International Union of Pure and Applied Physics

To stimulate and facilitate international cooperation in physics and the worldwide development of science.

C9. Commission on Magnetism - Report 2015 - 2017

Officers 2014-2017

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Alberto Passos Guimar (2014), Brazil
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Can-Ming Hu (2014), Canada
Jae Il Lee (2014),Korea
Kai Liu (2014),USA
YoshiChika Otani (2014), Japan
Vladimir Ustinov (2014) (2011), Russia
Luis Miguel García Vinuesa (2014), Spain

Meetings

2015:

The C9 Commission Meeting was held on July 07, 2015, Palau de Congressos de Catalunya, Barcelona, Spain.

1) The Chair of the ICM 2012, Shun-Chul Shin, presented the final report of the ICM 2012 in Busan, Korea.

2) The Chair of the ICM 2015, Amílcar Labarta presented that status of the ongoing conference and showed statistical data. He pointed out, that the number of attendees is very close to the record meeting in Rome in 2003. The C9 Chair thanked the Conference Chair and his team for all their intensive work and mentioned the excellent atmosphere the conference has created already in the first days. The commission members highly appreciated, that for the first time the Conference Chair provides the gender statistics

of participants, and encouraged forthcoming chairs to continue to do the same in forthcoming ICMs. The C9 Chair also reminded the Conference Chair to try the best to hand over the same amount of left over money from ICM 2012 to the next ICM in San Francisco.

3) Mark Stiles, Liesl Folks and Ron Goldfarb presented the current status of the preparation for the next ICM 2018 in San Francisco. Designated Conference Chair is Allen McDonald, designated Secretary General is Liesl Folks, and designated Program Chair is Mark Stiles. The members discussed how to better select all the oral presentations, including plenary, invited and oral talks, and encouraged the organizers to come up with some new ideas. The C9 Chair reminded the organizers to keep the traditional ICM social events.

4) Prof. Yizheng Wu presented a bid for the ICM 2021. He proposes to organize it in Shanghai, China. Members of the bidding group are Xiaofeng Jin, Jian Shen, and Jiang Xiao (all from Fudan University). The members reminded the bidding group that the final ICM local committee should be composed not only of Shanghai scientists but it should include scientists from entire China.

5) The C9 Chair pointed out that according to the IUPAP rules the Young Scientist Prize can be awarded to up to three recipients over three years. In the past, this award was given every three years to a group of one to three awardees, which is within the IUPAP rules. After a short discussion the members agreed, that from now on the Young Scientist Prize will be awarded every year to a single young scientist. The procedures for nomination and voting will be used as before (nomination from the IUPAP-C9 commission or the community, voting by e-mail).

The call for nominations will be put onto the IUPAP-C9 webpage. Awardees will be invited to the next ICM conference. They will receive the award during an award ceremony at this conference. They are invited for an invited talk, as well as to the award dinner.

2016:

No C9 Commission Meeting was held in 2016.

2017:

No C9 Commission Meeting was held in 2017. The next meeting will be held during the ICM 2018 in San Francisco, July 15-20, 2018.

Magnetism Awards

The IUPAP Magnetism Award and Néel Medal is awarded every third year on the occasion of the ICM conference. The next Magnetism Award and Néel Medal will be given in 2018 at the ICM in San Francisco. The selection process will begin in the winter of 2017/18.

The IUPAP Young Scientist Prize in the field of Magnetism is awarded every year.

2015:

The 2015 IUPAP Magnetism Award and Néel Medal has been awarded to Prof. Chia-Ling Chien, Citation: "*For pioneering discoveries in magnetic materials and nanostructures*".

The 2015 IUPAP Young Scientist Prize in the field of Magnetism have been awarded to (in alphabetical order): Dr. Marius V. Costache, citation: "*For the development of new methods to excite and detect on-chip ferromagnetic resonance and new detection schemes for the magnon-drag effect*" and Dr. Masamitsu Hayashi, citation: "*For the pioneering work on domain wall dynamics in magnetic nanowires and contributions to the development of current controlled magnetism in magnetic heterostructures using spin orbit effects*".

2016:

The 2016 Yong Scientist Prize winner is Dr. Wei Han, Peking University, China. The citation reads: *For significant contributions to spin injection, spin transport and spin relaxation in graphene, and for the discovery of interface transparency and triangular antiferomagnetic* $IrMn_3$ *for spin orbit torque in magnetic heterostructures.* The winner has been announced on the IUPAP website. Dr. Han will receive the award at the next ICM conference, which will be in July 2018 in San Francisco.

2017:

At the time of writing, the call for the 2017 Yong Scientist Prize is open with the deadline of August 31, 2017.

New Developments in Magnetism

The field of magnetism continues to be very vibrant. Of the many major aspects, significant progress has been made in materials, new phenomena, dynamics, new experimental techniques and applications. Magnetism continues to generate new fundamental discoveries and, at the same time, producing novel innovative ideas for applications.

Recent review publications highlight the fact that there is a good coverage of progress, see, as an example, the 2014 and 2017 Roadmap of Magnetism papers published in Journal of Physics D.

Materials: There have been much discussions addressing novel multiferroic materials, which combine magnetic, electric and other degrees of freedom. Particularly interesting is the prospect in electric switching of magnetic quantities especially for potential data storage and logic applications. Another very versatile class of materials includes the full and half Heusler compounds. They can be tailored via a very wide range of parameters including saturation magnetization, anisotropy, magnetic damping, conductivity, and more. Along with that they also have favorable magneto-transport properties. These materials are supplemented by complex oxides, garnet materials, and new granular materials for data storage applications. We have also witnessed a renaissance of Yttrium-Iron-Garnet, the material with the lowest Gilbert damping of all magnetic materials. It is widely used in the field of magnonics, and progress has been made to produce this material in the form of ultrathin films using advanced liquid phase epitaxy as well as by pulsed laser deposition and advanced sputtering methods.

