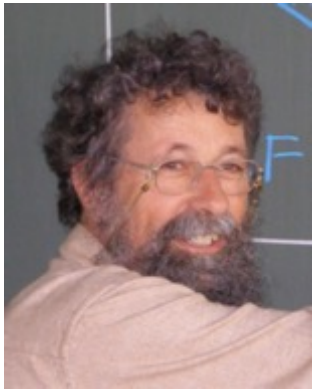
Physics of Quantum Materials Department

MAX-PLANCK-GESELLSCHAFT

Independent but collaborative groups (2018)

Michael Baenitz

Manuel Brando



Christoph Geibel

Clifford Hicks

Andy Mackenzie

Michael Nicklas

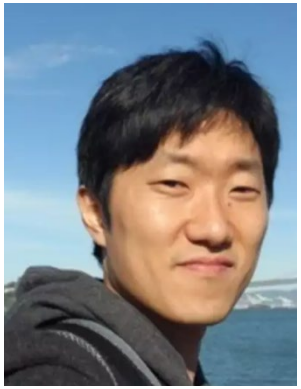
Takashi Oka

Helge Rosner

Independent but collaborative groups (2021)

Michael Baenitz

Manuel Brando



Seunghyun Khim

Elena Gati

Andy Mackenzie

Michael Nicklas

Ashley Cook

Helge Rosner

Haijing Zhang

Veronika Sunko

Goal and philosophy

- Carefully select model systems for study: simplicity and high purity
- Aim for the best possible resolution in all experiments
- Develop new instrumentation for our own purposes and to drive the field
- Within these general parameters, allow individual freedom of expression; there are many routes to discovery
- Goal of the report, talk and poster session – to introduce highlights from the full spectrum of the department's work

Congratulations to

Maja Bachmann

Springer Outstanding Thesis Award 2019

Otto Hahn Medaille 2021

Veronika Sunko

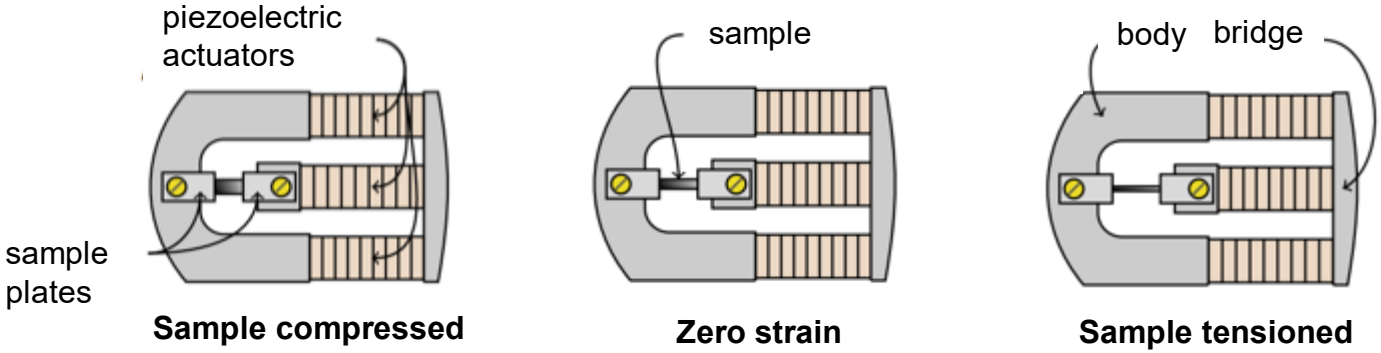
Springer Outstanding Thesis Award 2019

Otto Hahn Medaille 2020

Richard L Greene Dissertation Award of APS 2020

Woodruff Thesis Prize, UK IOP 2020

Uniaxial pressure as a probe of correlated electrons



Poster PQM_01

Stress-strain cell *M.E. Barber, A. Steppke, APM & C.W. Hicks, Rev. Sci. Inst.* ***90****, 023904 (2019)*

