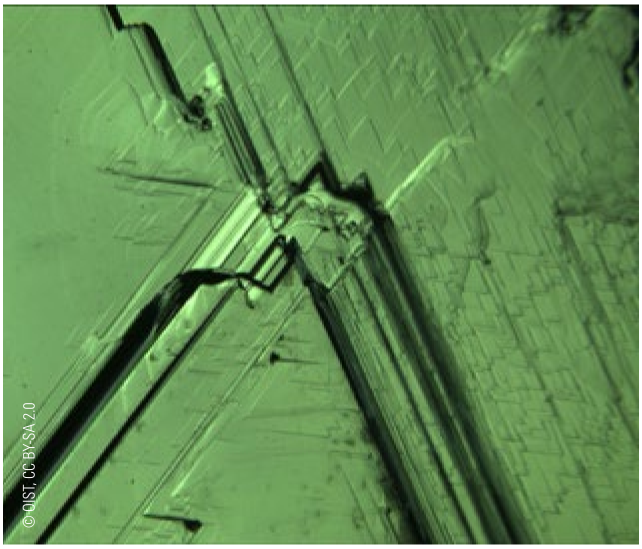
European Magnetic Field Laboratory

EMFLNEWS

N°3 2019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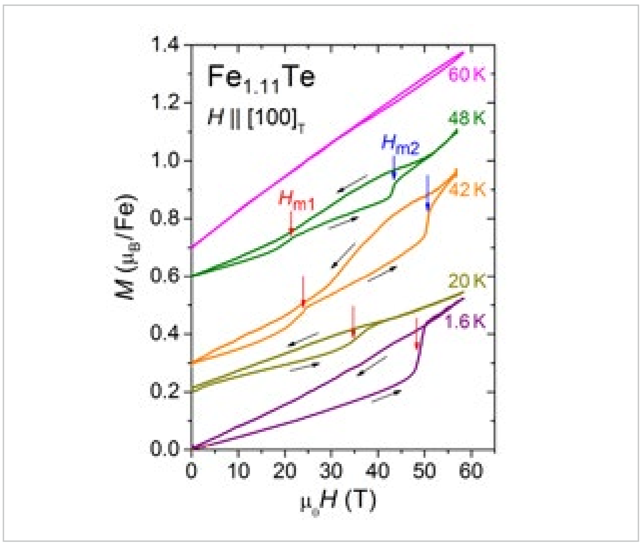

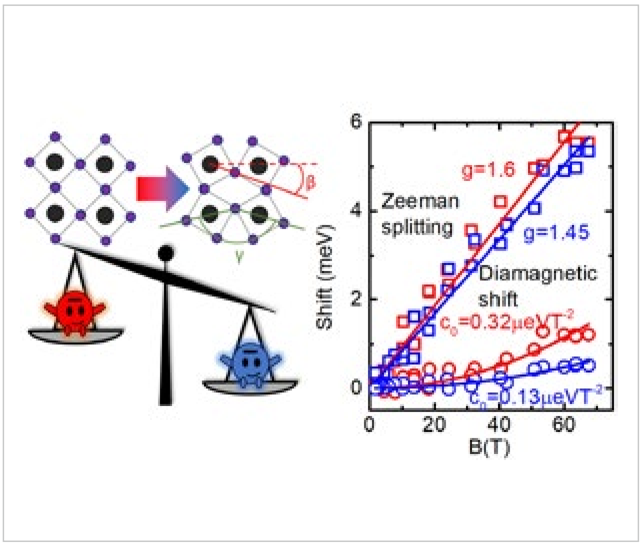

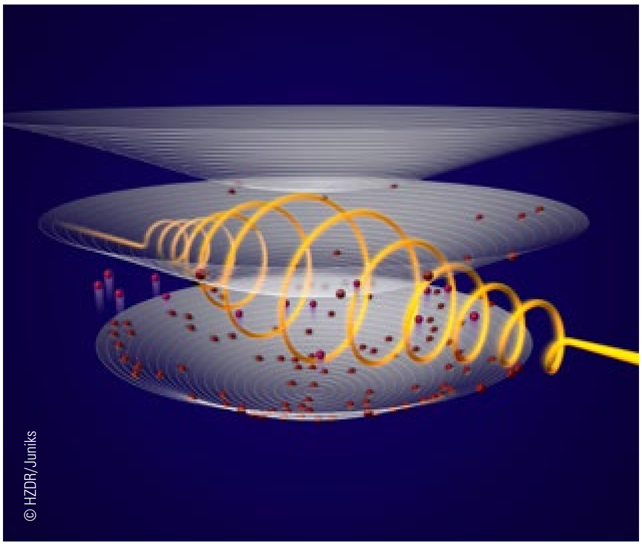
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DEAR READER

This first EMFL Newsletter after the vacation season is again filled with highlights that illustrate the good shape that European high-field research is in. The new call for proposals that has just opened will undoubtedly lead to new highlights that we will inform you of in the future.