Regarding thin films and heterostructures, exchange bias systems continue to be of interest. A recent highlight is the fabrication of perpendicularly magnetized exchange bias heterostructures.

The field of permanent magnets is advancing due to the growing need for applications in actuators, automation and robotics. Materials must be made available in bulk quantities at low cost and should be environmentally friendly. An important issue here is the search for rare-earth free magnets for applications in actuators, automation and robotics, as well as for use in magnetic refrigeration devices.

New experimental techniques: Progress has been seen in most of the established experimental techniques. A particular highlight is the increased availability of free electron lasers for spectroscopic and imaging investigations, such as the new XFEL facility at DESY near Hamburg in Germany. Regarding electron spectroscopy techniques, the new method of imaging electronic states in the momentum space has progressed particularly, as it relates to research in the fields of topological insulators.

New spin-transport phenomena: A lot of new developments have taken place. The field of spin-caloric transport based on the Spin Seebeck Effect (SSE) has been developing rapidly, along with new transport mechanisms such as through thermal magnons have been identified. Combined with the (inverse) Spin Hall Effect (SHE), electrical signals can be generated by spin and magnon currents and proposals have been made to use this effect for energy harvesting. Reversely, applying an electric voltage to a SSE-SHE device, spin and magnon currents can be generated or amplified.

Regarding spin torque oscillators, a better understanding based on new eigenmodes such as bubble excitations has been achieved. The Spin-orbit Torque Effect has been identified and applied in spin-current switching. Here the critical current density needed for switching is smaller than in conventional spin transfer torque devices. Other novel effects are the Rashba and the Dresselhaus spin-torque effects in systems with large Dzyaloshinskii-Moriya Interaction.

An entire new field is the current-induced switching of antiferromagnets. Devices made from this material class do not exhibit dipolar stray fields and are thus stable against external magnetic fields. It has been shown that driving a macroscopic electrical current through an antiferromagnetic crystal whose magnetic atoms occupy inversion partner lattice sites, reversible switching can be achieved.

Other new phenomena: The Dzyaloshinskii-Moriya Interaction (DMI) has gained greatly increased interest in several fields of magnetism, since it favors the formation of topological defects. In this way, phenomena of topological protection have been realized. In the presence of strong DMI the domain wall propagation velocity can be made faster exceeding the Walker breakdown threshold. DMI phenomena can be very pronounced especially for ultrathin films and nanostructures. Skyrmions, which are topologically stable vortices and the smallest spin-texture objects, have been realized and are currently subject to intense investigations with potential applications in data storage and communication technologies. Effects, such as the Skyrmion Hall Effect are discussed.

Related research fields are frustrated nanostructures, in particular spin-ice systems. Apart from the studies of phase transitions they allow model studies of a wide range of interesting phenomena, such as magnetic monopoles.

Another important research subject is the interaction of magnetic objects with light. Magneto-plasmonic phenomena are of increasing interest. They may help to increase the interaction strength, in particular in detecting magnetization states in the field of data storage.

Phase transitions and, more generally, electron correlation effects, in particular in the quantum regime, remain a very active topic. A hot topic is topological insulators with their specific surface and edge states. Also, interaction of magnetic systems with superconducting films has attracted increasing interest.

Dynamics: This very active field comprises new phenomena in magnonics, ultrafast and all-optical switching, as well as THz spintronic phenomena. In the field of magnonics the potential application of spin-waves and their quanta, magnons, in data processing has been pushed forward. Many devices such as several types of logic gates, conduits and switches, magnon transistors, and amplifiers have been proposed and demonstrated, forming the field of magnon computing. A specific focus lies on the interfacing magnonics with conventional CMOS electronics. Novel concepts have been proposed such as the use of magnonic macroscopic quantum states for the realization of magnonic supercurrents. The issue of magnonic superfluidity is currently being intensively discussed.

In the field of ultrafast and all-optical switching much progress has been made towards achieving stable switching. Switching can be achieved in a variety of materials. Specifically, switching in ferromagnetic materials at the angular momentum compensation point is currently heavily discussed.

Antiferromagnetic materials exhibit very high magnon frequencies and thus can be used for THz applications. The field of THz spintronics is currently developing into a new major direction. Jointly with the demonstrated capability to switch antiferromagnetic materials electrically, this might open the way to new future applications.

Applications: Although a major field of applications, the hard disk drive technology for data storage is coming to maturity. New fields of applications appear and have started to flourish, such as magnetic random access memory (MRAM) and the wide ranging field of magnetic sensors. MRAM is currently introduced into production for mass applications.

The field of magnetic sensors is largely expanding, in particular in view of the needs of industry 4.0, computerization of manufacturing, the internet of things, and cyber physical systems. While traditionally most sensors are based on the Hall Effect and GMR, TMR based sensors are increasingly being developed due to their much-reduced power requirements. Novel concepts are investigated such as organic spintronics and magnetic bio-sensors. Novel sensors show increased sensitivity together with wider temperature and frequency ranges, better CMOS compatibility and lower power consumption.

The field of data storage continues to demand for a high research effort. Concepts, such as heat assisted magnetic recording (HAMR) plan for read heads allowing for a storage density exceeding 2 terabytes per square inch.

Many proposals for new logic functionalities, based on, e.g., magnonic, domain wall, or on nanostructured devices, are being discussed on the basis of potential applications. An exciting new direction is based on using the magnetic degrees of freedom in quantum computing, although this is at a very early stage.