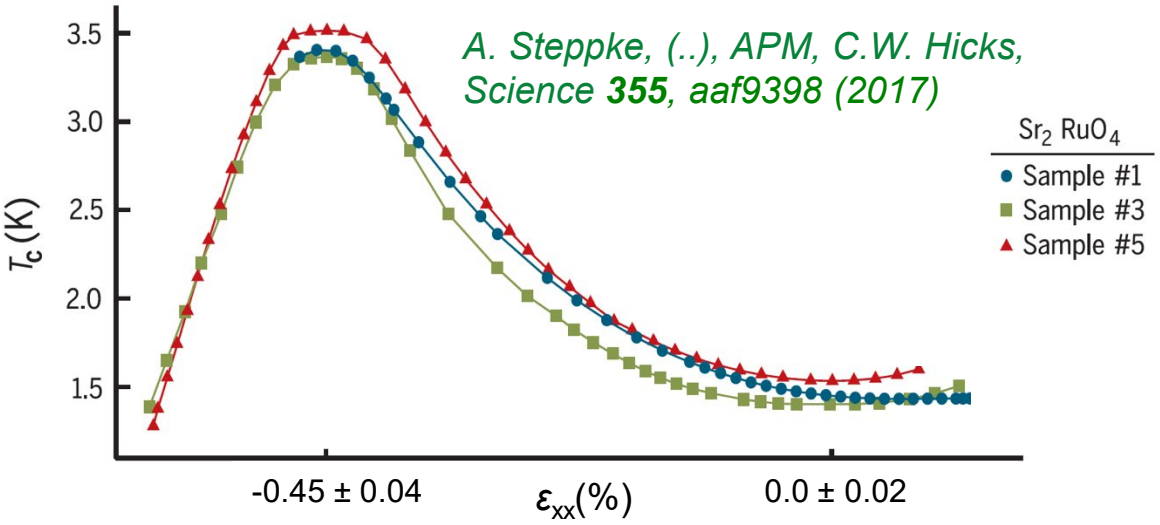
Strained platform cell for exfoliated samples *J. Park, (..), APM, A. Steppke & C.W. Hicks, Rev. Sci. Inst.* ***91****, 083902 (2020)*

High force cell for neutron and muon experiments *S. Ghosh, (..), APM & C.W. Hicks, Rev. Sci. Inst.* ***90****, 023904 (2019)*

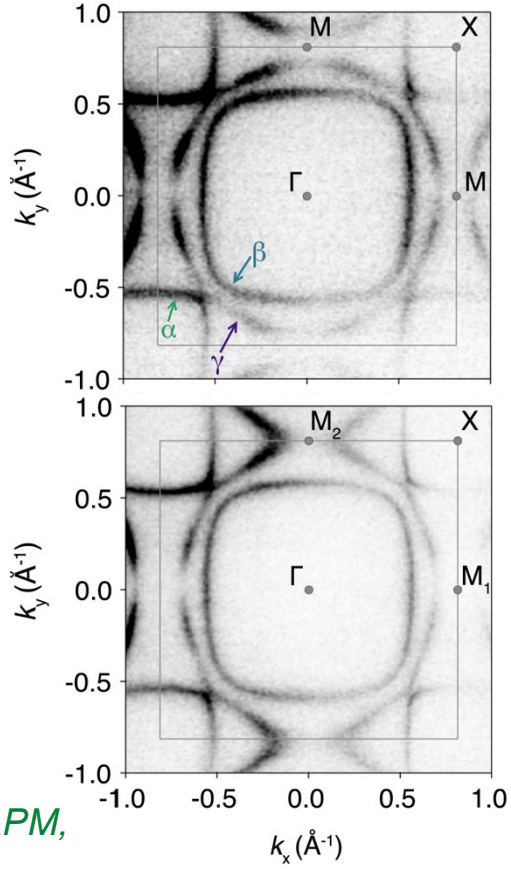
Most of our designs are commercialised under license by Razorbill Instruments under a deal with Max Planck Innovation; sales of over 100 units per year

Application of new cells of our design to study of e.g. FeSe [*Phys. Rev. X* ***11****, 021038 (2021)*], $La_{2-x}Ba_xCuO_4$ [*Phys. Rev. Lett.* ***125****, 097005 (2020)*], $YBa_2Cu_3O_{6.7}$ [*Science* ***362****, 1040 (2018); Phys. Rev. Lett.* ***126****, 037002 (2021)*] and Mn_3Sn [*App. Phys. Lett.* ***117,*** *233502 (2020)*].

