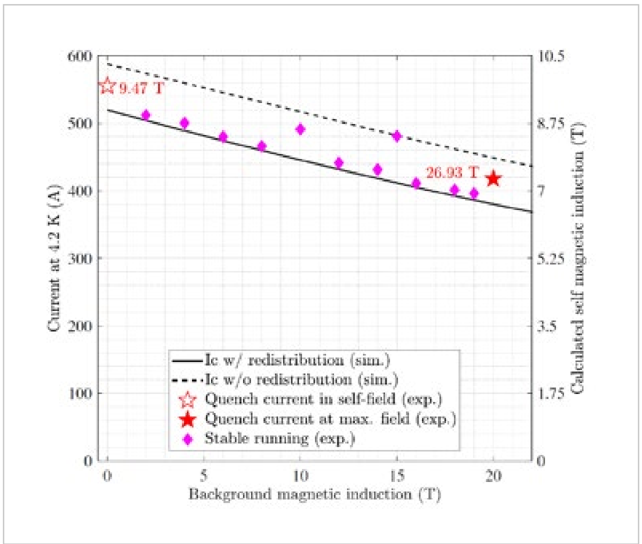
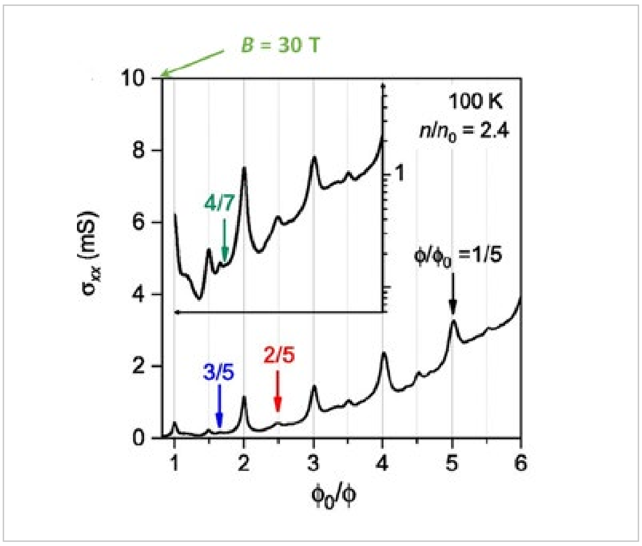
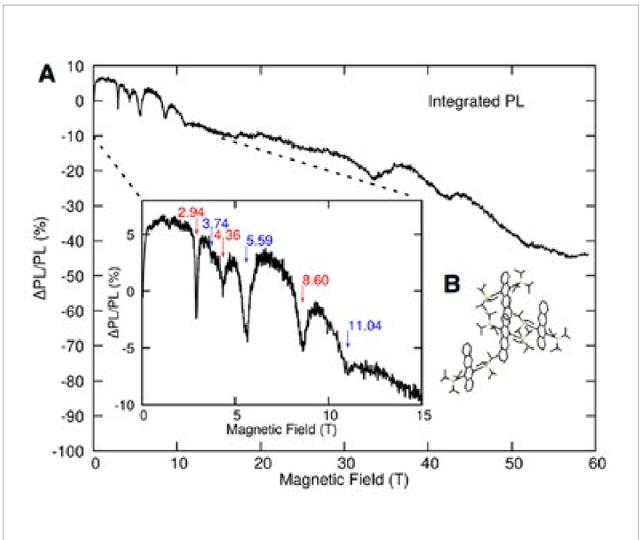
European Magnetic Field Laboratory

