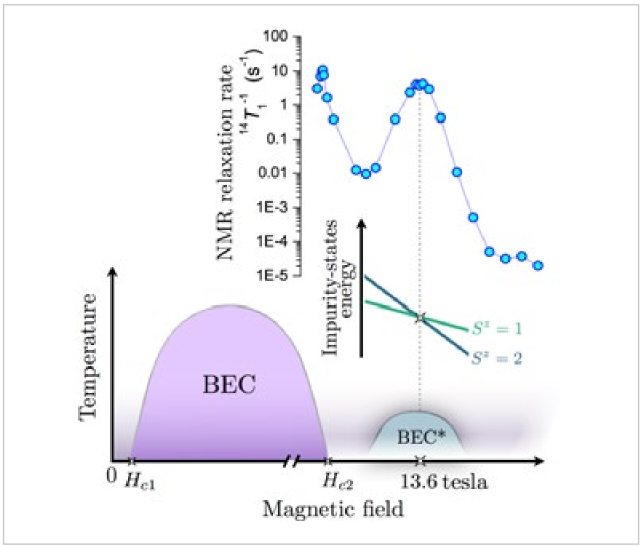
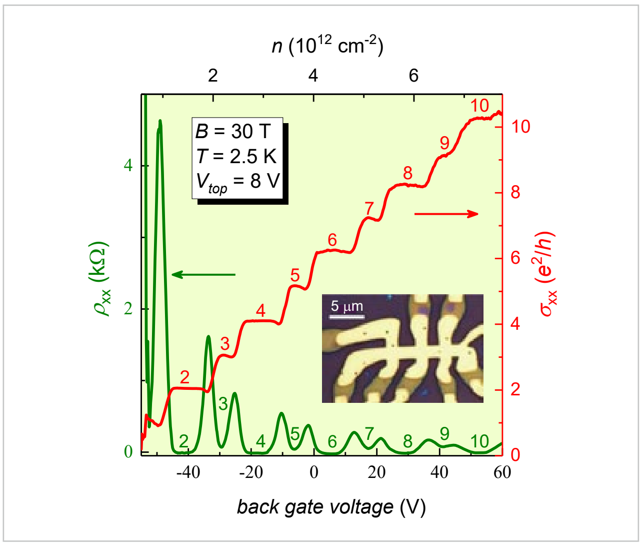
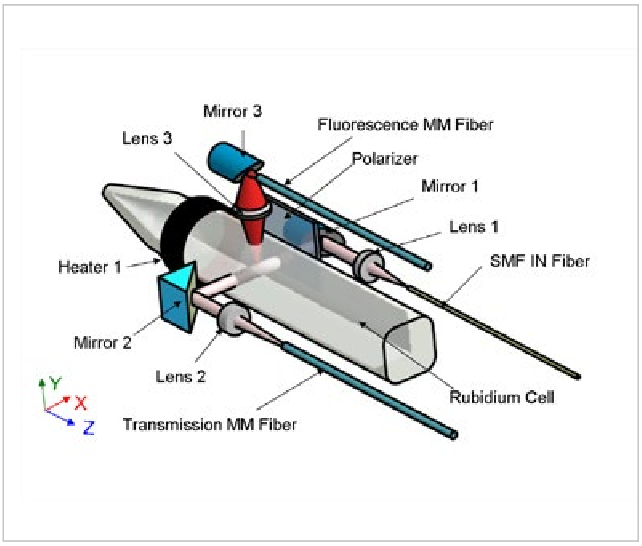
European Magnetic Field Laboratory