Superconductivity of Sr_2RuO_4 under uniaxial pressure



*A. Steppke, (..), APM, C.W. Hicks, Science **355**, aaf9398 (2017)*



Sr_2RuO_4, famous as an odd-parity unconventional superconductor, has a very strong response to uniaxial pressure

'.. our measurements open the possibility that highly strained Sr_2RuO_4 has an even-parity, rather than an odd-parity, order parameter.'

*V. Sunko, (..), C.W. Hicks, P.D.C. King & APM, npj Quantum Materials **4**, 46 (2019)*

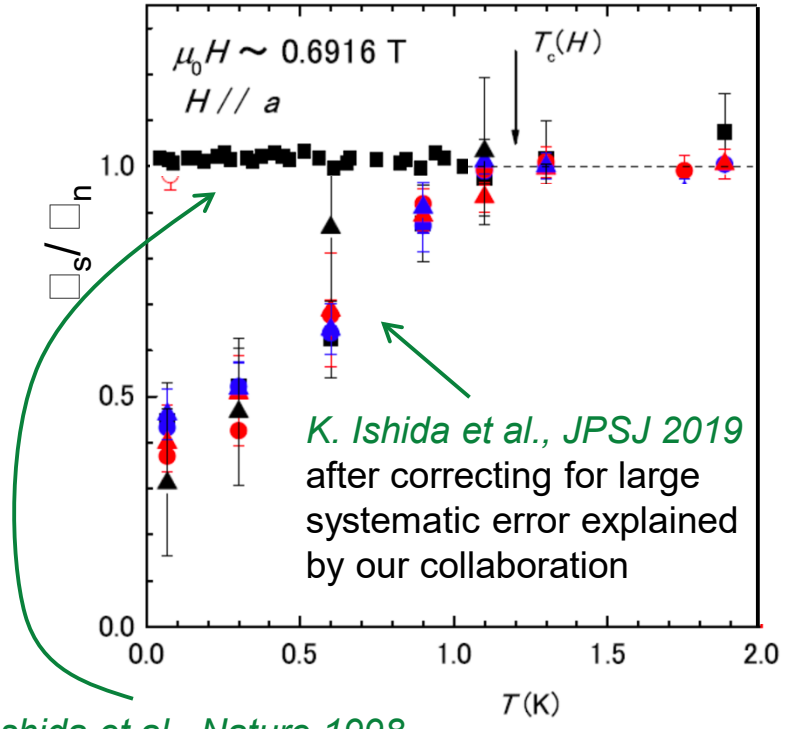
Sr_2RuO_4 under uniaxial pressure: spin susceptibility □

NMR collaboration with Stuart Brown (UCLA)

*Y. Luo, (..), F. Jerzembeck, N. Kikugawa, APM, C.W. Hicks, (..) & S.E. Brown, Phys. Rev. X **9**, 021044 (2019)*

*A. Pustogow, (..), F. Jerzembeck, N. Kikugawa, APM, C.W. Hicks, (..) & S.E. Brown, Nature **574**, 72 (2019)*

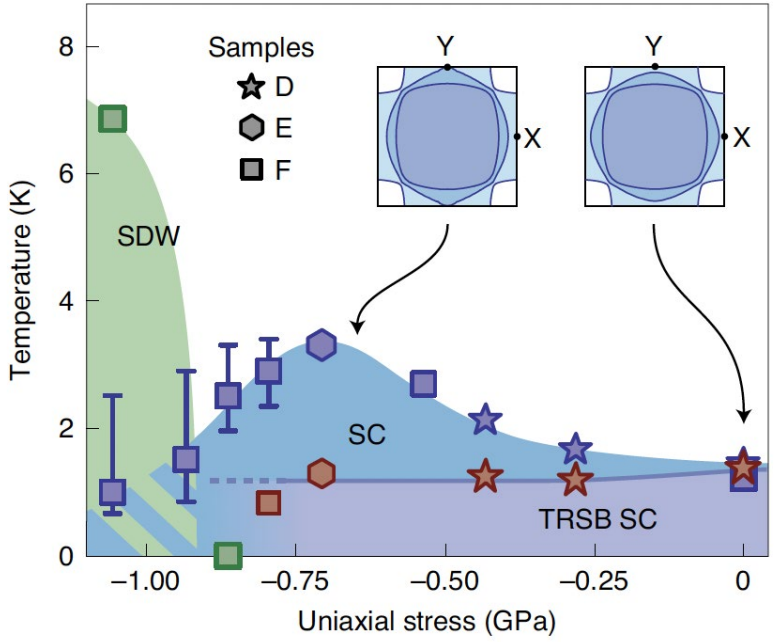
*A. Chronister, (..), F. Jerzembeck, N. Kikugawa, C.W. Hicks, APM, (..) & S.E. Brown, PNAS **118**, e2025313118 (2021)*