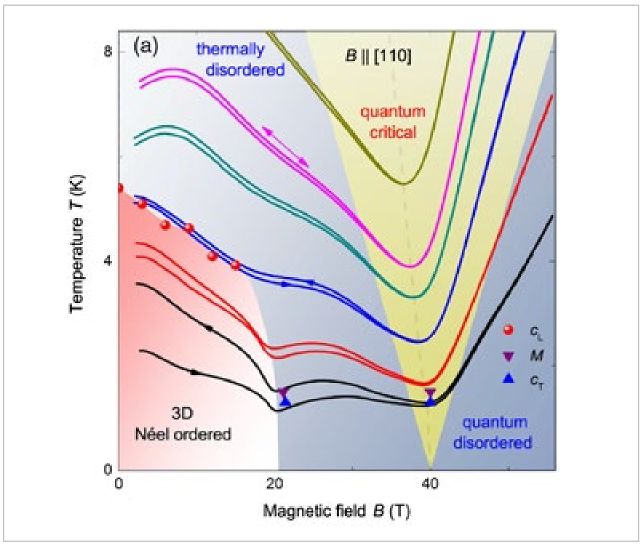
EMFLNEWS

N°2 2018









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DEAR READER

To stay in direct contact to our users and listening to their needs and wishes plays a central role in improving the attractiveness of the EMFL facilities. The yearly user meeting is the ideal floor to cultivate this exchange between users and facilities. This year, this user meeting was held in a very pleasant atmosphere at the Radboud University in Nijmegen, hosted by Prof. Nigel Hussey. In this excellently organized meeting, we enjoyed inspiring talks, lively discussions, and useful suggestions from our users via the User Committee. Besides that, the EMFL prize was handed over to Artem Mishchenko from the University of Manchester. Indeed, this was already the tenth time that we could confer the prize.

In this EMFL News we can proudly announce that HFML-FELIX were awarded a large grant in the Dutch-NWO "National Roadmap for Large-Scale Research Facilities" scheme. More details you will find in the following, as well as the usual articles on outstanding scientific results obtained by utilizing the EMFL facilities.

Have a stimulating reading,

Jochen Wosnitza
Director HLD
Chairman EMFL

MEET OUR PEOPLE

Marloes Gielen - communication officer HFML-FELIX

"HFML? EMFL? What's that?" My ultimate goal is to prevent anyone from saying that ever again.

I started June 1st, 2018 just in time for the EMFL user meeting. I see a lot of commitment and enthusiasm among users, technicians, and scientists. Entirely justified, as I think it is quite impressive what you can do with magnets and lasers. As a communication officer I try to convey this energy to the outside world, through for example the HFML website and social media. So yes, if you see me making movies or photos you should always be aware that I will use it somehow.

The past decade I had different positions at governmental organizations. With my background, I don't have the illusion that I can fully understand everything that is happening in the laboratory. As long as I know the basics, why it happens and why it is important. So expect a lot of those kind of questions from me. Hope to meet you soon!

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Marloes Gielen

7 T METAL-AS-INSULATION HIGH-Tc MOCK-UP INSERT IN 20 T

Xavier Chaud, LNCMI Grenoble

The development of high-temperature superconductor (HTS) inserts for all-superconducting magnets for fields above 23 T is highly desirable. With practically zero power consumption this will make possible long-duration experiments at a low operation cost and will be greatly beneficial for physics, chemistry, and live sciences requiring long data-acquisition times and low noise environment. Several projects in the world currently aim at producing fields around 30 T with an all-superconducting magnet. A record 32 T was produced at NHMFL (Tallahassee) while the HFLSM (IRM, Tohoku University) offers to its users 24 T in a 50 mm room-temperature bore of its cryogen-free magnet. Our own project aims at designing and building a 10 T HTS insert to be operated in a background field of 20 T. This first choice takes advantage of an existing large-bore (170 mm) resistive magnet as a robust way to focus on the operation and the protection modes under the high magnetic field of such an HTS insert to pave the way to a future implementation in a LTS magnet. The design relies on REBCO coated conductors because of their high electrical and mechanical performance under very high field and their commercial availability in length enabling a first design as a stack of pancake coils.

Building HTS inserts remains challenging in several ways, among which the quench protection is a delicate issue because of the inhomogeneous and slow-propagating quench behavior. We have explored the Metal-as-Insulation concept (MI) which relies on the co-winding of a bare HTS tape with a metallic ribbon such as Hastelloy, a stainless steel, for mechanical reinforcement as well as for electrical protection purpose. Since a single highly instrumented prototype MI pancake coil underwent several quenches without visible degradation and demonstrated the safety of the coil even in overcurrent condition, we have built a first insert mock-up with two double pancake coils.

The tests under very high external magnetic field – up to 20 T - at 4.2 K show excellent performance when compared to the design values. The magnet reached 9.5 T in standalone configuration with an engineering current density (J_e) of 873 A/mm^2. A total of 26.9 T were obtained in insert configuration with a current density of 658 A/mm^2, i.e., a current of 415 A, twice the foreseen operating current of the final insert. This is a very important step towards an all-superconducting 30 T+ magnet.