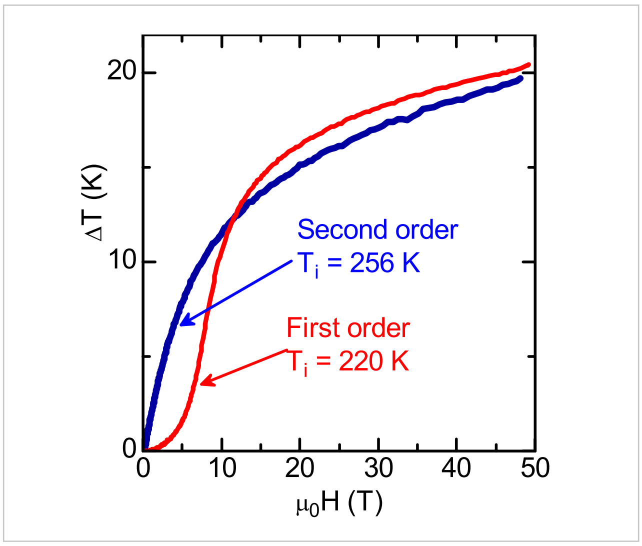
EMFLNEWS

N°3 2017









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DEAR READER

A central aspect of the EMFL facilities is the training and education of their own students and postdocs as well as of external future users and early-career scientists working with high magnetic fields. This is done not only in our usual day-to-day work in the laboratories, but every few years by organizing special summer schools for young researchers. After having organized such schools in Cargese and Rügen some years ago, we now are happy to announce the next EMFL summer school on science in high magnetic fields taking place in Arles, France, September 26 – 30, 2018.

You will find more on this and the announcement of the opening of the 18th call for access to our facilities in this issue of the EMFL News. Of course, the usual selection of highlights from the many high-level research results that are produced utilizing our world-class high-magnetic-field installations can be found as well.

Have a stimulating reading,
Jochen Wosnitza
Director HLD, Chairman EMFL

MEET OUR PEOPLE

Dmytro Kamenskyi, Head of the HFML-FELIX research group

„The HFML-FELIX set-up is unique, now we are preparing unique experiments that cannot be done elsewhere in the world. In this way, we will be able to really give something new to the scientific community."

Dr. Dmytro Kamenskyi is a postdoctoral researcher at the High Field Magnet Laboratory and head of the HFML-FELIX research group, dedicated to exploit the exclusive combination of intense, tunable THz radiation with high magnetic fields. During his PhD research at the Dresden High Magnetic Field Laboratory, Kamenskyi visited the HFML multiple times. Subsequently, he started a postdoc in Nijmegen in 2013.

„Around that time, the first connection between FELIX and HFML had been set up. It was still a rough tube about one centimeter in diameter instead of the real beam-transport system we have today, but it worked reasonably well. We performed some simple resonance experiments with exciting results, which we never have seen before. This showed us the unexpected things that can come from the combination of intense infrared light and magnetic fields."

Currently, Kamenskyi has two PhD students working on various aspects of the HFML-FELIX set-up. Bence Bernath focuses on the development of the pump-probe station and Andrea Marchese is performing cyclotron resonance experiments and developing a special cell for experiments with gases. Furthermore, the FELIX team has put a lot of effort in optimizing and improving the performance of FLARE, one of the free-electron lasers connected to the HFML.

„Our aim is to have perfectly functioning and well-characterized experimental setups in a few years. I hope to be able to provide our users with routinely working unique experimental techniques, which will attract top scientist from all over the world."

Apart from the FELIX-HFML joint activity, Dmytro is responsible for the user support of the infrared setup at HFML. He continuously takes care and improves the high-field setup based on a Bruker IFS113v spectrometer. "In 2016, we performed successful reflectivity measurements on topological insulators as well as in some dielectric materials. The opportunity to measure the reflectivity opens up a completely new area for us. Now, we can consider high-field infrared studies of superconductors and metals, which were not feasible for us one year ago."

