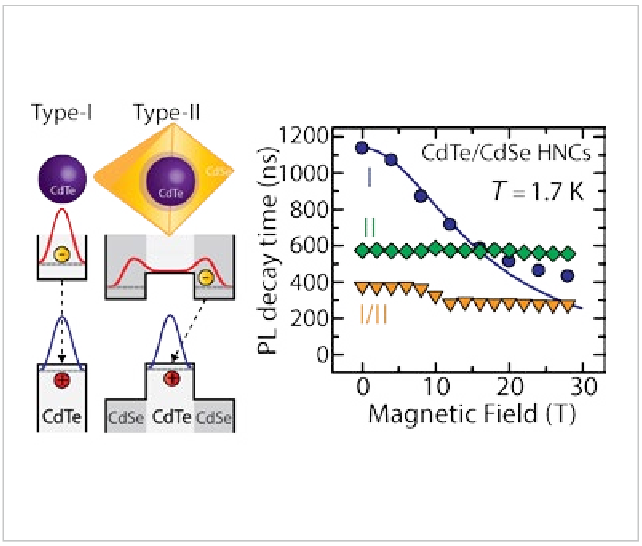
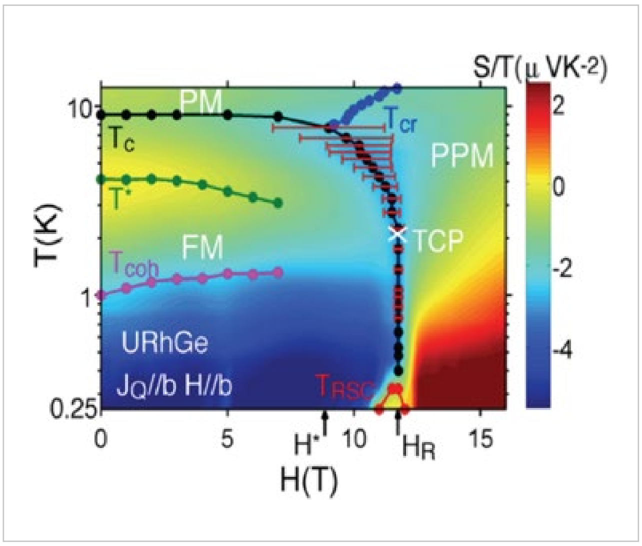
European Magnetic Field Laboratory

EMFLNEWS

N°2 2016





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DEAR READER,

We look back on a successful and lively User Meeting in Toulouse on June 16th. To mark the entrance of the UK high-field user community into EMFL, the next User Meeting will be organized in the UK. You will be informed about the details in due time and we all hope to see you there.

Of course, exciting new scientific results keep on pouring out of the EMFL facilities as you will see further on in this issue, and we continue to improve the EMFL installations and magnets for your benefit. Come and see for yourself!

Geert Rikken
Director LNCMI-CNRS
Chairman EMFL Board

MEET OUR PEOPLE

Younès Henni, LNCMI Grenoble

I am a PhD student in my final year at the Grenoble high magnetic field laboratory (LNCMI-G). During the three years I spent in our lab, my research topic was mainly focused on the optical properties of the two-dimensional (2D) carbon-based material graphene, under strong magnetic fields.

After a bachelor degree in fundamental physics at the University of Science and technology in Algiers (Algeria), I had the chance to come to France to pursue a Master thesis in condensed matter physics at the University of Strasbourg. In order to complete my Master degree, I applied for an internship of a few months at LNCMI-G for a scientific project focused on the magneto-optical properties of graphene-based heterostructures.

The experiments using the magnetic field facility of our lab hooked me up and I decided to pursue a PhD degree at LNCMI-G. The static magnetic field up to 36 T provided by the resistive magnets at LNCMI-G makes it one of the few labs in the world providing such an opportunity for high-field measurements. During this period, I worked in a very dynamical environment with strong international collaborations.

Our team is composed of highly qualified scientists, each one exploring the physical properties of a specific material, but with many overlaps from which new ideas are always generated. In my PhD, I had the chance to measure some very exciting data from the study of graphene multilayers with a peculiar symmetry of its crystal structure. Our studies focus on measuring the evolution of the electronic excitations as a function of magnetic field. This technique allows us to probe the energy levels of materials and to deduce their physical properties.

