power devices for computation and communication with new functionalities.

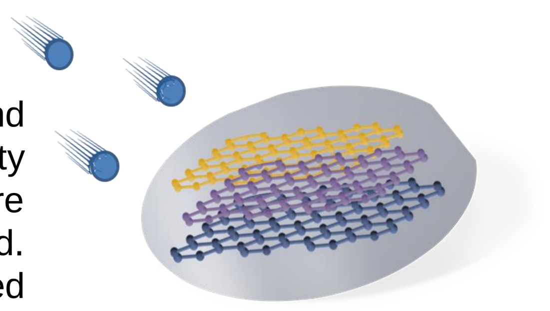
The consortium that has come together to deliver this training is uniquely qualified to do so, consisting of world-leading experts in condensed matter physics and leading private companies, along with a range of associated partners spanning basic research, machine tool development, industrial and consumer products. The consortium will provide a rich training environment that is international, intersectoral and multidisciplinary. ESRs will study at the cutting edge of science and technology and come to appreciate the breadth of the field in terms of its intellectual challenges, commercial concerns and relationship to society's need for ever more powerful information technologies with a reduced environmental footprint. This unique training program will enable ESRs to contribute to strengthening both the European Research Area and the European Information and Communication Technology industry in their future careers. The strategic importance of this topic, is indeed justified by numerous high-profile research programmes addressing the needs of development in spintronics technologies.[2]

THE MAGNEFI NETWORK – PEOPLE, INSTITUTES, SCIENCE

Fundamental Physics

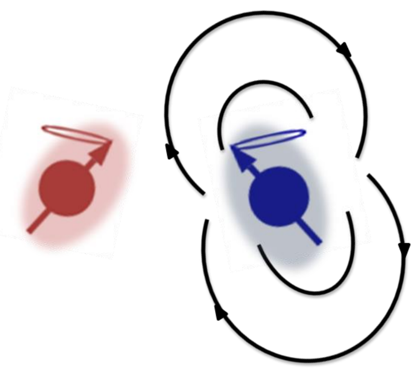
Material growth

This part of the consortium involves two industrial partners, Singulus and Spin- Ion Technologies. The aim is to develop and deposit high quality material stacks for electric field manipulation experiments. Partners are provided with layers sputtered with the most advanced tools in the world. Moreover, the magnetic properties of magnetic thin films will be tailored using ion irradiation induced interface engineering.



Theoretical modelling

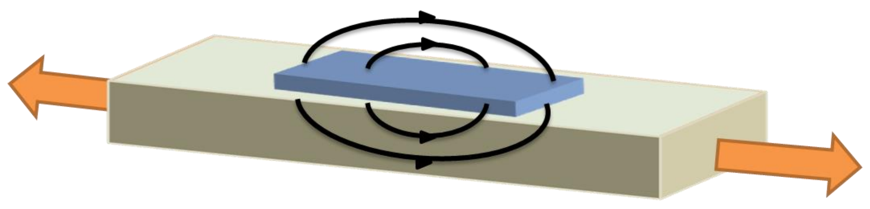
INRIM and Usal are the two institutions that will complement the experimental projects in the network with theoretical modelling of the effects of elctric field in magnetic thin layers. This will be done with the help of micromagnetic simulations [4] and machine-learning and deep learning techniques. Gate induced charge accumulation, optical effects and piezoelectric strain will be analysed.



Integration

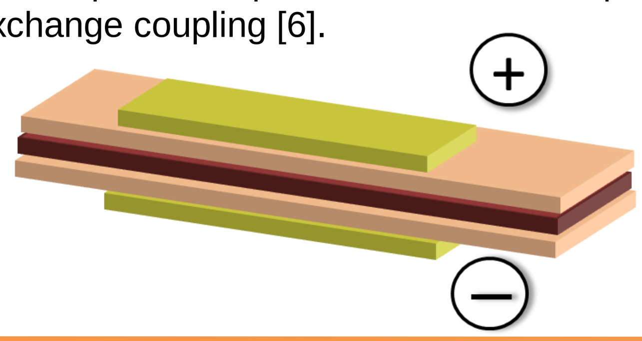
Strain

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 a magnetic thin film and manipulates its properties via magnetoelasticity [5]. The impact of the strain, intrinsically present in thin crystalline materials, is of fundamental importance for performances of devices like magneto resistive sensors based on Domain Wall motion.



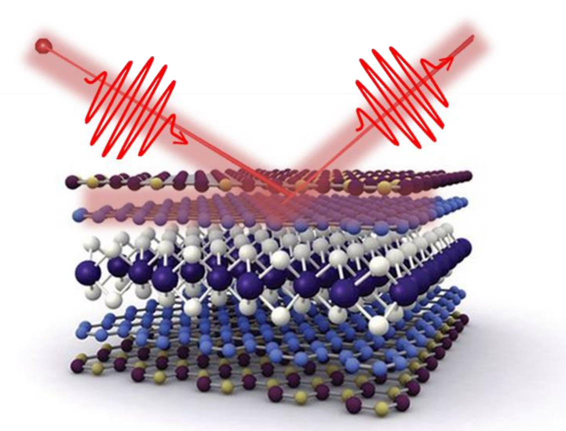
Electric field - Gating

Device architectures where magnetism is manipulated by electric fields could enable switching of the ferromagnetic state by an electric field instead of a magnetic field which promises much faster and energy efficient switching. An example is achieving electric field control features in perpendicularly magnetized systems by manipulating spin-dependent quantum well states, possibly tuning the interlayer exchange coupling [6].