Dmytro Kamenskyi, Head of the HFML-FELIX research group

IMPURITY-INDUCED DISORDER CAN GENERATE LONG-RANGE ORDER IN HIGH FIELDS

M. Horvatić, LNCMI Grenoble and N. Laflorencie, Laboratoire de Physique Théorique, Toulouse

In the two back-to-back articles published in Physical Review Letters, experimentalists from LNCMI Grenoble and theorists from the Laboratoire de Physique Théorique in Toulouse have demonstrated that, contrary to previous expectations, disorder can help to order quantum matter. To show this, they have studied the spin-chain based material $NiCl_2$-$4SC(NH_2)_2$, also called DTN, which at low temperature reveals a magnetic-field-induced ordered phase, described as a Bose-Einstein condensate (BEC). So far it was believed that, close to this BEC phase, chemical disorder created by doping Br impurities to substitute Cl ions in DTN would lead to localization, namely the so-called Bose-glass state. However, building on nuclear magnetic resonance (NMR) experiments on doped DTN at high magnetic fields, combined with state-of-the-art quantum Monte Carlo simulations, a radically different scenario was discovered: from a strong peak observed in the NMR relaxation rate, attributed to the crossing of energy levels of the impurity states, and an impurity-induced local spin-polarization value determined from the NMR spectra, a very precise microscopic image of the impurities could be established. Theoretical modelling then showed that the mutual pairwise effective interaction of the impurity states leads to a global quantum coherence over the full sample, which results in a new type of BEC ordering of these impurity states, in sharp contrast to a localized Bose glass.

The existence of this new, "order-from-disorder" phase is now definitely confirmed by further NMR data: in a higher-doped DTN sample, this new phase appears at experimentally accessible temperatures, and the corresponding experimental phase diagram is currently being determined. This remarkable discovery is thus rewarding a very successful collaboration between experimental and theoretical teams.

Nuclear magnetic resonance reveals disordered level-crossing physics in the Bose-glass regime of the Br-doped $Ni(Cl_{1-x}Br_x)_2$-$4SC(NH_2)_2$ compound at a high magnetic field, A. Orlova, R. Blinder, E. Kermarrec, M. Dupont, N. Laflorencie, S. Capponi, H. Mayaffre, C. Berthier, A. Paduan-Filho, and M. Horvatić, Phys. Rev. Lett. **118**, 067203 (2017).

Disorder-induced revival of the Bose-Einstein condensation in $Ni(Cl_{1-x}Br_x)_2$-$4SC(NH_2)_2$ at high magnetic fields, M. Dupont, S. Capponi, and N. Laflorencie, Phys. Rev. Lett. **118**, 067204 (2017).

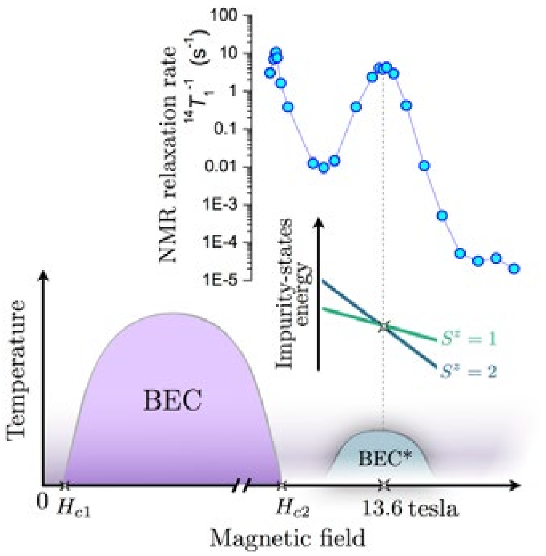

Figure: Besides the Bose-Einstein Condensate (BEC) extending between H_{c1} = 2.1 T and H_{c2} = 12.3 T, a new type of condensate (BEC*) appears near 13.6 T. This new quantum state, induced by disorder and revealed through a strong peak in the magnetic-field dependence of the NMR relaxation rate, emerges from the interaction between the localized impurity states.

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QUANTUM HALL EFFECT IN FEW-LAYER InSe

Sergio Pezzini, Uli Zeitler, HFML Nijmegen

The discovery of graphene in 2004 with its spectacular electronic properties has opened one of the fastest rising research fields in contemporary materials science. Indeed, graphene and other two-dimensional materials offer promising application perspectives for e.g. high-speed electronics beyond silicon. Specifically, graphene, with its ultra-high mobility even at room temperature has been proposed to replace silicon, but the absence of an energy gap makes it rather unsuitable for switching applications.