My project for the future will be to pursue a postdoc in a foreign country. This certainly will allow me to deepen my knowledge on physics and in material science in general. But one thing is for sure, I am counting on keeping a strong collaboration with the researchers at LNCMI-G and eventually to come again for exciting high magnetic field experiments.

Younès Henni, PhD student at LNCMI Grenoble

EXCITON RADIATIVE LIFETIMES OF CdTe/CdSe HETERONANOCRYSTALS

Peter Christianen, HFML Nijmegen

Colloidal semiconductor nanocrystals (NCs) are organically capped nanoparticles with optical properties that are dramatically different from those of the bulk semiconductor material. They exhibit very efficient light emission that can be tuned in wavelength by varying their size, composition and shape, making them suitable for optoelectronic and photonic applications.

Core-shell systems allow to design the spatial extent of the electron (e) and hole (h) wave functions in the conduction and valence bands, respectively. In type-I NCs, both electrons and holes are confined to the core, leading to a large e–h overlap, whereas in type-II NCs, the electrons and holes are spatially separated, reducing the e–h overlap (left panel in Figure). However, tuning the overlap between the e and h wave functions not only affects the oscillator strength of the coupled e–h pairs (excitons) that are responsible for the light emission, but also modifies the e–h exchange interaction, leading to an altered excitonic energy spectrum.

By measuring the photoluminescence (PL) decay times of a set of CdTe/CdSe core/shell heteronanocrystals as a function of magnetic field and temperature, we are able to unravel the separate effects of e–h overlap and e–h exchange on the exciton lifetimes. In a type-I structure (core only NC) the PL decay time drastically reduces with increasing magnetic field strength, whereas type-II structures do not show any field dependence at all (right panel in Figure). These results lead to a simple model that fully describes the recombination lifetimes of heteronanostructures as a function of core volume, shell volume, temperature, and magnetic fields.

Effect of Electron–Hole Overlap and Exchange Interaction on Exciton Radiative Lifetimes of CdTe/CdSe Heteronanocrystals, A. Granados del Aguila, E. Groeneveld, J. C. Maan, C. De Mello Donega, and P. C. M. Christianen, ACS Nano **10**, 4102 (2016).

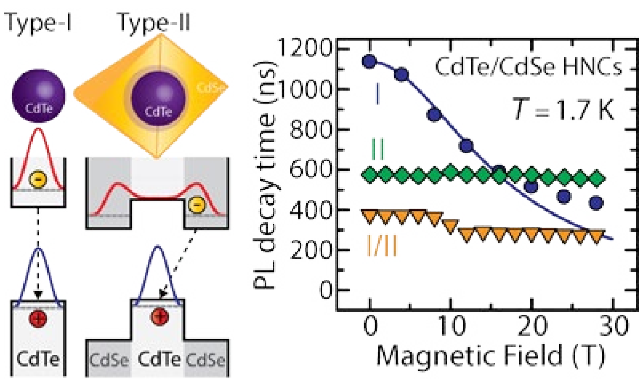

Figure: Core-shell colloidal nanocrystals allow to tune the spatial overlap of the electron (e, red curves) and hole (h, blue curves) wave functions from type I to type II (left panel). Measuring the photoluminescence (PL) decay times as a function of the magnetic field (right panel) and temperature permits to distinguish the different types

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FIELD-INDUCED ANOMALIES IN A SPIN-DIMERIZED ANTIFERROMAGNET

Zhe Wang, University of Augsburg and Sergei Zherlitsyn, HLD Dresden

Exotic quantum spin states and quantum critical points can be induced by magnetic fields. Specifically, dimerized spin-1/2 quantum antiferromagnets are of interest, such as $Sr_3Cr_2O_8$ being a quantum-disordered paramagnet in the ground state with gapped elementary magnon (singlet-triplet) excitations (spin-1 bosons). In a magnetic field the spin gap is closed resulting in a quantum phase transition into a three-dimensional (3D) canted-XY antiferromagnetic (AFM) phase at H_{c1}. This quantum phase transition is often discussed in the context of Bose-Einstein condensation of magnons and the AFM phase can be viewed as a magnonic superfluid. A second quantum phase transition at higher fields (H_{c2}) is associated with the field-induced ferromagnetic state.

