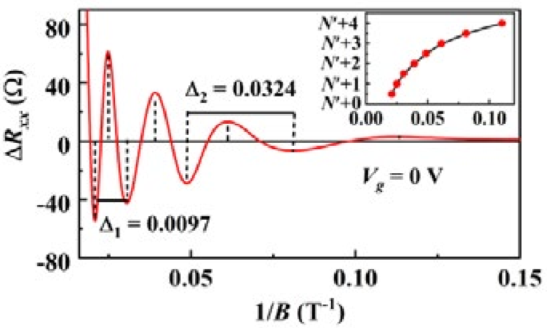
European Magnetic Field Laboratory

EMFLNEWS

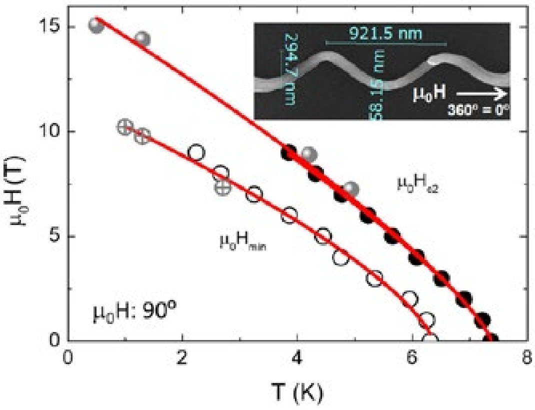
N°4 2019



cea SACLAY

DACM Département Accélérateurs Cryogénie Magnétisme

Irfu Institut de recherche sur les lois fondamentales de l'Univers



CONTENTS

DEAR READER

I hope all of you had an excellent start in 2020. All the best on behalf of the whole EMFL staff, for this new year and new decade, with lots of outstanding scientific results to come. This issue resumes the highlights of the last quarter of 2019, in which we were happy to welcome a new member to the EMFL family, the CEA-IRFU, and in which new and exciting high-magnetic-field results have been reported, as you will be able to read further on. We are also happy to announce a new EMFL initiative, the EMFL Hands-on workshop that will be organized at the EMFL Dresden site this summer, allowing newcomers to the high-field research area to acquire practical experience in high-field experiments. The workshop will be just after our annual User Meeting, also at EMFL Dresden, HZDR, and I am looking forward to seeing many of you there.

Geert Rikken, Director LNCMI, Chairman EMFL

MEET OUR PEOPLE

Sabrina Palazzese, HLD Dresden

I recently joined the Dresden High Magnetic Fields Laboratory (HLD) as a PhD student. During my diploma studies, I worked at the Low Temperatures Laboratory at the Venezuelan Institute for Scientific Research where the research is mainly focused on superconductivity in strongly correlated electron systems at very low temperatures and high pressures. In most of these systems, an antiferromagnetic phase arises in the low-temperature limit and under the presence of an external tunable parameter, such as pressure, doping, or magnetic field, this phase can be suppressed giving rise to superconductivity. Since then I have been fascinated by the underlying physics of matter under extreme conditions. This is why I find this opportunity of obtaining my PhD at the HLD very exciting as it would allow me to continue my research interests and being an active member of the scientific community.

Currently, we are studying the magnetic and electronic properties of single crystals of novel ternary rare-earth compounds with special crystalline structure. In order to study these compounds, we perform electrical-transport and magnetization measurements in which we submit our samples to high magnetic fields in a wide temperature range. This represents a challenge not only because of the experiment itself but also because the samples are extremely small and difficult to handle. The results obtained so far are very interesting as we've found many phase transitions and anisotropic magnetic behavior. It goes without saying that the most thrilling part of this investigation is to unravel the physical properties of novel compounds as there is plenty of new exotic phenomena that is not yet understood. For this reason, being part of the EMFL community and getting to meet people from other cultures and background is very important as it provides a different perspective through enriching conversations while stimulating new ideas for scientific research.

Sabrina Palazzese, HLD Dresden

THREADING FLUX THROUGH HELIXES

Rosa Córdoba, ICMol and Uli Zeitler, HFML Nijmegen

The fabrication and understanding of complex three-dimensional (3D) architectures on the nanoscale is one of the promising routes towards new schemes for a next generation of advanced electronic devices. This endeavor requires advanced new processing technologies, state-of-the-art structural and electronic characterization experiments, and cutting-edge theoretical models.

In this work, a team of researchers from Zaragoza, Paris, Madrid, Dresden, and Nijmegen has investigated the superconducting properties of 3D tungsten-carbide nanohelices. They were fabricated by means of He^+ focused-ion-beam (FIB) microscopy in combination with a precursor gas. The helices with pitches between 200 nm and 2.3 μm and diameters from 100 to 295 nm consist of nanowires as thin as 45 nm.