Researchers from Manchester and Nottingham (United Kingdom) have now fabricated and measured devices made from ultra-thin layers of InSe encapsulated in hexagonal boron nitride with room-temperature mobilities of more than 1000 $cm^2 V^{-1} s^{-1}$. Since InSe is a semiconductor with a large energy gap these devices open new venues for super-fast switching of transistors in next-generation electronics.

On a more fundamental point of view, experiments performed in collaboration with EMFL scientists at HFML-RU/FOM have revealed a fully developed quantum Hall effect at B = 30 T with spin-resolved Landau levels (see Figure). They have shown that electrons in InSe behave like classical massive particles (rather than massless Dirac fermions known in graphene). Using temperature-dependent Shubnikov-de Haas experiments the effective cyclotron mass of electrons in 6-layer InSe was determined as $m^* = (0.14 \pm 0.01)\, m_e$ and their Landé g-factor to $g^* \approx 2$.

High electron mobility, quantum Hall effect and anomalous optical response in atomically thin InSe, D. A. Bandurin, A. V. Tyurnina, G. L. Yu, A. Mishchenko, V. Zólyomi, S. V. Morozov, R. K. Kumar, R. V. Gorbachev, Z. R. Kudrynskyi, S. Pezzini, Z. D. Kovalyuk, U. Zeitler, K. S. Novoselov, A. Patanè, L. Eaves, I. V. Grigorieva, V. I. Fal'ko, A. K. Geim, and Y. Cao, Nat. Nanotechnol. **12**, 223 (2017).

These first results obtained on the quantum Hall effect in InSe indicate that this material might be another fascinating playground for studying the fundamental properties of low-dimensional electron systems in view of promising applications in future high-mobility nanoelectronics of ultra-thin devices.

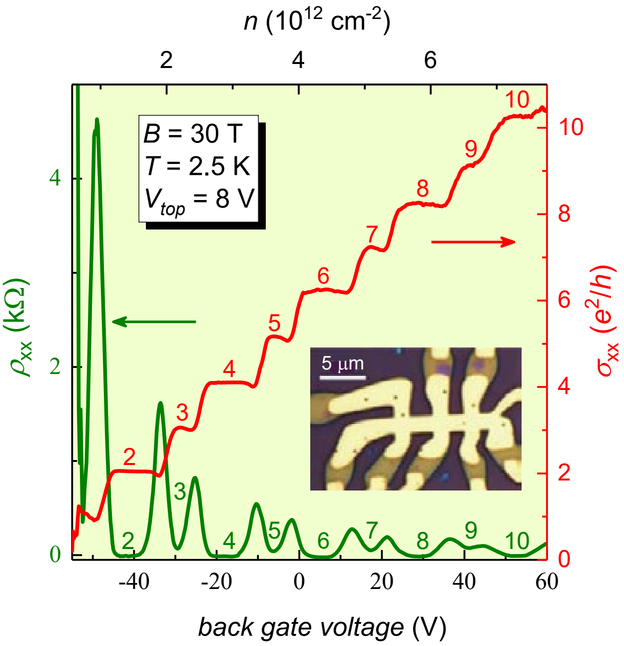

Figure: Resistivity ρ_{xx} (green, left axis) and Hall conductivity (red, right) of a 6-layer InSe field-effect transistor with a top gate and a back gate in a magnetic field B = 30 T. The numbers mark the integer filling factors of the corresponding quantum Hall states, with even numbers corresponding to Landau-level splitting and odd numbers to Zeeman spin splitting. The inset shows a micrograph of the device with the top gate and contacts in yellow and the encapsulated InSe in brown.

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PULSED HIGH MAGNETIC FIELD MEASUREMENT VIA A RUBIDIUM VAPOR SENSOR

Sylvie George, Nicolas Bruyant, Jérôme Béard, Stefano Scotto, Ennio Arimondo, Remy Battesti, Donatella Ciampini, Carlo Rizzo

We have realized a new technique to measure pulsed magnetic fields based on the use of rubidium in the gas phase as a metrological standard. For that, we have developed a measurement device based on laser-induced transitions at about 780 nm (D2 line) in a rubidium gas contained in a miniature cell of 3 x 3 mm^2 cross section. To be able to insert such a cell in a standard high-field pulsed magnet we have realized a fiber-connected probe kept at a fixed temperature.