Figure 1: Pictures of the HTS mock-up insert. Left, before overbanding. Right, during its insertion into the cryostat.

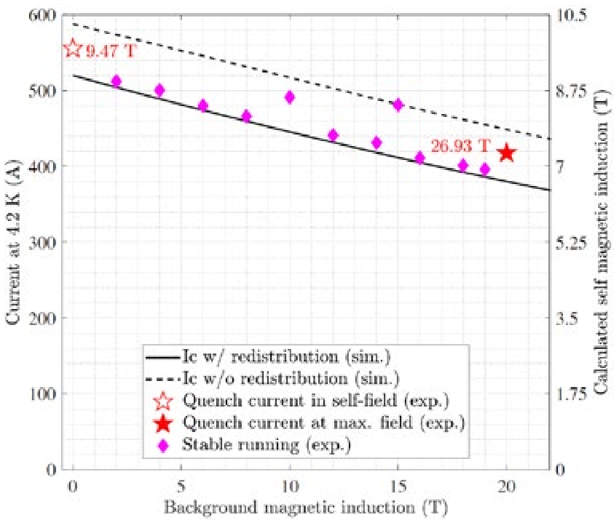

Figure 2: Evolution of the magnetic induction as a function of external background field.

Metal-as-Insulation sub-scale prototype tests under High Background Magnetic Field, P. Fazilleau, B. Borgnic, X. Chaud, F. Debray, T. Lécrevisse, and Jung-Bin Song, Supercond. Sci. Technol. **31** (2018), in press.

Metal-as-insulation variant of no-insulation HTS winding technique: pancake tests under high background magnetic field and high current at 4.2K, T. Lécrevisse, A. Badel, T. Benkel, X. Chaud, P. Fazilleau, and P. Tixador, Supercond. Sci. Technol. **31** (2018) 055008.

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INTERPLAY BETWEEN FIELD QUANTIZATION AND BLOCH STATES IN GRAPHENE SUPERLATTICES

Sergio Pezzini, Uli Zeitler, HFML Nijmegen

Using high magnetic fields, the Bloch states in two-dimensional graphene superlattices can be influenced in a way that adding fractions of flux quanta into a superlattice unit cell lead to high-temperature quantum oscillations in its resistance. This phenomenon can be explained by the recurrence of straight trajectories of the Bloch states whenever a fraction p/q of flux quanta threads through a unit cell yielding a self-similar fractal electronic spectra around this points which can then be interpreted as an effective zero magnetic field.

Researchers from the University of Manchester have now extended the parameter range of this so-called Brown-Zack oscillations [1,2] to higher electron concentrations and higher magnetic fields (30 T) available at HFML Nijmegen. This has allowed the observation of a fractal pattern in the conductance originating from high-order magnetic Bloch states (p > 1) which agrees well with band-structure calculations (Figure). Although predicted more than half a century ago, it was only possible now to observe and model these intriguing electronic states convincingly.

[1] E. Brown, Bloch electrons in a uniform magnetic field, Phys. Rev. **133**, A1038 (1964); J. Zak, Magnetic translation group. Phys. Rev. **134**, A1602 (1964).

[2] R. Krishna Kumar et al., High-temperature quantum oscillations caused by recurring Bloch states in graphene superlattices. Science **357**, 181 (2017).

High-order fractal states in graphene superlattices, R. Krishna Kumar, A. Mishchenko, X. Chen, S. Pezzini, G.H. Auton, L.A. Ponomarenko, U. Zeitler, L. Eaves, V. I. Fal'ko, and A. K. Geim, Proc. Natl. Acad. Sci. USA **115**, 5139 (2018).