We have also been working hard to improve the EMFL website and I hope that you will soon be able to judge the result for yourself. During the successful EMFL summer school in Arles last year, several participants suggested that, in addition to the theoretical course on research in high magnetic fields, EMFL should also provide hands-on training for new users of its installations. Therefore, we will organize next year, coupled to the 2020 EMFL User Meeting, to be held in Dresden in June, a practical course on high magnetic field measurements.

Geert Rikken, Director LNCMI, Chairman EMFL

MEET OUR PEOPLE

Florent Durantel, LNCMI-Toulouse

I joined the LNCMI Toulouse last September, but I am not completely new, as I made a short stay in this laboratory quite a long time ago now! At that time, together with Loic Drigo, we developed a contactless measurement method in pulsed fields, and it was quite nice to see that this method is still used today, with some improvements of course. After that, I have worked for more than 10 years with fast heavy ions at GANIL (Grand Accélérateur National d'Ions Lourds, Caen, France), in the CIMAP (Center of Research on Ions, Materials and Photonics) laboratory, where I was beam coordinator and head of the Interdisciplinary Research Platform, which welcomes a wide range of researchers, from atomic physics, through solid-state physics to biology. I also worked on the design of different particle detectors and on dosimetry methods for radiobiology and carbon hadron therapy. And finally, I have been strongly involved in developments of time-resolved methods for ion-beam-induced luminescence (TR-IBIL).

Today, I am delighted to find within EMFL the same atmosphere of large facilities and a strong network rich in collaborations between its laboratories. In my current position, I will continue to work on experiment management and I will continue to focus on instrumental and experimental development. And who knows, one day I may be able to combine intense magnetic fields and ion beams.

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› Florent Durantel, LNCMI Toulouse

CYCLOTRON EMISSION FROM MASSLESS KANE ELECTRONS

Milan Orlita, LNCMI-Grenoble

When a magnetic field is applied to a solid, the continuous density of electronic states transforms into a set of discrete energy levels, known as Landau levels. Electrons excited in such a ladder may recombine, with emission of photons. This process can be viewed as the inverse of a cyclotron resonance and it is referred to as 'cyclotron emission'. The idea to construct a Landau-level laser via stimulated cyclotron emission is as old as the experimental realization of the very first laser itself, and wavelength tunability is the great advantage of this concept. The strength of the magnetic field defines the spacing between Landau levels, and, therefore, also the emission frequency of the laser. This frequency typically corresponds to the far-infrared (THz) spectral range. The successful realization of a Landau-level laser would thus bridge the so-called terahertz gap, which still exists despite the considerable efforts of several generations of physicists. So far, however, despite many efforts, this appealing concept never progressed to the design of a reliable device. This is because of the efficient Auger scattering of Landau-quantized electrons, an intrinsic non-radiative recombination channel that eventually gains over cyclotron emission in all materials studied so far (conventional semiconductors with parabolic bands, but also in graphene with massless electrons). Auger processes are favored in these systems because the Landau levels (or their subsets) are equally spaced in energy.

Recently, researchers from Grenoble, Dresden, Montpellier, and Novosibirsk have explored the Auger processes and cyclotron emission in gapless HgCdTe, a ternary compound with three-dimensional massless Kane electrons. They find that the unwanted Auger processes are significantly suppressed and the lifetime of excited Landau-quantized massless Kane electrons reaches the nanosecond range. It is thus, under comparable conditions, by two or three orders of magnitude longer than for electrons in graphene or conventional semiconductors. The difference is related to the particular spacing of the Landau levels in gapless HgCdTe, which does not include subsets of equidistant levels (for low-energy Landau levels). Consistently with this finding, profound (spontaneous) cyclotron emission from massless Kane electrons has been observed. Systems hosting massless Kane electrons are thus promising candidates for the active medium of a Landau-level laser, which would, in this particular case, operate in the THz and infrared spectral ranges and would be widely tunable by very low magnetic fields.