The transition frequencies for both the π (light polarization parallel to the magnetic field) and σ (light polarization perpendicular to the magnetic field) configurations are measured by a commercial wavemeter. One innovation of our sensor is that, in addition of monitoring the light transmitted through the Rb cell – done usually – we also monitor the fluorescence emission of the gas, sampled from a very small volume with the advantage of reducing the impact of field inhomogeneities on the field measurement.

Our sensor has been tested up to fields of about 58 T and is now availible to externals users.

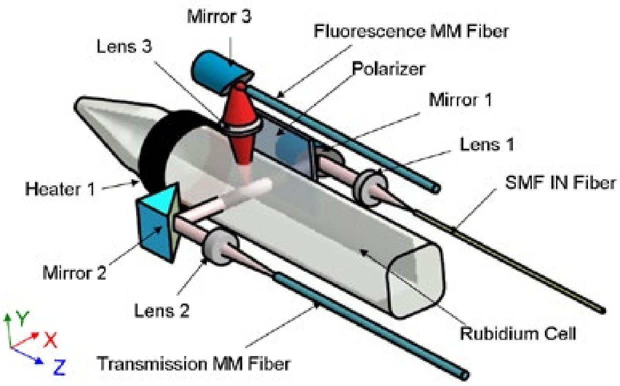

Figure 1: Schematic of the miniature optical head for combined gas-phase spectroscopy and fluorescence.

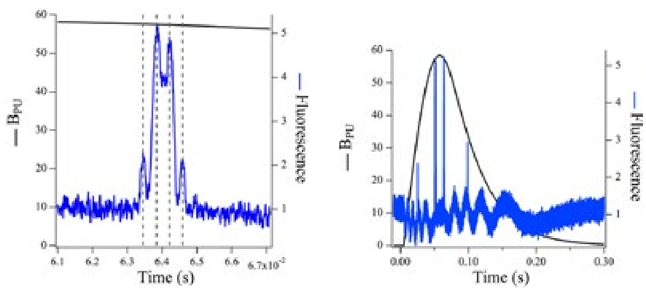

Figure 2: Signal from Rb fluorescence up to 58 T showing 4 accurate field markers ranging from 57.865(13) T (First line) to 58.204(13) T (last line).

Pulsed high magnetic field measurement with a rubidium vapor sensor, S. George, N. Bruyant, J. Béard, S. Scotto, E. Arimondo, R. Battesti, D. Ciampini, and C. Rizzo, Rev. Sci. Instr. **88**, 073102 (2017).

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MAGNETOCALORIC EFFECT DIRECTLY MEASURED IN PULSED MAGNETIC FIELDS

Y. Skourski, HLD Dresden

Magnetocaloric materials are the basis for a solid-state alternative to conventional compressor-based refrigeration techniques at ambient temperature. The rapidly developing class of magnetic refrigerators, heat pumps, and air-conditioning units based on these materials is considered to be environmentally friendly, silent, compact, and energy efficient. The typical thermal-cycle design frequency of a magnetic refrigerator is in the range of 1–10 Hz (corresponding to a magnetic-field change rate of 2–50 T/s). Relevant materials, however, are often studied using indirect, steady-field experiments with typical field-change rates of only 0–0.01 T/s. In order to determine the magnetocaloric effect close to real operational conditions, direct measurements of adiabatic temperature changes by using fast-sweeping magnets are needed. Pulsed-field magnets are ideally suited for such investigations with the additional benefit of the nearly perfect adiabatic condition during the short pulse time.

Scientists from Darmstadt and Dresden have performed magnetization, magnetostriction, and magnetocaloric-effect measurements in magnetic fields up to 60 T for a promising magnetocaloric system $La(Fe,Co,Si)_{13}$. Here the temperature, and the character of the transition can be tuned by slight composition variations.