At temperatures below 7 K, these nanohelices display superconductivity with a large critical magnetic field (up to 15 T) depending on the direction of the field with respect to the helix axis. This suggest that the geometry of the helices and their orientation in a magnetic field play a significant role in the superconducting phase transition, which can be qualitatively explained using an approach for the properties of thin-film superconductors. In this respect, the results form an important starting point for a fully quantitative 3D modelling of superconducting nanohelices with dimensions comparable to or smaller than the superconducting penetration depth.

Eventually, as a more general perspective, the peculiar superconducting properties of novel nanostructures may then pave the way towards promising new device applications, such as sensors, energy-storage elements, and nano-antennas.

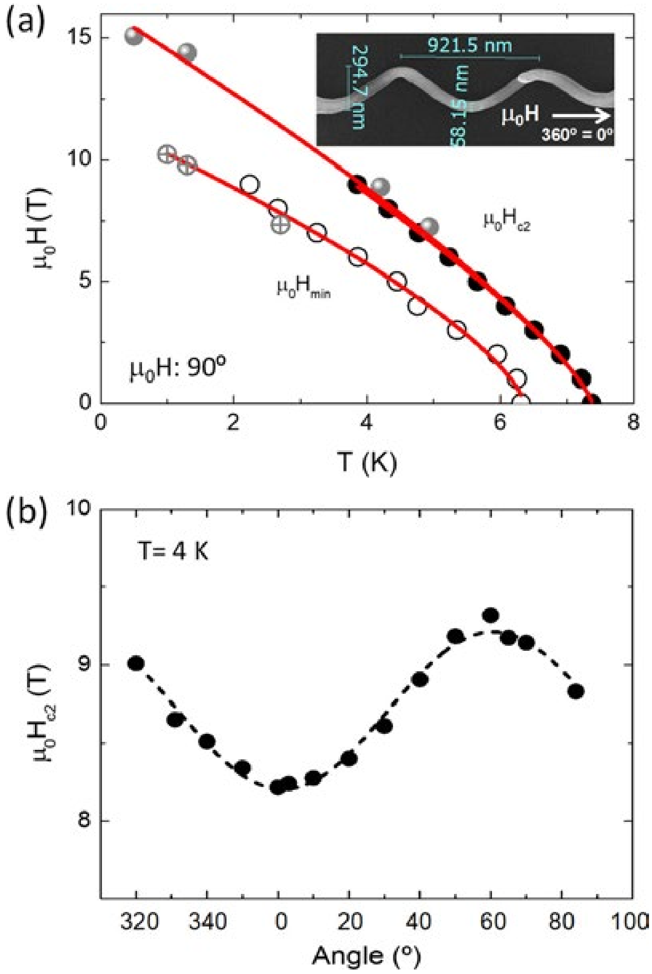


Figure: (a) Temperature dependence of the critical field of a tungsten-carbide nanohelix in a perpendicular magnetic field. The values for H_{c2} and H_{min} are determined from R vs. T and R vs. B sweeps as the points where the resistance reaches 90 % and 10 % of the normal-state resistance, respectively. The inset shows a scanning-electron micrograph of the structure. (b) Dependence of H_{c2} on the angle between the helix axis and the applied magnetic field at 4 K, see inset in (a).

Three-Dimensional Superconducting Nanohelices Grown by He⁺-Focused-Ion-Beam Direct Writing, R. Córdoba, D. Mailly, R. O. Rezaev, E. I. Smirnova, O. G. Schmidt, V. M. Fomin, U. Zeitler, I. Guillamón, H. Suderow, and J. M. De Teresa, Nano Lett. **19**, 8597 (2019).

Contact: uli.zeitler@ru.nl; rosa.cordoba@uv.es

NMR STUDY OF CHARGE-DENSITY WAVES UNDER HYDROSTATIC PRESSURE IN $YBa_2Cu_3O_y$

Igor Vinograd and Marc-Henri Julien, LNCMI-Grenoble

High-temperature superconductivity in the cuprates arises in close proximity to a charge density wave (CDW) phase. A challenge in the field is to understand how both phenomena compete and whether, behind pure competition, there is a more involved relationship between them. To tackle this question, various experiments have used temperature, magnetic field, hole-doping or uniaxial strain to tune the competition between CDW and superconducting phases. The effect of hydrostatic pressure, on the other hand, has been controversial, especially in the archetypal cuprate $YBa_2Cu_3O_y$, where high-field transport and zero-field x-ray scattering results have led to opposite conclusions.

In order to clarify this issue, we have used ^{17}O nuclear magnetic resonance (NMR) with the aim to study both the low-field (short-ranged) and high-field (long-ranged) CDW phases of $YBa_2Cu_3O_y$ under a pressure of 1.9 GPa.