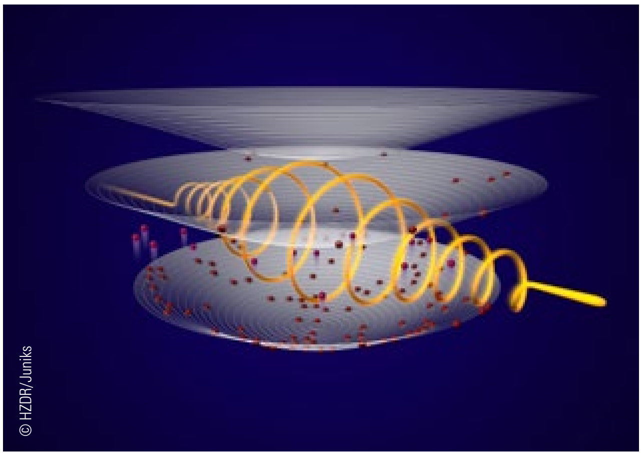
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Figure: Artist view of cyclotron emission from Landau-quantized massless Kane electrons.

Suppressed Auger scattering and tunable light emission of Landau-quantized massless Kane electrons, D. B. But, M. Mittendorff, C. Consejo, F. Teppe, N. N. Mikhailov, S. A. Dvoretskii, C. Faugeras, S. Winnerl, M. Helm, W. Knap, M. Potemski, and M. Orlita, Nature Photonics **13**, 783 (2019).

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NEGATIVE THERMAL EXPANSION IN A MAGNETICALLY FRUSTRATED SPINEL

Lisa Rossi and Ben Bryant, HFML Nijmegen

Frustrated magnets are materials with competing spin interactions, which cannot be simultaneously satisfied. While these materials have become most famous as a playground for novel phases, such as quantum spin liquids, they also exhibit technologically relevant properties, such as multiferroicity and an enhanced magnetocaloric effect. Negative thermal expansion (NTE) is another unusual phenomenon observed in frustrated magnets, which means that the crystal expands as it cools and which might provide a route for the control of thermal expansion necessary to ensure the performance of high-precision devices.

If there is a strong coupling between the spin and lattice degrees of freedom, the interplay between magnetic field and spin-lattice coupling produces a range of phases in which frustration is partially relieved, an effect known as “order by distortion”. A paradigm for this type of behavior is provided by Cr spinels, which exhibit many different magnetically ordered phases as a function of magnetic field. Many of these systems exhibit NTE, including the spinel $CdCr_2O_4$ in zero magnetic field. This suggests that the unusual thermodynamic behavior may have a common origin; however, to date there is no general understanding of this phenomenon or how it is linked to spin-lattice coupling. Moreover, to obtain a complete picture of NTE in spinels, high-precision measurements are also needed for the ordered phases induced by the magnetic field.

We examined the thermal expansion and magnetostriction of $CdCr_2O_4$ in magnetic fields up to 30 T. The results were used to determine the respective phase diagram, which we matched to that derived from a microscopic model of spin-lattice coupling. We found that the high-field, half-magnetization plateau phase exhibits enhanced thermal stability compared to theory, characteristic of a strong spin-lattice coupling in this phase. This state also shows a marked NTE, distinct from that observed in zero field (Figure). Starting from the same model of spin-lattice coupling, we developed a microscopic theory of this NTE and identified its origin as being a band of nearly localized magnetic excitations. These results provide a general framework for modeling and predicting NTE in pyrochlore lattices and in frustrated magnets in general.