The magnetocaloric response is maximized at the ordering transition. Two members of the series with different Co content have been chosen, behaving as first- and second-order materials. The former shows a first-order metamagnetic transition with an abrupt increase of magnetization and volume in fields up to 5 T. The transition is accompanied by a substantial heat release. The second-order material, on the other hand, does not show a metamagnetic behavior and, above the Curie temperature, is an ordinary paramagnet. The magnetocaloric effect reaches about 20 K at 50 T in both compounds (Figure). Measurement of magnetization and magetostriction under adiabatic conditions allowed for obtaining the magnetoelastic coupling in those materials. It was shown that the order of the transition is likely to be driven by magnetoelasticity.

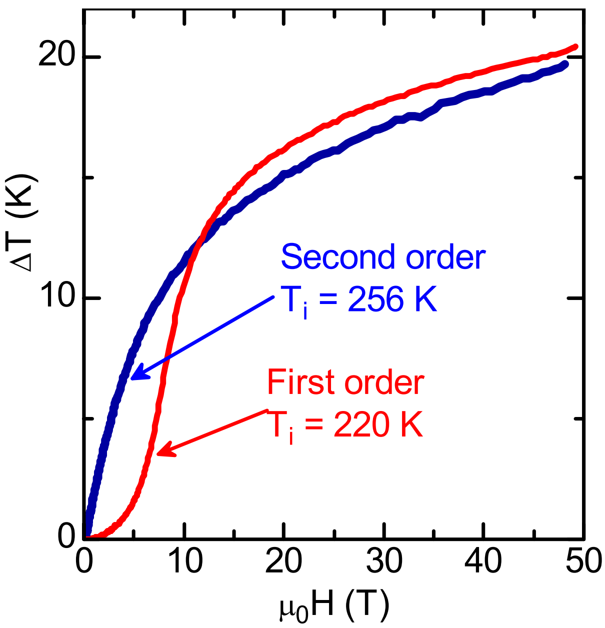

Figure: Field dependence of the magnetocaloric effect of $LaFe_{11.74}Co_{0.13}Si_{1.11}$ (first order), and $LaFe_{11.21}Co_{0.65}Si_{1.11}$ (second order) measured in pulsed magnetic fields up to 50 T at the given initial temperatures T_i.

Direct Measurement of the Magnetocaloric Effect in $La(Fe,Si,Co)_{13}$ Compounds in Pulsed Magnetic Fields, M. Ghorbani Zavareh, Y. Skourski, K. P. Skokov, D. Yu. Karpenkov, L. Zvyagina, A. Waske, D. Haskel, M. Zhernenkov, J. Wosnitza, and O. Gutfleisch, Phys. Rev. Applied **8**, 014037 (2017).

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OPENING OF THE EIGHTEENTH CALL FOR ACCESS

The 18th call for proposals has been launched in October, 2017 inviting researchers worldwide to apply for access to one of the large installations for high magnetic fields collaborating within EMFL.

The four facilities

> LNCMI - Grenoble - France: Static magnetic fields up to 36 T
> HFML - Nijmegen - the Netherlands: Static magnetic fields up to 37,5 T
> HLD - Dresden - Germany: Pulsed magnetic fields to beyond 90 T
> LNCMI - Toulouse - France: Pulsed magnetic fields of long duration to beyond 90 T and on the microsecond scale to beyond 180 T

run a joint proposal program, which allows full access to their installations and all accompanying scientific infrastructure to qualified external users, together with the necessary support from their scientific and technical staff.

Users may submit proposals for access to any of these installations by a unified procedure. The online form for these proposals can be found on the EMFL website.
www.emfl.eu/user

The next deadline for proposals for magnet time is November 15, 2017.

Proposals received after the deadline, that are considered of sufficient urgency, may be handled as they arrive and fit into any available time.

The proposals will be evaluated by a Selection Committee. Selection criteria are scientific quality (originality and soundness), justification of the need for high fields (are there good reasons to expect new results) and feasibility of the project (is it technically possible and are the necessary preparations done). It is strongly recommended to contact the local staff at the facilities to prepare a sound proposal and ideally indicate a local contact.