The main finding of this study is that the amplitude of both the short-range CDW and the long-range CDW are, at most, weakly weakened at 1.9 GPa. Nonetheless, quantitative analysis, taking the pressure-induced change in doping into account, shows that both the NMR and transport data are actually compatible with the proposal by Taillefer and coworkers that the increase in T_c upon increasing pressure arises from a concomitant disappearance of the CDW phase on the scale of 10 to 20 GPa. As a matter of fact, we find a clear increase of the onset field for long-range CDW order at 1.9 GPa (see Figure) that closely matches the concomitant decrease in the superconducting upper critical field B_{c2}. This shows that pressure affects both the CDW and superconductivity on the same footing.

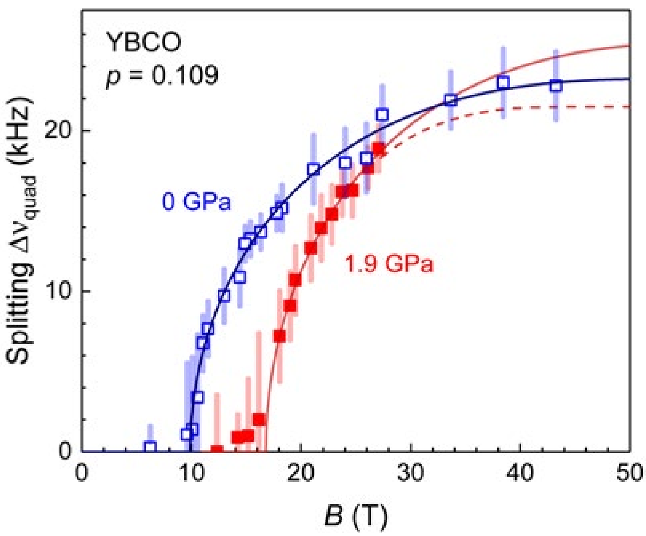


Figure: Field dependence of the quadrupole splitting (produced by long-range CDW order) at 3 K for 0 and 1.9 GPa for a hole doping of p = 0.109. Lines are fits to a BCS-like order parameter, with the dashed red line corresponding to a fit excluding the highest field point to visualize the uncertainty in the saturation value of the splitting.

Nuclear magnetic resonance study of charge density waves under hydrostatic pressure in $YBa_2Cu_3O_y$, I. Vinograd, R. Zhou, H. Mayaffre, S. Krämer, R. Liang, W. N. Hardy, D. A. Bonn, and M.-H. Julien, Phys. Rev. B **100**, 094502 (2019).

Contact: marc-henri.julien@lncmi.cnrs.fr, grvngrd@gmail.com

APERIODIC QUANTUM OSCILLATIONS IN THE TWO-DIMENSIONAL ELECTRON GAS AT THE $LaAlO_3/SrTiO_3$ INTERFACE

Walter Escoffier, Michel Goiran, LNCMI Toulouse and Km Rubi, HFML Nijmegen

The discovery of a two-dimensional electron gas (2DEG) at the interface between the two insulators $LaAlO_3$ (LAO) and $SrTiO_3$ (STO) has not only enhanced the expectations of oxide-electronics but has also brought new and exciting opportunities to explore the novel physics of 2DEG with unmapped parameters. First-principles calculations of the band structure reveal the occupancy of several non-degenerate sub-bands d_{xy}, d_{xz}, and d_{yz}, originating from crystal-field-split Ti 3d – t_{2g} orbitals; located at the interface or in its vicinity. The existence of many anisotropic and non-parabolic sub-bands, together with a large spin-orbit splitting at the crossing point of the d_{xy} and $d_{xz/yz}$ bands, provides a complex band structure which has received only partial support from transport experiments. In this study, we investigated the transport properties of a high-mobility quasi-2DEG at this interface under high magnetic field (55 T) and provided new insights in its electronic band structure by analyzing the Shubnikov-de Haas oscillations. Interestingly, the quantum oscillations are not periodic in 1/B and produce a highly non-linear Landau plot (Landau-level index versus 1/B). The aperiodic character of the oscillations entails the failure of standard Fourier-transformation data processing. Very low temperatures combined with high-field measurements are necessary to address the multi-band origin of the measured non 1/B-periodic oscillations. We explore several alternative scenarios, and in particular the generalized Onsager relation involving the magnetic response functions of the system. This study brings further evidence for a non-trivial band structure at the Fermi energy of this system, consistent with density-functional-theory calculations.