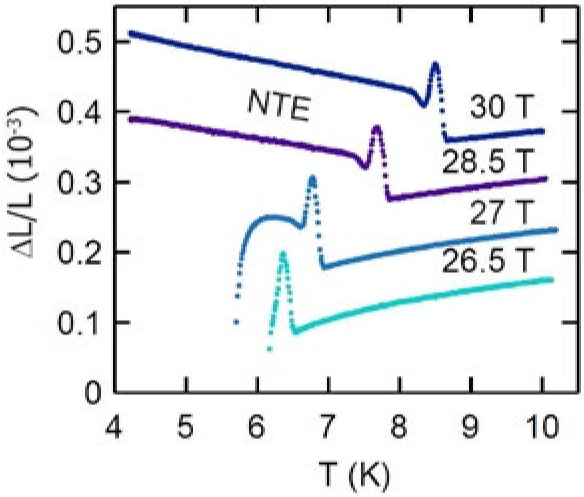

Figure: Thermal-expansion measurements from 4.2 to 10.4 K in fields up to 30 T, measured on warming, showing transitions from a paramagnetic state to a half-magnetization plateau state and the presence of NTE in the plateau state above 27 T.

Negative Thermal Expansion in the Plateau State of a Magnetically Frustrated Spinel, L. Rossi, A. Bobel, S. Wiedmann, R. Küchler, Y. Motome, K. Penc, N. Shannon, H. Ueda, and B. Bryant, Phys. Rev. Lett. **123**, 027205 (2019).

Contact: Lisa.Rossi@ru.nl

PHASE-TRANSITION-INDUCED CARRIER-MASS ENHANCEMENT IN 2D RUDDLESDEN–POPPER PEROVSKITES

Michal Baranowski and Paulina Plochocka, LNCMI-Toulouse

Organic-inorganic halide perovskites have become the “next big thing” in emerging semiconductor materials, with their unprecedented rapid development and successful application in high-performance photovoltaics. Yet, their inherent instabilities with respect to moisture remain a crucial challenge for these materials. This directed the interest of the scientific community to perovskite derivatives such as two-dimensional (2D) perovskites. These materials are significantly more stable and possess higher tunability of their properties which expands the field of their application from energy harvesting through LED to single-material-white-light emitters.

The 2D perovskites are often regarded as perfect quantum wells, because they are not plagued by interfacial roughness or intermixing characteristics of epitaxially grown quantum wells. The well layers consist of planes of lead-halide octahedra, separated by organic spacers. The research of these natural perovskite quantum wells is in its infancy and their structural, dielectric, optical, and excitonic properties remain to be explored, in particular the influence of organic spacers. Although the band-edge states are composed of lead and halide orbitals, the organic ligands affect the band structure and the electron-phonon coupling, via distortion of the octahedral cages. The optical properties of these materials are dominated by strong electron-hole attraction, resulting from dielectric confinement. Very often these materials exhibit complex absorption and emission spectra with many sidebands. Their origin generates much controversy since they can be attributed to phonon replicas or to bound excitonic states. We address this issue for $(C_nH_{2n+1}NH_3)_2PbI_4$ (with n = 4, 6, 8, 10, 12) by means of optical spectroscopy in magnetic fields up to 67 T. We show that the complex absorption features shift parallel in magnetic field, indicating the phonon-related nature of the observed side bands. Moreover, we have found that the diamagnetic shifts of the high- and low-temperature crystal phases of the investigated materials are significantly different (Figure), pointing to a notable modification of the carrier effective mass and/or dielectric screening upon the phase transition into the low-temperature phase, entailing an octahedral distortion. Since the phase transition occurs close to room temperature, our results provide an additional way for 2D perovskite engineering via moderate cooling achievable by Peltier coolers.

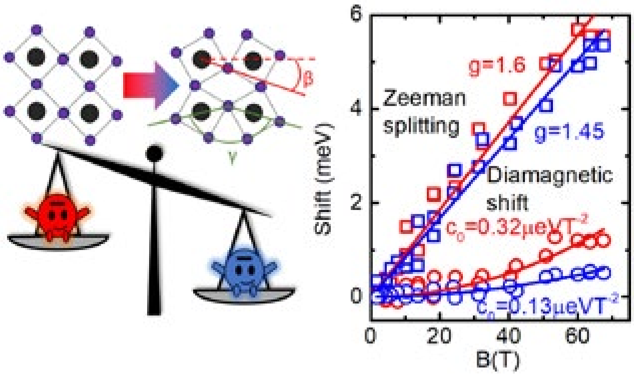

Figure: Zeeman splitting and diamagnetic shift of the high- and low-temperature phase of the crystals with n = 8.

Phase-Transition-Induced Carrier Mass Enhancement in 2D Ruddlesden–Popper Perovskites, M. Baranowski, S. J. Zelewski, M. Kepenekian, B. Traoré, J. M. Urban, A. Surrente, K. Galkowski, D. K. Maude, A. Kuc, E. P. Booker, R. Kudrawiec, S. D. Stranks, and P. Plochocka, ACS Energy Letters **4**, 2386 (2019).