Researches from the University of Augsburg, the Helmholtz-Zentrum Berlin, and the HLD have measured magnetization and sound velocity of $Sr_3Cr_2O_8$ in pulsed magnetic fields and found pronounced field-induced anomalies above the 3D AFM phase.

The magnetization data (Fig. 1) show a clear onset of finite magnetization at H_{c1} (at 1.5 K at about 31 T) when the spin gap closes. Above this field, the magnetization grows continuously with increasing magnetic field, reflecting a continuous growth of magnon density. Fig. 2 shows the relative sound velocity of one special mode as a function of magnetic field. At low temperatures the sound velocity exhibits a small step-like decrease at H_{c1}, decreases further with increasing slope, and finally shows a sharp step-like increase at H_{c2}. Remarkably, similar anomalies in the magnetization and sound velocity can be observed at higher temperatures above the 3D AFM phase that is known to exist only up to about 8 K. These anomalies are indicative of phase transitions into a magnonic-liquid state.

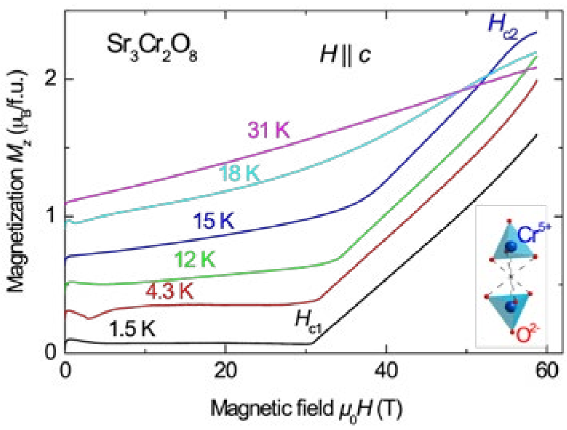

Figure 1: Magnetization M_z as a function of magnetic field along the c axis in $Sr_3Cr_2O_8$ at various temperatures. Inset: Spin dimer formed by two CrO_4 tetrahedra.

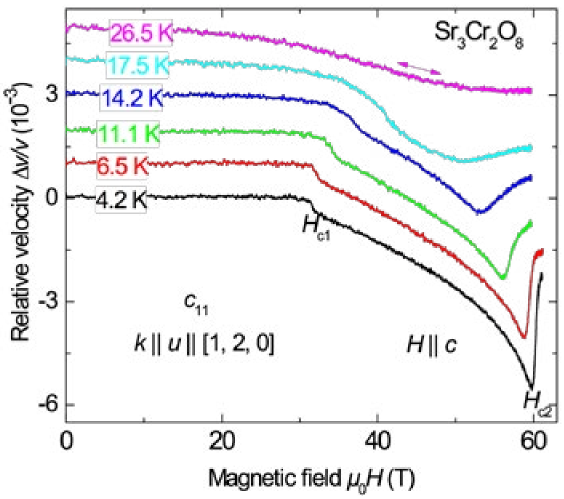

Figure 2: Sound velocity of the tensile mode, c_{11}, as a function of magnetic field at various temperatures.

Field-Induced Magnonic Liquid in the 3D Spin-Dimerized Antiferromagnet, Z. Wang, D. L. Quintero-Castro, S. Zherlitsyn, S. Yasin, Y. Skourski, A. T. M. N. Islam, B. Lake, J. Deisenhofer, and A. Loidl, Phys. Rev. Lett. **116**, 147201 (2016).

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MAGNETIZATION MEASUREMENTS ABOVE 100 T

Atsushiko Miyata and Oliver Portugall, LNCMI Toulouse

Magnetization measurements up to 130 Tesla using compensated pick-up coils have been performed with the Toulouse Megagauss facility. The new setup features a flow-type cryostat providing temperatures down to 4.2 K and is now available for external users.