Please do acknowledge any support under this scheme in all resulting publications with „We acknowledge the support of the HFML-RU/FOM (or HLD-HZDR or LNCMI-CNRS), member of the European Magnetic Field Laboratory (EMFL)“

> You may find more information on the available infrastructures for user experiments on the facility websites.

www.hzdr.de/hld
www.lncmi.cnrs.fr
www.ru.nl/hfml

EMFL
European Magnetic Field Laboratory

The EMFL develops and operates world class high magnetic field facilities, to use them for excellent research by in-house and external users.

TIME TO SAY GOODBYE

On October 12th the HZDR celebrated its annual reception. Within this formal event the official farewell of Peter Joehnk was held. After 15 ½ years as Administrative Director of the HZDR, he goes into well-earned retirement.

Peter Joehnk worked for 37 years in science management, among others for the Federal Research Ministry in Bonn, in the Nuclear Research Center Karlsruhe and the Leibniz Institute for Solid State and Materials Research Dresden (IFW) that he co-founded and led from 1992 to 2002.

The important stimulus to move to Rossendorf was given by the possibility to construct the new high-magnetic-field laboratory Dresden (HLD). The prototype high-field lab at the IFW was realized under

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the structural responsibility of Peter Joehnk. The large user facility HLD, however, had to be built at the HZDR.

The construction of this first HLD part as well as later the expansion of the laboratory and the additional construction of a helium liquefier for the supply with cooling liquids was in his responsibility. Together with his colleagues from Grenoble, Toulouse, and Nijmegen, Peter Joehnk played a substantial role in the establishment of the legal body for the EMFL in the form of an AISBL (seated in Brussels) for which the solemn act of signing took place in January 2015.

As EMFL, we thank Prof. Dr. Dr. h. c. Peter Joehnk for his commitment and his support during his time at the HZDR. We are very thankful for his achievements, his motivation, and his willingness to contribute to EMFL.

RHMF2018

24-29-JUN 2018, Santa Fe, New Mexico

The 12th International Conference on “Research in High Magnetic Fields” (RHMF 2018) will take place in Santa Fe, New Mexico, USA, 24 - 29 June 2018. This conference is devoted to all aspects of research in high magnetic fields and covers areas such as magnetism, semiconductor physics, superconductivity, studies of strongly correlated electron systems, low-dimensional and nano-scale materials, spin liquids, topological materials, molecular systems, high magnetic field technology, and new high-field experimental techniques. The conference is hosted by the National High Magnetic Field Laboratory-Pulsed Field Facility at the Los Alamos National Laboratory.

Important Dates

- 12 February 2018: Abstract submission
- 16 March 2018: Abstract acceptance notification
- 20 April 2018: Extended early registration deadline
- 24-29 June 2018: Conference period

› Supporting Organizations

EUROPEAN MAGNETIC FIELD LABORATORY SUMMER SCHOOL SCIENCE IN HIGH MAGNETIC FIELDS

26 - 30 September 2018—Arles, France

This school is dedicated to recent advances in science in high magnetic fields. Renowned scientists will give tutorial lectures on different areas such as semiconductor physics, low-dimensional materials and nano-scaled objects, strongly correlated electron systems, magnetism, superconductivity, molecular systems, high magnetic field technology and new high-field experimental techniques.

Participants will be selected among young scientist based on their motivation, curriculum vitae and abstract submission. They will have the possibility to present their work as an oral contribution or a poster. The EMFL will provide substantial financial support for accommodation.

High magnetic fields are an indispensable tool to access the fundamental properties of matter. In the 20th century they enabled significant breakthroughs witnessed by several Nobel prizes, and, undoubtedly, high magnetic fields will continue to play a decisive role in shaping the European landscape in the future.

Important dates:

- October 2017: 1st announcement
- February 2018: 2nd announcement with list of subjects and invited speakers
- June 2018: Application and abstract submission deadline
- July 2018: Notification of acceptance
- 26-30 September 2018: EMFL Summer School

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