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MAGNETIC SHAPE MEMORY EFFECTS AND MAGNETO-STRUCTURAL COUPLING IN $Fe_{1+y}Te$

S. Rößler, S. Wirth, MPI CPfS Dresden and Y. Skourski, HLD Dresden

In recent years, the iron chalcogenides received considerable attention in the condensed-matter physics community which was mainly sparked by the discovery of superconductivity below $T_c \approx 8.5$ K in bulk FeSe. The binary sister compound $Fe_{1+y}Te$ is not superconducting, yet an interesting material in its own right, exhibiting several unusual structural and magnetic phase transitions. Recently, researchers from different institutions in Dresden found two different types of magnetic shape memory effects in this enigmatic compound. Such effects are extraordinary phenomena referring to a change in shape and/or size of a magnetic material upon applying a magnetic field. These effects emerge from either a persistent de-twinning of a twinned magnetically ordered material, in which the crystallographic axes are irreversibly reoriented by the applied magnetic field, or a magneto-elastic phase transition driven by an external magnetic field. Typically, these effects are observed in ferromagnetic materials with strong spin-lattice couplings, and the two types are rarely found in the same material. Conventional shape memory alloys have found a tremendous number of applications in biomedical, technological, domestic, and textile industries. The magnetic analogues are increasingly gaining interest due to potential applications in magnetic actuators or sensors.

However, magnetic shape memory effects are not commonly observed in antiferromagnets, and the exact mechanisms driving the effects are not well understood. Therefore, the identification of a new class of materials where these types of transformation in crystalline solids can be observed is expected to provide new and much-desired insight. The experimental results clearly indicate that the two above-mentioned magnetic shape memory effects take place in the low-temperature antiferromagnetic phase of the material $Fe_{1+y}Te$ ($y = 0.11, 0.12$). The antiferromagnetism of the monoclinic ground state allows for a magnetic-field-induced reorientation of the twin variants by the motion of one type of twin boundary, as evidenced by jumps in the magnetization (Figure) and magnetostriction measured along certain crystallographic directions in high applied magnetic fields.

At even higher magnetic fields, a second transition is observed, e.g., at about 52 T at 1.6 K for $Fe_{1.12}Te$. This second transition is isotropic in nature, which calls for a different underlying mechanism. Yet, its irreversible behavior also indicates a memory effect. Accompanying density functional theory (DFT) calculation allowed us to estimate the strength of the magnetocrystalline anisotropy and the direction of the magnetic easy axis.

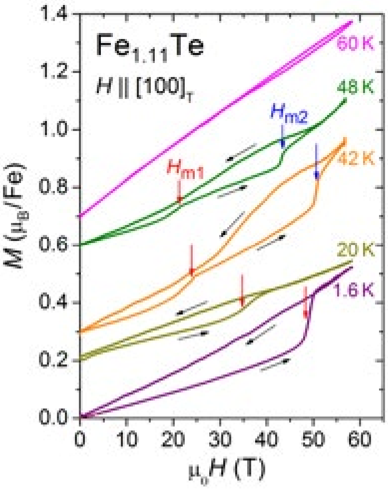

Figure: Magnetization measurements up to 60 T on a $Fe_{1.11}Te$ single crystal at different temperatures. At T = 1.6 K, a jump is observed at H_{m1} (red arrows) which is not seen in the curve for decreasing field, consistent with a magnetic shape memory effect. H_{m1} shifts to lower magnetic fields as T is increased. At 42 K and higher, a second transition H_{m2} is found (blue arrows). In the paramagnetic phase above 57 K, the transitions are no longer observed. Black arrows indicate the direction of the field sweep.

Two types of magnetic shape memory effects from twinned microstructure and magneto-structural coupling in $Fe_{1+y}Te$,
S. Rößler, C. Koz, Z. Wang, Y. Skourski, M. Doerr, D. Kasinathan, H. Rosner, M. Schmidt, U. Schwarz, U. K. Rößler, and S. Wirth, Proc. Natl. Acad. Sci. USA **116**, 16697 (2019).