The Megagauss generator at the LNCMI in Toulouse provides the highest magnetic fields for scientific applications in Europe. The installation makes use of fast capacitor discharges into single-turn coils to produce pulsed fields with microsecond duration reaching between 100 and 200 Tesla. While the coils are destroyed in the process, cryogenic equipment, probe heads, and samples generally survive as conductor fragments are projected away from the bore. The installation is equipped with flow-type cryostats providing temperatures down to 4 K and permits several pulses per day.

In the past, the Megagauss facility has been primarily used for optical experiments ranging from the visible to the mid-infrared. A new setup permits now for the first time magnetization measurements. The inductive probe makes use of a pair of compensated pick-up coils to detect magnetization changes (dM/dt) as the field is swept. Due to the intrinsically high sweep rates of Megagauss fields that typically reach 10^7-10^8 T/s the coils require only a few windings to generate relatively large induced voltages which makes them highly adaptable.

The new system has been successfully tested using $CdCr_2O_4$, a geometrically frustrated Heisenberg spin system. A typical experimental result is shown in the Figure. Further tests using more diluted spin systems to determine sensitivity limits in the presence of electromagnetic noise associated with the Megagauss generation are underway. The system is now available for EMFL users.

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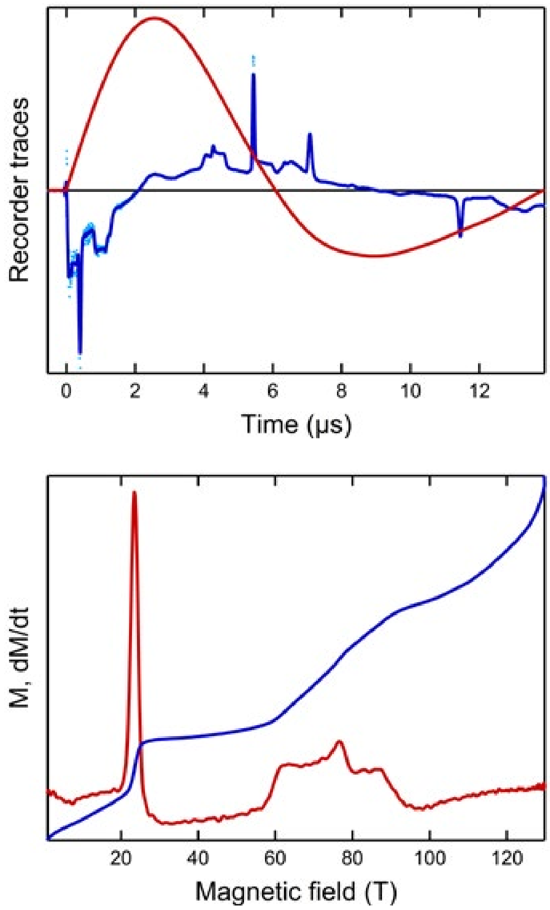

Figure: Example of experimental data obtained with the new magnetization setup. Original recorder traces of the magnetic field pulse (red) and magnetization change (dM/dt, blue) are shown in the upper panel. The amplitude and orientation of the most prominent peak shows clearly the usual relationship with the magnetic field slope. In the lower panel, both dM/dt (red) and the integrated signal M (blue) are plotted as function of magnetic field.

COLLAPSE OF FERROMAGNETISM AND FERMI SURFACE INSTABILITY NEAR THE REENTRANT SUPERCONDUCTIVITY OF URhGe

Alexandre Pourret, INAC-PHELIQS Grenoble

Quantum phase transitions (QPT) are a central topic in contemporary condensed-matter research. Their rich underlying physics plays an important role in explaining exotic low-temperature properties of a variety of strongly correlated materials such as high-T_c superconductors, quantum magnets, or heavy-fermion compounds. URhGe is one of the four uranium-based heavy-fermion compounds where microscopic coexistence of ferromagnetism (FM) and superconductivity has been observed. A transverse magnetic field higher than the superconducting critical field H_{c2} applied along the hard magnetization b axis induces at low temperature a QPT with a reorientation of the magnetic moments from the c to the b axis at H_R = 11.75 T. A field-reentrant superconducting phase (RSC) appears in a narrow field window around H_R below T_{RSC} = 410 mK. Thus, URhGe is a key case to study a ferromagnetic QPT.