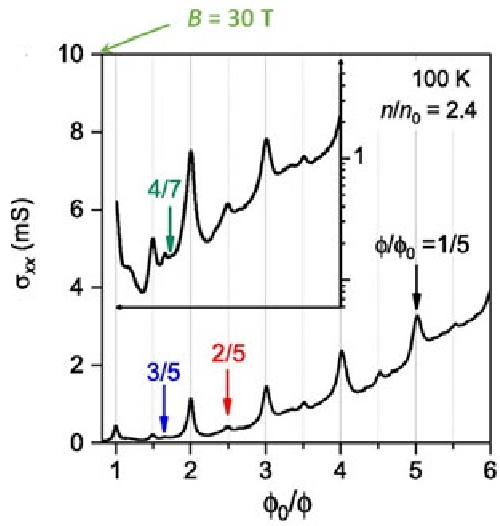

Figure: High-order magnetic Bloch states in a graphene superlattice: The conductivity σ_{xx} as a function of the inverse magnetic field expressed in units of ϕ_0/ϕ up to 30 T (left end). The recurring maxima at ϕ/ϕ_0 = p/q can be interpreted as fractal Bloch states in an effective zero magnetic field.
In order to emphasize weaker features, the inset shows the same data on a logarithmic vertical scale with the same horizontal axes.

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HIGH MAGNETIC FIELDS PROBE MULTI-EXCITON STATES IN ORGANIC MATERIALS

Leah Weiss, Sam Bayliss, University of Cambridge and Paulina Plochochka, LNCMI-Toulouse

Intermolecular coupling plays a key role in charge transport and excited-state dynamics in organic systems. A key example of the influence of intermolecular interactions is the process of singlet fission, which involves the production of two triplet excitons on neighboring molecules from excitation of a singlet exciton on one molecule. This intermolecular pair-production process has the potential to boost the efficiency of photovoltaics beyond the Shockley-Queisser limit and has been used to produce photovoltaics with external quantum efficiency above 100% [D. L. Dexter, J. Lumin. **18**, 779 (1979); D. N. Congreve et al., Science **340**, 334 (2013)]. A key challenge in the field of singlet fission has been to quantify the strength of intermolecular spin coupling.

To address this question, we have applied pulsed (up to 68 T) and static (up to 30 T) magnetic fields to induce avoided spin-level crossings, which allows us to measure the exchange interaction between triplet excitons in an organic semiconductor. At magnetic fields where bright and dark pair-states mix, the excited-state emission diminishes, yielding an optical signature of the spin-level structure. Using a canonical singlet-fission molecule we extract distinct exchange values ranging from 0.4-5.0 meV (Figure). This variation in spin-spin coupling arises from the intrinsic variation in pair conformation in this material. We have further shown that the sensitivity of the exchange interaction can be used to distinguish the optical signatures of distinct pair sites. This method for quantitatively probing excitonic spin interactions presents an opportunity for understanding the role of molecular conformation in spin coupling and paves the way for molecular design of excitonic interactions in optoelectronic and spintronic devices.

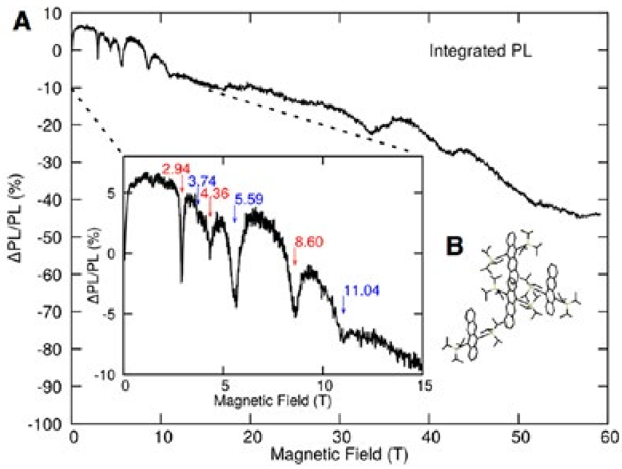

Figure: Optical signatures of strongly coupled triplet pairs in high magnetic fields. (A) Photoluminescence-detected spin level anti-crossings from triplet pairs in TIPS-tetracene. (B) TIPS-tetracene crystal structure.

Site-selective measurement of coupled spin pairs in an organic semiconductor, S. L. Bayliss, L. R. Weiss, A. Mitioglu, K. Galkowski, Z. Yang, K. Yunusova, A. Surrente, K. J. Thorley, J. Behrends, R. Bittl, J. E. Anthony, A. Rao, R. H. Friend, P. Plochocka, P. C. M. Christianen, N. C. Greenham, and A. D. Chepelianskii, Proc. Natl. Acad. Sci. USA **115**, 5077 (2018).