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OPENING OF THE CALL FOR ACCESS NO. 22

The 22nd call for proposals has been launched on October 15, 2019, 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 38 T
- HLD - Dresden - Germany: Pulsed magnetic fields to beyond 90 T
- LNCMI - Toulouse - France: Pulsed magnetic fields of long duration to beyond 99 T and on the microsecond scale to beyond 200 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

Please note that each experiment carried out on our high magnetic field installations must be followed up by a progress report and your publication record filled out online on the EMFL website. Please be aware that this information will also be made available to the Selection Committee.

To further improve our user program, your feedback to the User Committee is highly appreciated.
Please find the form on the EMFL website.
https://emfl.eu/SelCom/UserCommittee/feedbackform.php

The next deadline for proposals for magnet time is November 15, 2019.
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).“ UK users should, in addition, add “A portion of this work was supported by the Engineering and Physical Sciences Research Council (grant no. EP/K016709/1).“

- 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.

VISCOSITY MEASUREMENTS IN PULSED MAGNETIC FIELDS

Toshihiro Nomura and Sergei Zherlitsyn, HLD Dresden*

A quartz-crystal microbalance (QCM) is an ultrasensitive device to detect changes of the mass. When an external mass is coupled to the surface of the quartz micromembrane, the resonance frequency f_0 of the QCM decreases. Owing to the high quality factor, Q, of the QCM, a relative frequency change of 10^{-9} can be resolved. Immersed in liquid, the QCM oscillates still in resonance, but with significantly decreased f_0 and Q. This reduction is proportional to $(\rho\eta)^{0.5}$, where ρ is the mass density and η is the shear viscosity of the liquid. Thus, the QCM is a useful device to investigate the viscous properties of liquids with high resolution.

Viscosity measurements using a QCM in combination with pulsed magnetic fields were developed at the HLD (Figure). In these experiments, we use a commercial AT-cut quartz resonator chip (thickness-shear mode). The advantages to use a commercial chip are the following. First, the QCM is relatively stable and robust against mechanical vibrations and turbulences in liquid. Second, it has high f_0 and Q, leading to higher sensitivity. Here, a high f_0 is favorable for a high repetition rate as well. Third, the QCM is relatively small and cheap.

During the magnetic-field pulse, f_0 and Q of the QCM are measured using a ring-down dissipation monitoring technique, by which we can simultaneously monitor both quantities with a repetition rate of 10 kHz. In this technique, the QCM is intermittently excited by an RF generator. Even after the RF generator is switched off, the mechanical oscillation of the QCM persists with exponential decay. This residual oscillation directly reflects the resonant properties of the QCM, characterized by f_0 and Q. The typical resolution of $(\rho\eta)^{0.5}$ is 0.5 %. As a benchmark, the viscosity of liquid oxygen was measured up to 55 T.

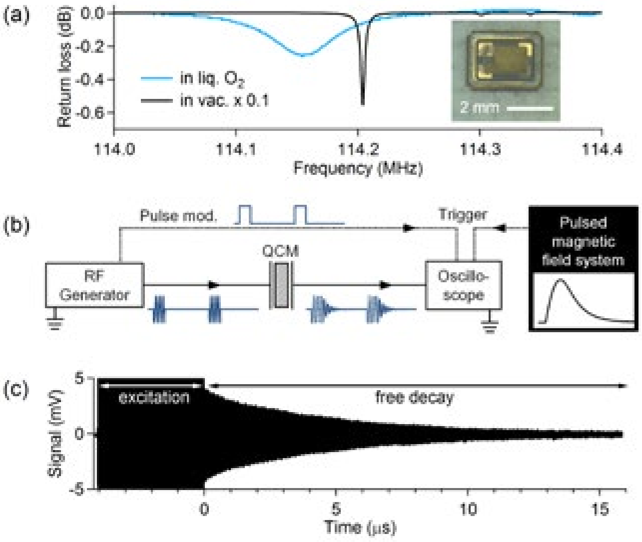

Figure: (a) Return loss spectra of the QCM in liquid oxygen (cyan) and in vacuum (black).The photograph shows the used QCM. (b) Schematic diagram of the ring-down measurement. (c) Typical free-decay curve of the QCM, which is fitted by an exponentially damped sinusoid.

Viscosity measurements in pulsed magnetic fields by using a quartz-crystal microbalance, T. Nomura, S. Zherlitsyn, Y. Kohama, and J. Wosnitza, Rev. Sci. Instrum. **90**, 065101 (2019).