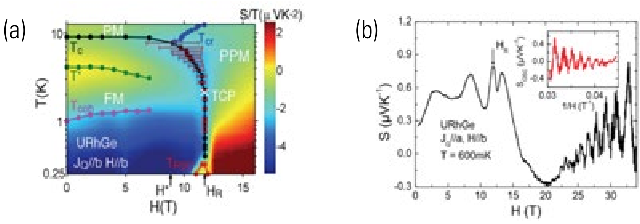

Figure: (a) Linear color map of S/T (TEP divided by T) in the (T, H) plane. The Curie temperature T_c (black circles), the reentrant superconductivity T_{RSC} (red circles) and the crossover line T_{cr} between the paramagnetic (PM) and the polarized paramagnetic (PPM) state (blue circles) are superimposed. The transition width observed in the TEP around H_R is also represented (red horizontal lines).
(b) Magnetic-field dependence of the TEP for J_Q||a, H||b up to 34 T at 600 mK. S shows quantum oscillations above 22 T, represented as a function of 1/H in the inset. [1]

Recent thermoelectric power (TEP) measurements (Ref. [1]) performed for magnetic field applied along the hard magnetization b axis shows clearly the first-order nature of the QPT at H_R and the existence of a tricritical point (TCP, see Figure 1(a)). The abrupt change of sign of the TEP at H_R suggests that a topological change of the Fermi surface is associated with the QPT. The possibility of a Lifshitz transition at H_R in URhGe was already proposed in Ref. [2] from Shubnikov de Haas (SdH) experiments. Indeed, it has been observed that SdH oscillations below H_R, corresponding to a small orbit of only a few percent of the Brillouin zone, vanish on approaching H_R. It has been claimed that this Lifshitz-type transition, leading to the collapse of the Fermi velocity, is the driving force for the RSC. However, as shown in Figure 2(b), the TEP measured up to 34 T shows large quantum oscillations above 22 T. The corresponding frequency, ~ 500 T, is very similar to the frequency observed in the previous SdH measurements below H_R. This demonstrates that a Lifshitz transition as the sole driving force for the RSC seems unlikely. Our study presents clear evidence that both Fermi-surface instabilities and magnetic fluctuations occurring around H_R are the key ingredients for the apparition of the RSC.

[1] **Collapse of ferromagnetism and Fermi surface instability near the reentrant superconductivity of URhGe**, A. Gourgout, A. Pourret, G. Knebel, D. Aoki, G. Seyfarth, and J. Flouquet, Phys. Rev. Lett., **117**, 046401 (2016).

[2] E. A. Yelland, J. M. Barraclough, W. Wang, K. V. Kamenev, and A. D. Huxley, Nat. Phys. **7**, 890 (2011).

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RESULTS OF THE FIFTEENTH CALL FOR ACCESS

On May 16, 2016, the 15th call for access ended inviting proposals for research requiring access to the large installations for high magnetic fields collaborating within EMFL.

The four facilities

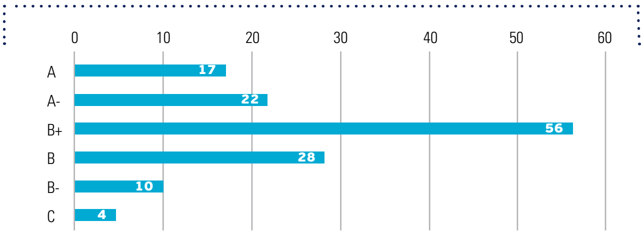
> LNCMI - Grenoble - France: Static magnetic fields to 36 T
> HFML - Nijmegen - the Netherlands: Static magnetic fields to 37.5 T
> HLD - Dresden - Germany: Pulsed magnetic fields to beyond 90 T
> LNCMI - Toulouse - France: Pulsed magnetic fields of long duration, to over 90 T and on the microsecond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

operate a joint transnational access program, organizing the use and access to their installations and all accompanying scientific infrastructure to qualified external users, together with the necessary support from their scientific and technical staff.