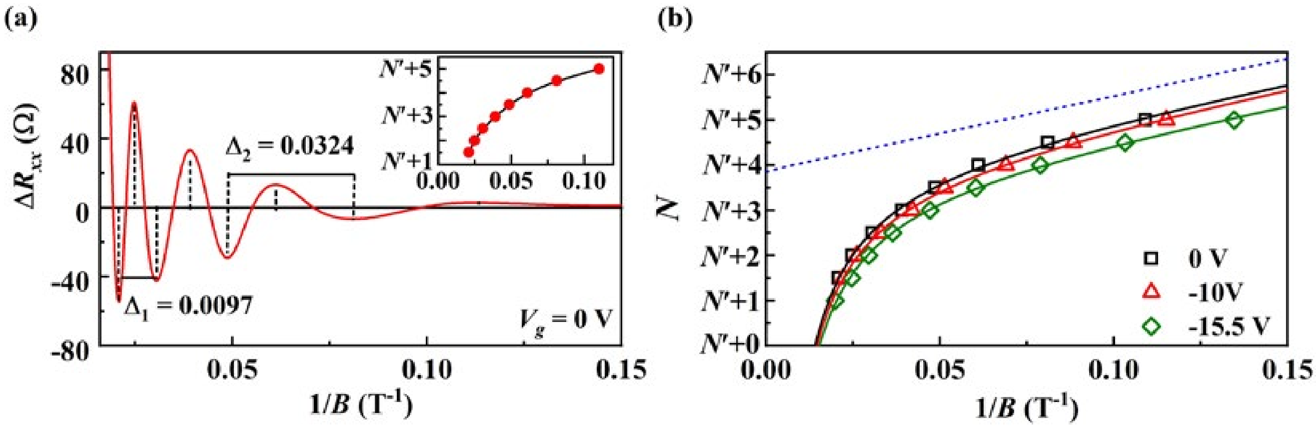


Figure: (a) Main panel: Inverse-field dependence of relative resistance oscillations, ΔR_{xx}, for zero gate voltage. Inset: Corresponding Landau plot. (b) Landau-level plots (symbols) for various gate voltages together with fits derived from the generalized Onsager relation (solid lines). The dashed line represents the asymptote for zero gate voltage. The index N is given within an integer offset N'.

Aperiodic quantum oscillations in the two-dimensional electron gas at the $LaAlO_3/SrTiO_3$ interface, K. Rubi, J. Gosteau, R. Serra, K. Han, S. Zeng, Z. Huang, B. Warot-Fonrose, R. Arras, E. Snoeck, Ariando, M. Goiran, and W. Escoffier, npj Quantum Mater. 5, 9 (2020).

Contact: walter.escoffier@lncmi.cnrs.fr

LOCALIZED VERSUS DELOCALIZED 5f ELECTRONS IN ANTIFERROMAGNETIC U_2Rh_2Sn

Denis Gorbunov, HLD Dresden

The physical properties of uranium-based intermetallic compounds depend strongly on the degree of localization of the 5f electrons. The extended character of the 5f states leads to a high sensitivity to external parameters. The pronounced spin-orbit interaction of uranium provides significant orbital polarization of the 5f states, strongly couples the direction of the uranium magnetic moments, and influences both the crystal and electronic structures. The direction of the uranium magnetic moments is determined by the bonding symmetry through a two-ion 5f-5f interaction, which often leads to extremely large anisotropy.

Usually, it is challenging to determine the degree of 5f electron localization. In a recent work, scientists from the Czech Republic, Japan, and Germany used a crystal-electric-field model to analyze their static- and pulsed-field magnetization and ultrasound data of U_2Rh_2Sn. The analysis strongly suggests that in this material the 5f electrons tend to be localized in the paramagnetic state.

U_2Rh_2Sn is a strongly anisotropic antiferromagnet with a Néel temperature of 25 K and uranium magnetic moments aligned along the [001] axis of the tetragonal crystal structure. For field applied along the easy direction, U_2Rh_2Sn shows a spin-flop-like transition at 22.5 T (Figure, panel a). The transition is accompanied by pronounced anomalies in the sound velocity as seen for the longitudinal, C_{11}, and transverse, C_{44}, elastic moduli in panel b of the figure. The sound velocity for C_{11} shows a sharp maximum at the magnetization jump followed by a broad minimum in the field range where the magnetization changes the slope. The sound velocity for C_{44} displays a step-wise softening at the transition and changes the slope near 30 T. The transition field decreases to zero upon approaching the Néel temperature (inset in panel a). Using their data in the paramagnetic state, the researchers determined the crystal-electric-field scheme. The analysis shows that quadrupolar interactions have to be taken into account to reproduce the field-dependent sound-velocity data.

Acoustic signatures of the phase transitions in the antiferromagnet U_2Rh_2Sn,
D. I. Gorbunov, A. V. Andreev, I. Ishii, K. Prokeš, T. Suzuki, S. Zherlitsyn, and J. Wosnitza, Phys. Rev. B **101**, 014408 (2020); Editors' Suggestion.