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QUANTUM CRITICALITY OF A SPIN-1/2 ANTIFERROMAGNETIC CHAIN

Zhe Wang, HZDR and S. Zherlitsyn, HLD Dresden

Understanding quantum phase transitions, i.e., phase transitions at zero temperature driven by non-thermal parameters, has become one of the most significant topics in condensed-matter physics. It is generally believed that universal scaling occurs near a quantum critical point, which can be thermodynamically characterized by a divergent Grüneisen parameter. However, for the quantum critical point of the one-dimensional transverse-field Ising chain, a recent theory work shows that the Grüneisen parameter should be finite, when the quantum critical point is approached. The transverse-field Ising spin chain plays an important role in quantum statistical and condensed-matter physics, because quantitative understanding of the relevant physics can be achieved exactly, based on its rigorous solvability by analytical as well as numerical methods. However, it remains very challenging to experimentally realize such a paradigmatic model in a real material for the study of quantum critical behavior.

By performing magnetization, sound velocity, and magnetocaloric-effect measurements in pulsed high magnetic fields, researchers from Augsburg, Cologne, Dresden, and Tokyo have identified a quantum critical regime induced by a transverse field in the Ising-like spin-1/2 antiferromagnetic chain material $BaCo_2V_2O_8$.

In this quantum critical regime at about 40 T, the system is disordered and the thermal energy is much smaller than the intrachain exchange interaction. The high-field experimental results show that the magnetic Grüneisen parameter follows a universal divergence on approaching the quantum critical point as a function of magnetic field at the lowest temperature, but it converges with decreasing temperature at the critical field (Figure). These features jointly point to the one-dimensional transverse-field Ising universality class of the underlying quantum critical point.

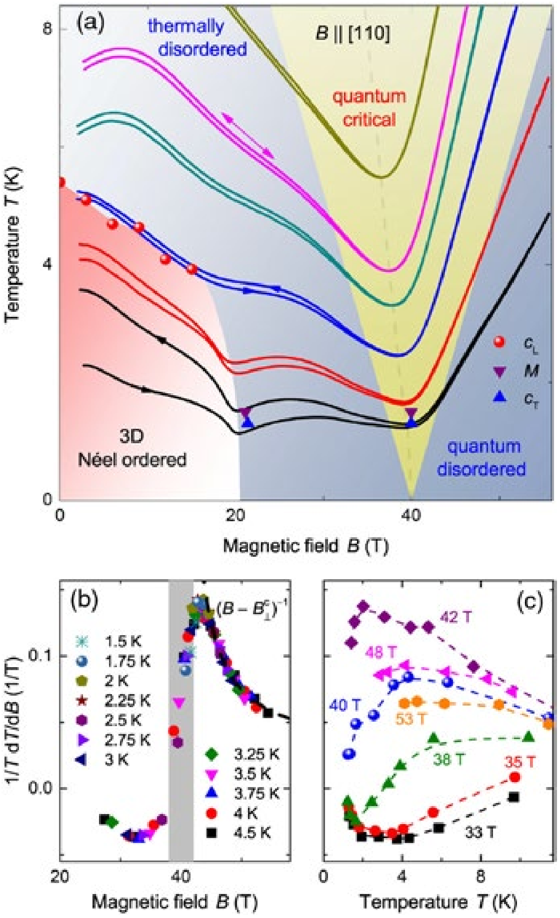

Figure: (a) Magnetocaloric effect of $BaCo_2V_2O_8$ measured for different starting temperatures in pulsed magnetic fields. Experimental values of the Grüneisen parameter, (1/T)(dT/dB), as a function of (b) magnetic field and (c) temperature.

Quantum Criticality of an Ising-like Spin-1/2 Antiferromagnetic Chain in Transverse Magnetic Field, Zhe Wang, T. Lorenz, D. I. Gorbunov, P. T. Cong, Y. Kohama, S. Niesen, O. Breunig, J. Engelmayer, A. Herman, Jianda Wu, K. Kindo, J. Wosnitza, S. Zherlitsyn, and A. Loidl, Phys. Rev. Lett. **120**, 207205 (2018).

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RESULTS OF THE NINETEENTH CALL FOR ACCESS

On May 15th, 2018, the 19th call for access ended inviting proposals for research requiring access to the large installations for high magnetic fields collaborating within EMFL.