For this 15th call, 137 applications from 19 different countries were received which have been evaluated by the Selection Committee until June 17th, 2016. The Selection Committee consists of 18 specialists covering the five types of scientific topics

> Magnetism (46 applications),
> Metals and Superconductors (40 applications),
> Semiconductors (36 applications),
> Soft Matter and Magnetoscience (9 applications),
> Applied Superconductivity (6 applications),

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



Evaluation of applications

Projects are classified in three classes:

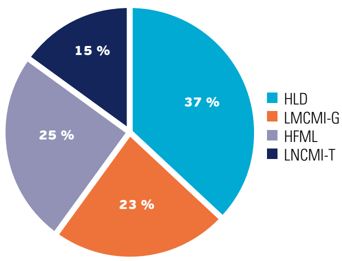
A (excellent proposal to be carried out),

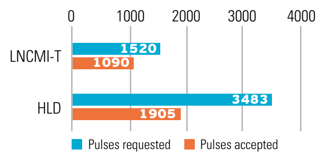
B (should be performed but each facility has some freedom considering other constraints),

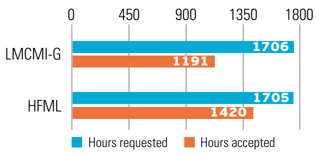
C (poor proposal or one that does not need any of the four unique high magnetic field laboratories).

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

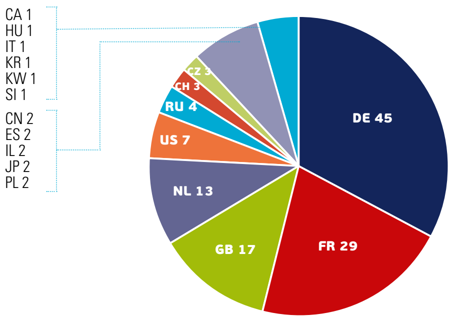






NEXT CALL :
Launch: October 15, 2016
Deadline: November 15, 2016

Distribution by countries
Number of applicants

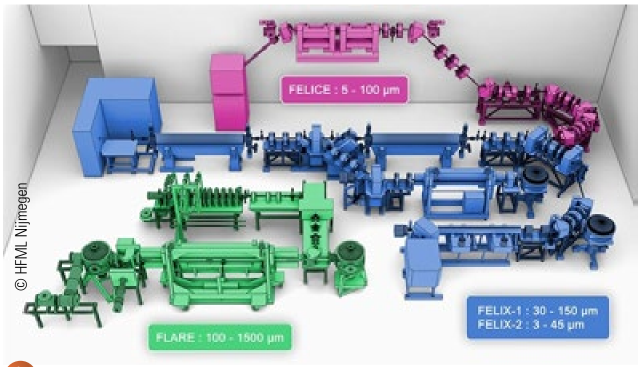


THE NIJMEGEN CONNECTION - ALL FELIX PHOTONS REACH HFML

Due to the hard work of scientists, engineers, and technicians at the High Field Magnet Laboratory (HFML), the photons of the three beamlines of the FELIX Laboratory – FLARE, FELIX-1, and FELIX-2, now reach the magnet cells of the EMFL facility at the Radboud University in Nijmegen.

This combination of intense, tunable infrared and THz radiation with high magnetic fields allows to study matter in magnetic fields up to 33 T irradiated with radiation in the range from 0.25 – 120 THz. A dedicated HFML-FELIX research team has started to explore and exploit this world-unique combination. Researchers use (far-)infrared and THz spectroscopy for measuring low-energy optical excitations in high magnetic fields, for instance electron magnetic resonance (ESR), cyclotron, and antiferromagnetic resonance.

The infrared and THz radiation from the different FELIX beamlines travels more than 80 m from the free electron lasers into the magnets at HFML through a quasi-optical transport system consisting of more than 40 mirrors. One of the technical challenges is that the diffraction of laser radiation is proportional to its wavelength and, therefore, needs to be refocused approximately every 8 meters to accommodate the longest wavelength of 1.5 mm that the FLARE laser of the FELIX Laboratory produces. The new optical transport system does not only warrant high transmission of the intense radiation but also maintains the short pulse lengths of the lasers providing excellent opportunities for time-resolved experiments in high magnetic fields.