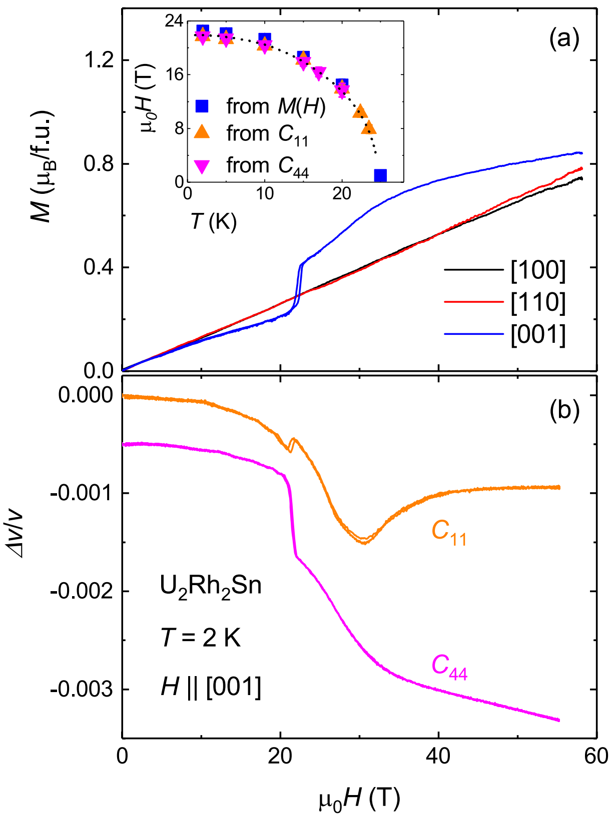


Figure: (a) Magnetization and (b) relative sound-velocity changes for the acoustic modes C_{11} and C_{44} measured in pulsed magnetic fields up to 58 T at 2 K. The inset in panel a shows the magnetic phase diagram for field applied along the [001] axis.

Contact: d.gorbunov@hzdr.de

RESULTS OF THE TWENTY-SECOND CALL FOR ACCESS

On November 15th, 2019, the 22nd call for access ended. Proposals for research activities requiring access to the large-scale high magnetic field facilities collaborating within EMFL were submitted to be ranked on a competitive basis.

Our four facilities

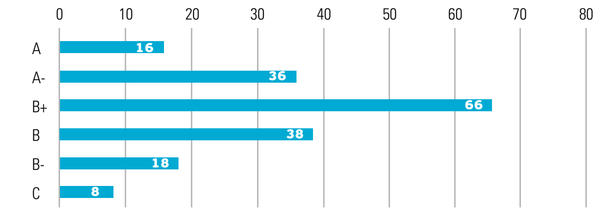
> LNCMI - Grenoble - France: Static magnetic fields to 36 T
> HFML - Nijmegen - the Netherlands: Static magnetic fields to 37.5 T
> HLD - Dresden - Germany: Pulsed magnetic fields to beyond 95 T
> LNCMI - Toulouse - France: Pulsed magnetic fields of long duration to over 90 T, and on the microsecond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

are open to users worldwide. EMFL operates a joint transnational access program, which grants 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 on site.

For this 22nd call, 182 applications from 25 different countries were received and evaluated by the EMFL selection committee until December 15th, 2019. The Selection Committee consists of 18 specialists covering the following five scientific topics:

> Metals and Superconductors (52 applications),
> Magnetism (74 applications),
> Semiconductors (43 applications),
> Soft Matter and Magnetoscience (8 applications),
> Applied Superconductivity (5 applications).

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



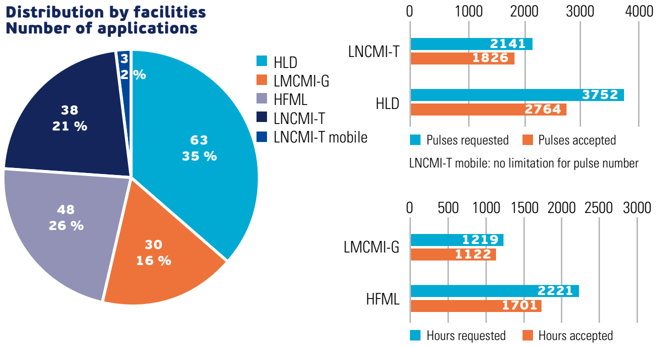
Evaluation of applications

The proposals are ranked in three classes:

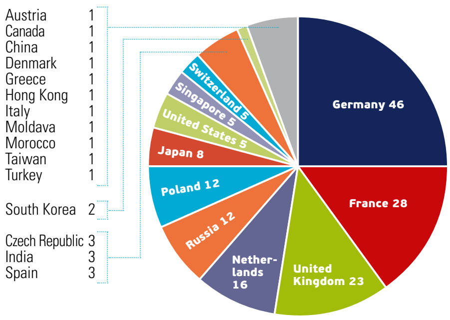
A (excellent proposal to be carried out),
B (should be performed but each facility has some freedom considering other constraints),
C (poorly crafted proposal, or one that does not need any of the four unique high-magnetic-field laboratories).