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HFML-FELIX: OFFICIAL OPENING COMBINED BUILDING

The combined building of the HFML and the FELIX Laboratory has been officially opened on July 8, 2019. Ingrid van Engelshoven, Minister of Education, Culture and Science, officiated the opening.


© Dick van Aalst

From left to right: Prof. Han van Krieken (Rector, RU), Dr. Britta Redlich (Director FELIX Laboratory), Minister Ingrid van Engelshoven (OCW), Prof. Peter Christianen (Director HFML), Prof. Lutgarde Buydens (Dean FNWI, RU), Prof. Niek Lopes Cardozo (NWO), Dr. Wilma de Koning (University Board, RU), Dr. Iwan Holleman (Director FNWI, RU), Prof. Daniël Wigboldus (President of the University Board, RU).

The very powerful magnets and free-electron lasers of the large-scale infrastructures draw scientists from around the world who want to study the properties and functions of matter. No other facility offers both static high magnetic fields and intensive (far) infrared light at a single location.

Groundbreaking discoveries are already made in the separate laboratories. Using the powerful magnetic field at HFML, Konstantin Novoselov and Andrei Geim were the first to discover the 2D material graphene. A Nobel Prize-winning, fundamental discovery that paved the way to new types of electronics. The strong laser light at FELIX plays a crucial role in the mapping of chemical processes and molecular structures, among others. An example is the study into new biomarkers that help physicians in the tracking of various diseases.


© Dick van Aalst

The combined HFML-FELIX building.

The laser light reaches the magnets from the laser basement through an 86-meter vacuum pipe, in which it is directed by 41 gilded mirrors. “Getting this to work was a huge challenge,” says HFML Director Peter Christianen. “It is a new combination of technology, and we, therefore, had to come up with everything ourselves, make it or have it made, test it, double check: am I measuring what I want to measure, or do I have noise on the line? For example, once it was in the magnetic field, the helium that we use to cool our experiments had an unintentional interaction with the photons of the laser.”

“With this combination of our infrastructure, we enter an entirely new scientific domain. It is impossible to predict which breakthroughs we will make. One could compare this with a new building in which all doors are closed. One magnetic field strength combined with one light frequency can open one door, thus allowing us to see what is behind it. We now have the unique opportunity to change both the magnetic field strength and the frequency of the light at will. This will allow us to open all doors at the same time,” says FELIX Director Britta Redlich.

HFML-FELIX USER MEETING

Directly after the opening of the new combined building the first HFML-FELIX User Meeting took place. Local research groups, external users and other interested scientists exchanged experiences and the latest scientific news. The aim was to bring the high field and free electron laser communities together and inform both scientific research areas about the possibilities of the facility. During this lively and inspiring user meeting, new ideas were born, suggestions were made and connections between the different fields were established. The meeting was well received by the community and hopefully enables new ground-breaking experiments using the intense radiation of FELIX and the high fields of HFML.

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Participants of the HFML-FELIX User Meeting 2019.

UPCOMING EVENTS

1. APS March Meeting, Denver, USA, March 2-6, 2020.
https://www.aps.org/meetings/march/

2. DPG Spring Meeting of the Condensed Matter Section, Dresden, Germany, March 15-20, 2020.
https://dresden20.dpg-tagungen.de

3. The International Magnetics Conference (INTERMAG), Montreal, Canada, May 4-8, 2020.
https://intermag2020.com/

4. International Conference on Highly Frustrated Magnetism (HFM), Shanghai, China, May 17-22, 2020.

5. 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/

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

7. International Conference on the Physics of Semiconductors (ICPS), Sydney, Australia, August 9-14, 2020.
https://www.icps2020.org/

8. 29th International Conference on Low Temperature Physics (LT29), Sapporo, Japan, August 15-22, 2020.
http://www.lt29.jp

9. 24th International Conference on High Magnetic Fields in Semiconductor Physics (HMF), Hong Kong, China, August 16-21, 2020.
https://hmf24.ust.hk/

10. IRMMW-THz 2020, 45th International Conference on Infrared, Millimeter, and Terahertz Waves, Buffalo, USA, September 13-18, 2020.
https://irmmw-thz.org/current-conference/home

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


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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
3/2019
www.emfl.eu