Overview of the four FELIX free electron laser beamlines. The beamlines FLARE, FELIX-1, and FELIX-2 are connected to the magnets at HFML.

Specs:	FELIX:	FLARE:	FELICE:
e-beam energy	50/45 – 15 MeV	15 – 10 MeV	50/45 – 18 MeV
spectral range	2.7 – 150 micron	100 - 1500 micron	5 - 100 micron
	3600 - 66 cm^{-1}	100 - 6 cm^{-1}	2000 - 100 cm^{-1}
	120 – 2 THz	3 – 0.25 THz	60 - 3 THz
	450 – 8 meV	12 – 0.75 meV	250 - 12 meV
pulse structure	micro / macropulse	micro / macropulse	micro / macropulse
rep. rate	25 MHz/1 GHz@10 Hz	3 GHz@10 Hz	16 MHz/1GHz@10 Hz
micropulse energy	1-20 µJ	≈ 5 µJ	max. 1 mJ
macropulse energy	≤ 100 mJ @ 1 GHz	≤ 100 mJ @ 3 GHz	max. 5 J @ 1 GHz
peak power	≤ 100 MW	≤ 10 MW	≤ 5 GW
polarisation	linear	linear	linear
spectral bandwidth (FWHM)	0.2 - 5%	≤ 1% spectral mode $\leq 10^{-4}$	0.4 – 3%
continuous tunability	200 - 300 %	?	200 – 300 %

Overview of the four FELIX free electron laser beam lines. The beamlines FLARE, FELIX-1, and FELIX-2 are connected to the magnets at HFML.

OPEN LAB DAY AT HZDR ATTRACTED 3,500 GUESTS

Scientific findings are often complex stories, especially when they belong to the realm of basic research. This is the case with almost all the work conducted at the EMFL high-field labs. But how can one tell these difficult stories to lay persons? "A good way to approach interested people is to open your doors and let them have a look into your labs," Jochen Wosnitza, HLD Director at the Helmholtz-Zentrum Dresden-Rossendorf (HZDR), is convinced.

What is more, the HLD team in Dresden not only opened the doors but prepared astounding and enjoyable experiments on the occasion

Hands-on experience: to let nitrogen cooled superconductors go

Open doors: visitors could have a look on their own or participate in a tour to the HLD labs.

Open house: Saturday, May 28, 10 a.m. to 5 p.m.

Levitation: the famous floating frying pan experiment

of the HZDR Open Lab Day on May 28, 2016. With great passion and creativity the scientists took the young and old visitors on a scientific journey: What is magnetism? How are the highest possible magnetic fields generated? What is that good for? Which important questions could be answered by research undertaken at the EMFL labs?

As roughly 2,000 out of the total number of 3,500 guests on the Dresden-Rossendorf campus visited their labs, the HLD scientists had to answer a lot of questions. The next Open Lab Day is scheduled for May 2018.

ANNUAL USER MEETING

The eighth annual User Meeting, for the fourth time organized under the EMFL flag, has been held at the Laboratoire National des Champs Magnétiques Intenses (LNCMI) in Toulouse on June 16th, 2016. The Meeting took place in a lively and pleasant atmosphere, with 35 participants, with an inspiring and informative program for the EMFL high-field users, and well organized by the local staff.

The Meeting started with a welcome by Geert Rikken (chair of EMFL) who presented the current state of EMFL and future perspectives. A technical session followed where Catalina Salazar (HLD), Ben Bryant (HFML) and Fabienne Duc (LNCMI) presented some of the instrumentation developments taking place at the EMFL facilities and the unique scientific results obtained with them. Afterwards, users from the facilities and key players in different research areas presented highlight results obtained an the EMFL facilities.

The User Committee this year was chaired for the last time by Amalia Patané (University of Nottingham), who will from now on be the UK representative in the EMFL Council. Raivo Stern (NICPB, Tallinn, Estonia) was nominated by acclaim as her successor as User Committee chairman. During the User Committee Meeting (open for all external users) suggestions for improvements at the EMFL facilities were discussed. The session was closed with an update by Amalia Patané to the lab directors and all users on the outcome of the User Committee Meeting.