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

Distribution by facilities
Number of applications



Distribution by country of PI affiliation



NEXT CALL :
Launch: April 15th, 2020
Deadline: May 15th, 2020

CEA-IRFU NEWEST MEMBER OF THE EUROPEAN MAGNETIC FIELD LABORATORY

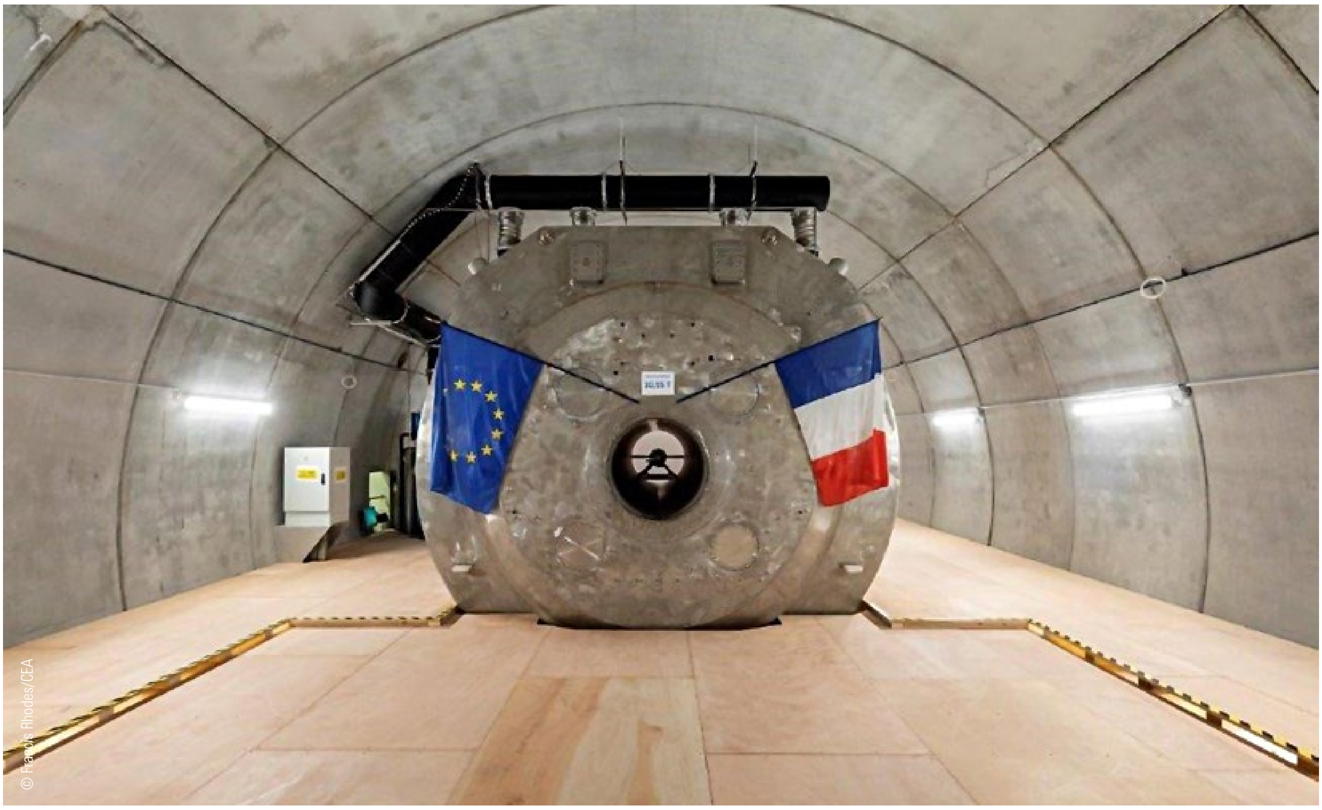
The French Alternative Energies and Atomic Energy Commission (CEA) institute of Research into the Fundamental Laws of the Universe (IRFU) located in Paris-Saclay has joined EMFL, starting December 1st, 2019. The membership is a logical next step in the collaboration of CEA-IRFU and EMFL. Both have already applied together for several EC grants for magnet-technology developments.

The CEA-IRFU has a longstanding involvement and experience in the development of high-field/high-volume superconducting magnets. CEA-IRFU is, therefore, interested in strengthening its links with the EMFL facilities to develop the next generation of superconducting high-field magnets.

Dr. Pierre Vedrine, the head of the Accelerator, Cryogenics, and Magnetism Department (DACM): "EMFL and CEA-IRFU have complementary skills in the area of magnet technology, enabling to collect the scientific needs and to be able to provide the necessary tools for advances in fundamental and applied research."

Dr. Rikken (chair of the EMFL board of directors): "Our scientific and technical collaboration with CEA-IRFU has always been very strong. This membership of CEA-IRFU is a consolidation of our longstanding relationship"

Dr. Pierre Vedrine will be representing CEA-IRFU in the EMFL Council.



Iseult, a whole-body 11.7 T MRI magnet, is an actively shielded magnet manufactured from NbTi superconductor, with a homogeneous field provided in a 90 cm warm bore.

EMFL EXCHANGE PROGRAM 1: VISITING HLD FROM BARCELONA

Tino Gottschall, HLD Dresden

The last two month of 2019 saw one of the first scientific secondments funded by the newly implemented exchange program of the EMFL. PhD student Adrià Gràcia-Condal from the University of Barcelona came to visit the HLD at the Helmholtz-Zentrum Dresden-Rossendorf for one month. Funded by EMFL, expenses for travelling and accommodation were supported with a lump-sum payment of 2.000 €.