Our four facilities

- LNCMI - Grenoble - France: Static magnetic fields to 36 T
- HFML - Nijmegen - the Netherlands: Static magnetic fields to 37.5 T
- HLD - Dresden - Germany: Pulsed magnetic fields to beyond 95 T
- LNCMI - Toulouse - France: Pulsed magnetic fields of long duration, to over 90 T and on the microsecond scale to beyond 180 T

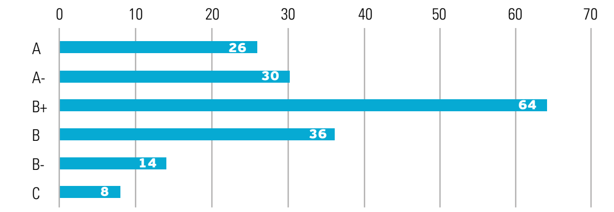
are open to users worldwide. EMFL operates a joint transnational access program, which gives full access to these installations and all associated scientific infrastructure to qualified external users, together with the necessary support from the scientific and technical staff.

For this 19th call 178 applications from 26 different countries were received which have been evaluated by the EMFL selection committee until June 22nd, 2018. The Selection Committee consists of 18 specialists covering the following five types of scientific topics

- Metals and Superconductors (44 applications),
- Magnetism (77 applications),
- Semiconductors (45 applications),
- Soft Matter and Magnetoscience (7 applications),
- Applied Superconductivity (5 applications).

Besides of ranking the proposals the committee decides on the number of accepted magnet hours or number of pulses.

NEXT CALL :
Launch: October 15, 2018
Deadline: November 15, 2018



Evaluation of applications

Projects are classified in three classes:

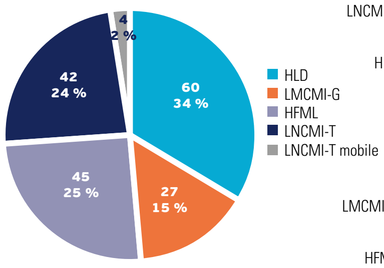
A (excellent proposal to be carried out),

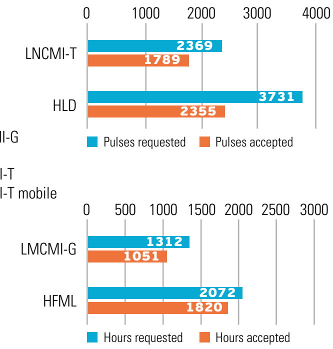
B (should be performed but each facility has some freedom considering other constraints),

C (poor proposal or one that does not need any of the four unique high-magnetic-field laboratories).

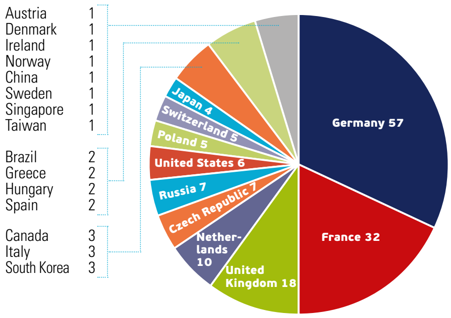
In the B category, the ranking + or - serves as a recommendation to the facility. This freedom within the B category is necessary to allow the facilities to consider other aspects such as, for instance, available capacity and equipment necessary for a successful project.

Distribution by facilities
Number of applications





Distribution by countries
Number of applicants



HFML-FELIX AWARDED NATIONAL ROADMAP GRANT

HFML-FELIX is one out of ten research infrastructures that have been awarded a grant in the latest round of the Dutch NWO "National Roadmap for Large-Scale Research Facilities" scheme by minister Ingrid van Engelshoven.

The Free-Electron Lasers for Infrared eXperiments Laboratory (FELIX) and the High Field Magnet Laboratory (EMFL-HFML) are two unique infrastructures that enable research under extreme conditions. The instrumentation at the experimental end stations is largely unmatched and the opportunities created by combining the strengths of the two facilities are world-wide unique. As such, HFML-FELIX provides a world-class infrastructure to its users, allowing researchers to investigate matter under extreme conditions and to enter the "terra incognita" in which new effects and phenomena can be realized in molecules and materials. Examples include new routes for biomarker discovery and targeted drug discovery, ultrafast magnetic switching for more efficient data storage and investigations of new smart materials with interesting properties for potential applications.