To mark the entry of the UK high-field user community in the EMFL, it was decided to organize the next User Meeting in the UK, chaired by Amalia Patané. The User Meeting ended with a visit to the new LNCMI building.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Participants of the EMFL User Meeting

AND THE EMFL PRIZE 2016 GOES TO …

… Alix McCollam from the High Field Magnet Laboratory in Nijmegen. She was awarded for her outstanding research in Fermi-surface studies of various materials and the development of high-field magnetometry with extraordinary sensitivity. The EMFL prize was conferred during the User Meeting in Toulouse where Alix as well presented highlights of her recent work. Already since 2009, the EMFL members award annually the EMFL prize (up to 2012 called EuroMagNET prize) for exceptional achievements in science done in high magnetic fields.


© Julien Billette

Alix McCollam received the EMFL prize from HLD Director Jochen Wosnitza

REPORT FROM THE ANNUAL EMFL USER COMMITTEE MEETING - TOULOUSE 16th JUNE 2016

The EMFL User Committee Meeting was held on the 16th of June 2016 in Toulouse at the LNCMI (Laboratoire National des Champs Magnétiques Intenses) as part of the annual EMFL User Meeting. Four of the seven members of the User Committee (A. Patanè, M. Doerr, C. Putzke, K. Prokes) and several users attended the meeting with Prof. Patanè chairing the committee. The meeting was followed by a discussion meeting with the Board of Directors of the EMFL and the user community. Several matters were discussed and recommendations made to the Board of Directors, as outlined below.

Members of the User Committee

Two members have now resigned (A. Patanè and H. Hilgenkamp) to take on other duties and activities within the EMFL. Dr. Raivo Stern (NICPB, Tallin) has kindly agreed to become the new Chair and two new members will be invited to join the User Committee. Suggestions for new members should be sent to Dr. Stern for discussion within the User Committee.

User feedback

Following an early recommendation of the User Committee, the EMFL has now adopted an online user feedback form for all the laboratories of the EMFL. This has facilitated a larger number of users providing feedback and comments on their experience at the installations of the EMFL. Most users have judged the facilities excellent/very good (e.g. magnets, equipment, and local contacts) and have made constructive comments about a number of matters, including improvement of the new installations of the LNCMI Toulouse, a regular update on the website of the EMFL on new techniques/equipment available to users, improved feedback on the assignment of magnet time and scheduling experiments. To further increase the number of feedback forms, the EMFL facilities will actively stimulate the users to provide their feedback to the User Committee. Also, all User Committee members should automatically receive the feedback forms as they are filled out online. A revised online feedback form could include additional questions centered around scheduling experiments with the local contacts and assignment of magnet time.

EMFL membership

Representatives of research councils from various countries and the direction of the EMFL met in Brussels in February 2013 to discuss opportunities for new members to join the EMFL. Members of the EMFL will be able to shape the EMFL policy, including future developments and user access. In December 2015, the UK has officially become a member of the EMFL with the support (2015-20) of The Engineering and Physical Sciences Research Council (EPSRC), the UK's main agency for funding research in engineering and the physical sciences. Other users from other countries should try to engage with their research councils to discuss a possible membership as already done by the UK. A successful outcome of this membership will strengthen the EMFL and could also lay the basis for future funding opportunities within Horizon2020, which has identified high magnetic fields as a topical area for development of research infrastructures. As an immediate benefit of such membership all UK users will receive reimbursement for their travel and accommodation costs from EMFL.

Finally, the User Committee acknowledged the Board of Directors for arranging an excellent user workshop where both users and representatives of the EMFL reported on recent technological developments of high magnetic field infrastructures/equipment, scanning probe microscopy in high magnetic fields, magnetocaloric effects in pulsed fields, X-ray and neutron scattering, and research in topical areas ranging from graphene-like two-dimensional materials and heterostructures to novel material systems of fundamental and technological interest. This rich program was very well received by the User Community.

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