The scientific purpose of the visit was to design, to manufacture, and to assemble a new uniaxial-load cell for the use in pulsed magnetic fields. With the new insert, direct measurements of the adiabatic temperature change of materials in magnetic field pulses up to 70 T are now feasible, enabling to study the influence of uniaxial loads up to 100 MPa in a constant force regime. The temperature change during a pulse is determined via ultrathin thermocouples, and the mechanical stress is detected by use of a piezo sensor. Furthermore, the displacement of the sample is measured with a strain gauge that is attached to the surface. First measurements were successfully performed. Likewise, the visit succeeded to intensify the collaboration established before, namely between the University of Barcelona and HLD.

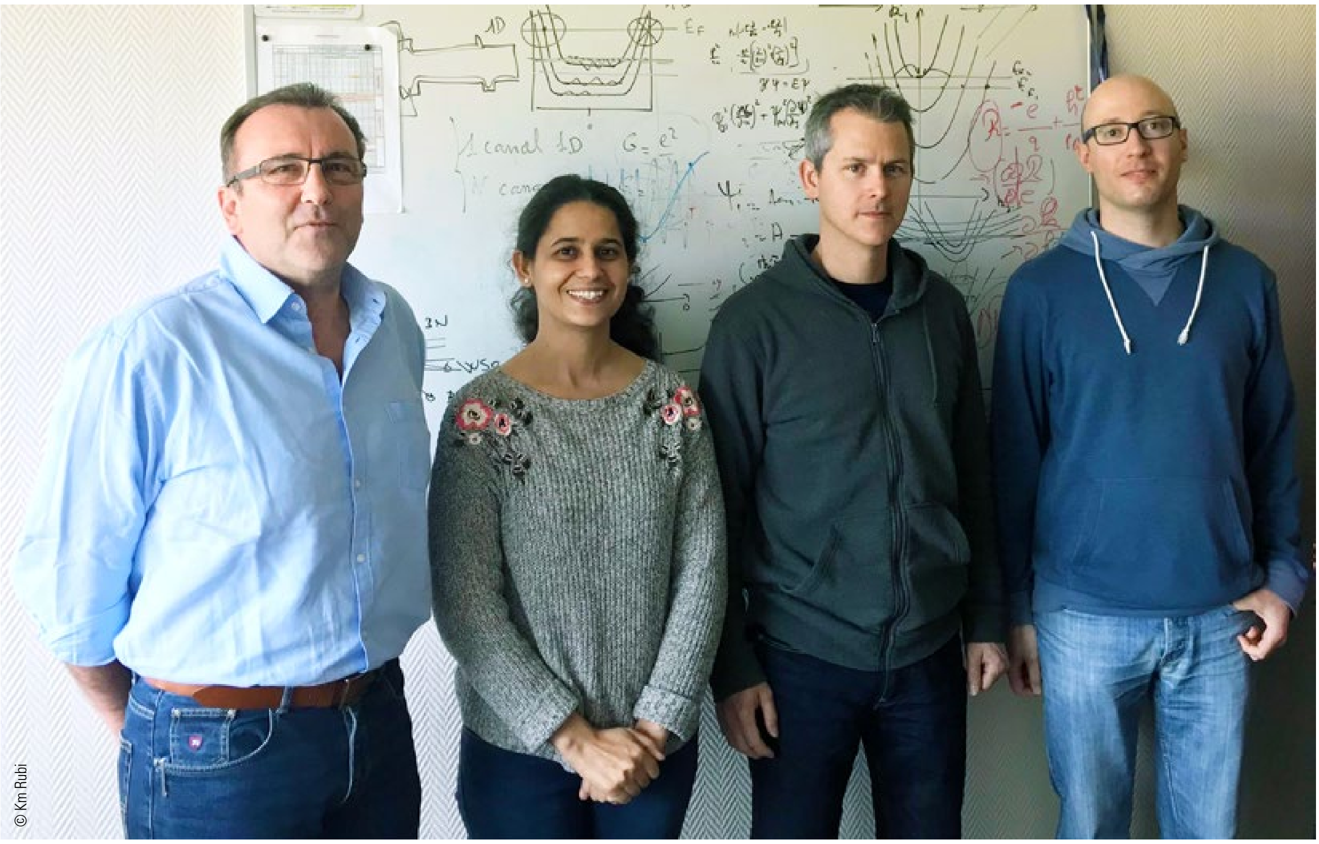
› From left to right: Tino Gottschall, Adrià Gràcia-Condal, and Eduard Bykov while inspecting the new measuring device, before submitting it to first pulsed-field experiments.