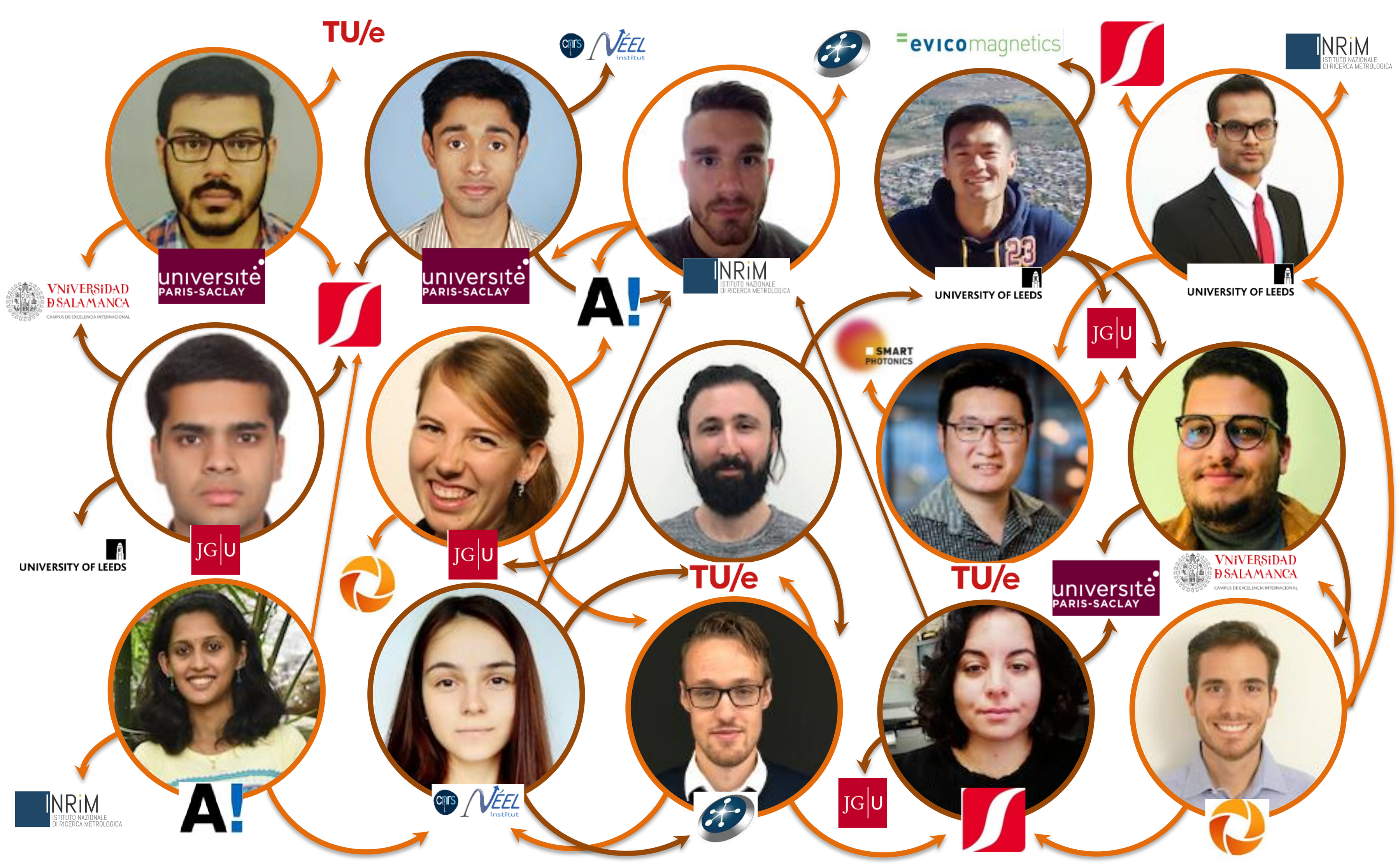


Light

Controlling magnetism with light (femtoseconds laser pulses) [7] could pave the way towards integrating photonics with nano-magnetism for future data buffering. One possibility is to implement all optical switching in nanowires structured on top of a photonic waveguide, which is considered a unique building block for future magneto-photonic integrated circuits.



One of the main pillars of MSCA ITNs is the creation of an international and intersectoral network of colleagues and mentors around the EU. Through interactions and collaborations on scientific projects, secondments, summer schools, workshops and conferences, the Early Stage Researchers (ESRs) will create a long-lasting network of colleagues, acquire intersectoral work experience and training corresponding to their diverse motivations and career ambitions. In the following figure, the 15 ESRs are represented and their planned secondments are indicated with arrows.



Expectations and goals

The intertwining of three scientific approaches to applying E-fields to nanomagnetic structures will produce young researchers with a breadth of expertise that will be vital to sustaining the research and development of electronics for GreenIT in the EU in the future.

The interconnections between the ESRs and the beneficiaries will last beyond the lifetime of the project and boost the future careers of the ESRs as they move into academia or industry.

The goal of the programme is to to learn the route to engineering devices in a collaborative way thereby enabling creativity to flourish.

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References and acknowledgements

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European Commission

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