This grant will enable an expansion in the capabilities of the suite of free-electron lasers and the creation of three dedicated research laboratories: the "Molecular ID lab", where complex mixtures can be analyzed and molecular structures isolated and identified swiftly and accurately, the "Condensed Matter lab" for studying the interaction of condensed and magnetic materials with intense THz radiation and a laboratory that will focus on new opportunities created by the combination of very high magnetic fields with intense THz radiation.

Britta Redlich, the director of FELIX said: "I am delighted and grateful for the recognition by the Roadmap committee that HFML-FELIX is a truly unique international facility on Dutch soil. This grant will allow us to maintain and expand the leading position of HFML-FELIX and to face the global competition. It is very exciting to look ahead and envision the science that can be expected from these new developments and the unique combination of the FELIX lasers with high magnetic fields."

Societal relevance

The Roadmap committee recognized the societal relevance and contribution of the research facility in the important fields of health, energy and smart materials. HFML-FELIX also attracts world-leading researchers to the Netherlands and educates a large number of students.

SUCCESSFUL EMFL USER MEETING IN NIJMEGEN

Thursday, June 21st 2018, the 6th EMFL User Meeting took place in Nijmegen. Over 60 users of the European Magnet Laboratories (HFML-Nijmegen, HLD-Dresden, LNCMI-Grenoble, and LNCMI-Toulouse) shared developments, scientific results, and exchanged ideas on high-field research.

The day started with a welcome by Prof. Nigel Hussey, director of HFML. During the day 11 users and one prize winner (see page 10) presented results of their research and the facility developments at EMFL. There was a poster session, a tour around the HFML and FELIX labs and of course the yearly EMFL prize was awarded. With over 60 participants, there was a lively and enthusiastic atmosphere.

All and all it was a successful day. Prof. Jochen Wosnitza, chair of the EMFL Board of Directors: “This user meeting was first of all well organized. And there was a lot of diversity in the scientific talks. They were all interesting and inspiring. I think the user meetings are getting better every year!”

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ARTEM MISHCHENKO TAKES HOME THE EMFL AWARD

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During the EMFL User Meeting in Nijmegen, the yearly EMFL prize was awarded. This time Dr. Artem Mishchenko, EPSRC Research Fellow in the Condensed Matter Physics Group of the University of Manchester, had the honor to receive the prize.

Jochen Wosnitza, Director of the Dresden High Magnetic Field Laboratory and chair of the EMFL Board of Directors, handed over the award. Artem Mishchenko received the award for his groundbreaking discoveries at EMFL. He is working on graphene and other related 2D materials and used the EMFL labs in Grenoble and Nijmegen intensively and extremely successfully. In particular, using advanced magneto-transport and magneto-capacitance techniques, he demonstrated how high magnetic fields can be beneficial for uncovering and manipulating spectacular physical phenomena in 2D materials.

Since 2009, the EMFL members award annually the EMFL prize for exceptional achievements in science done in high magnetic fields.

UPCOMING EVENTS

1. EMFL Summer School, Arles, France, September 26-30, 2018
http://www.emfl.eu/meetings-and-events/emflschool-2018.html

2. M²S-HTSC-XII, The 12th International Conference on the Materials and Mechanisms of Superconductivity and High-Temperature Superconductors, Beijing, China, August 19-24, 2018.
http://m2s2018.medmeeting.org/3046?lang=en

3. Thermag VIII, International Conference on Caloric Cooling, Darmstadt, Germany, September 16-20, 2018.
http://thermag2018.de

4. MG-XVI, 16th International Conference on Megagauss Magnetic Field Generation and Related Topics, Kashiwa, Japan, September 25-29, 2018
https://www.issp.u-tokyo.ac.jp/public/MG-XVI/

5. EMFL Summer School, Arles, France, September 26-30, 2018.
http://www.emfl.eu/meetings-and-events/emflschool-2018.html

6. 2019 Joint MMM-Intermag Conference, The IEEE International Magnetics Conference (INTERMAG) and the Conference on Magnetism and Magnetic Materials (MMM). Washington DC, USA, January 14-18, 2019.
http://www.magnetism.org

7. MT26, International Conference on Magnet Technology, Vancouver, Canada, September 22-27, 2019.
http://mt26.triumf.ca/

8. SCES 2019, International Conference of Strongly Correlated Electron Systems, Okayama, Japan, Sep. 23-28, 2019.
http://sces2019.org

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