EMFL EXCHANGE PROGRAM 2: VISITING LNCMI-TOULOUSE FROM NIJMEGEN

Km Rubi, HFML Nijmegen

In order to extend the field range (0 - 30 T) of the data measured at HFML-Nijmegen, I performed magnetotransport measurements on an ionic-liquid gated two-dimensional electron gas (2DEG) at complex oxides interface in pulsed magnetic fields up to 60 T and at temperatures down to 350 mK at LNCMI-Toulouse. These complementary data will certainly help to better understand the complex quantum-oscillation spectra in the 2DEG at oxide interfaces. Apart from the measurements, I had the opportunity to discuss the obtained results and strategies for common publications with the LNCMI team, including Dr. Walter Escoffier and Prof. Michel Goiran, as well as with Dr. Ariando from the National University of Singapore. Since I worked as a postdoctoral researcher at LNCMI-Toulouse in 2018, the EMFL exchange program gave me the excellent opportunity to utilize my pulsed-field expertise and to deepen the ongoing collaboration with my former colleagues.

From the technical point of view, it has been a great and unique experience to perform electrical-transport experiments in both pulsed and DC field facilities since these installations involve different equipment, such as dedicated probes, sample holders, and electrical devices for the measurements. My exchange visit contributed meaningfully to an optimization of future combined magnetotransport measurements in pulsed and continuous magnetic fields. As an immediate result of my work, we submitted an EMFL magnet-time proposal to HMFL Nijmegen.



Km Rubi with the "Nano-objects and Semiconducting Nano-structures" group at LNCMI-Toulouse during her EMFL exchange visit. From left to right: Prof. Michel Goiran, Dr. Km Rubi, Dr. Walter Escoffier, and Dr. Mathieu Pierre.

EMFL HANDS-ON WORKSHOP

What is it about?
Learn and improve your practical skills in cryogenics, vacuum technology, and measurement techniques in magnetic fields.

For whom?
Master and PhD students in physics or materials science at the beginning of their doctoral thesis.

When?
17th and 18th of June 2020, just after the EMFL User Meeting

Where?
The workshop is organized by the Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany.

How to apply?
Submit your application form to emfl-workshop@hzdr.de until 17th of April 2020. The informal application should contain all essential information, like affiliation, supervisor, and reason for applying.

What does it cost?
The workshop is free of charge. The number of participants is limited!

Wednesday – 17.06.2020		Thursday – 18.06.2020	
9:00	Welcome and Introduction	9:00	Seminar III
9:15	Seminar I	10:00	Practical Session III
10:15	Practical Session I	12:30	Lunch
12:45	Lunch	13:15	Seminar IV
13:30	Seminar II	14:15	Practical Session IV
14:30	Practical Session II	16:45	Closing Remarks
18:00	Dinner and Podium Discussion	17:00	Departure

UPCOMING EVENTS

1. Gordon Research Conference: Topology and Correlations: Long-Range Entanglement in Many-Body Systems, Massachusetts, USA, June 28 – July 3, 2020.
https://www.grc.org/correlated-electron-systems-conference/2020/

2. Joint European Magnetic Symposia (JEMS), Lisbon, Portugal, July 27-31, 2020.
https://www.jems2020.com/

3. International Conference on Strongly Correlated Electron Systems (SCES 2020), Guarujá, Brazil, September 20-25, 2020.
https://sces2020.org/

4. International Conference on Magnetism (ICM), Shanghai, China, July 4-9, 2021.
http://www.icm2021.com/

HFML
Radboud Universiteit Nijmegen
Toernooiveld 7
6525 ED Nijmegen
The Netherlands
www.ru.nl/hfml

Centre National de la Recherche Scientifique (CNRS)
LNCMI Toulouse
143 avenue de Rangueil
31400 Toulouse
France

Centre National de la Recherche Scientifique (CNRS)
LNCMI Grenoble
25 rue des Martyrs, B.P. 166
38042 Grenoble cedex 9
France

Helmholtz-Zentrum Dresden-Rossendorf (HZDR)
Dresden High Magnetic Field Laboratory
Bautzner Landstrasse 400
01328 Dresden
Germany
www.hzdr.de/hld

IMPRINT

Publisher / Contact:
Helmholtz-Zentrum Dresden-Rossendorf
Bernd Schröder
Phone: +49 351 260-2711
Email: b.schroeder@hzdr.de
contact@emfl.eu

Editorial Staff:
EMFL Board of Directors, Christine Bohnet, Martin van Breukelen, Benjamin Piot, Bernd Schröder, Larysa Zviagina

Responsible for the content:
Peter Christianen (peter.christianen@ru.nl), Geert Rikken (geert.rikken@lncmi.cnrs.fr), Joachim Wosnitza (j.wosnitza@hzdr.de)

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

Printing:
reprogress GmbH

Layout:
Pfefferkorn & Friends, www.pfefferkornundfriends.de

EMFL News, the newsletter of the European Magnetic Field Laboratory, is published quarterly.
Printed on FSC-certified paper.

ISSN 2196-0909
4/2019
www.emfl.eu