Our findings turned the field on its head: Sr_2RuO_4 cannot have an odd parity order parameter at all!

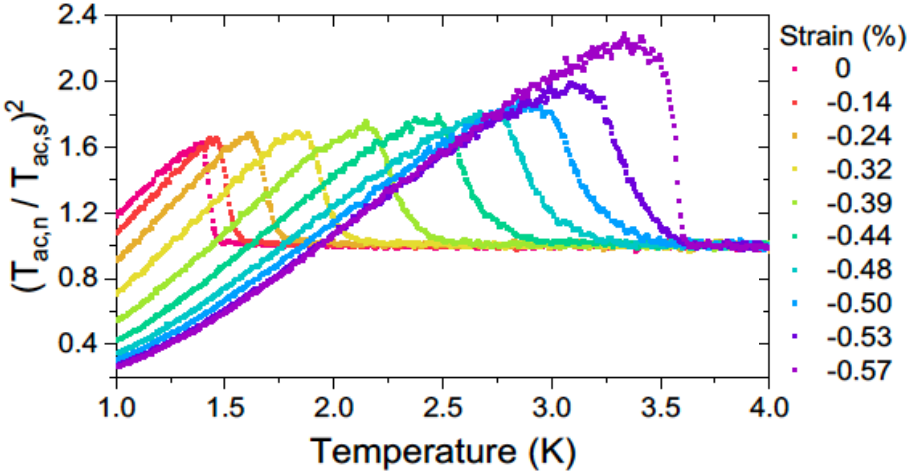
Sr_2RuO_4: two-component superconducting order?

Muon spin relaxation collaboration with Hans-Henning Klauss (TU Dresden)



V. Grinenko, (..), APM, (..) C.W. Hicks, & H.H. Klauss, Nat. Phys. ***17****, 748 (2021)*

However, no sign seen of a thermodynamic transition at T_{TRSB} in a.c. heat capacity

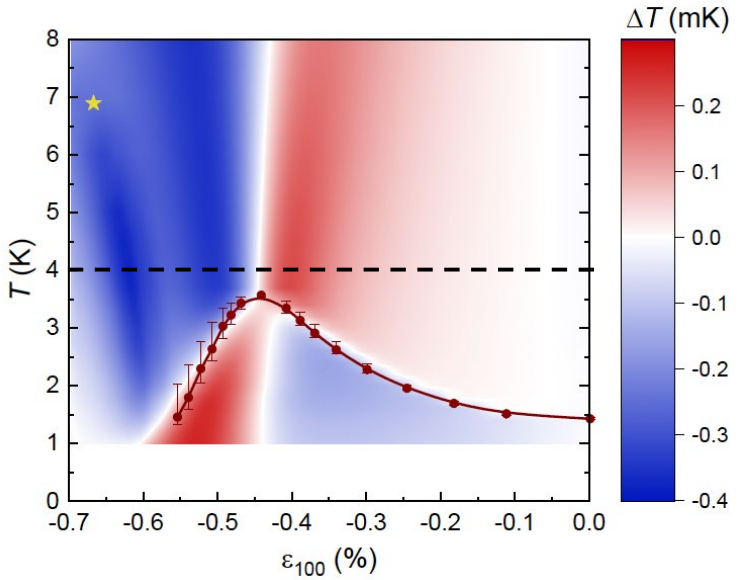


Y.-S. Li, (..), C.W. Hicks, M. Nicklas & APM PNAS ***118****, e2020492118 (2021)*

Also resonant ultrasound in collaboration with Cornell: *S. Ghosh, F. Jerzembeck, (..), APM, C.W. Hicks & B.J. Ramshaw, Nat. Phys.* ***17****, 199 (2021)*

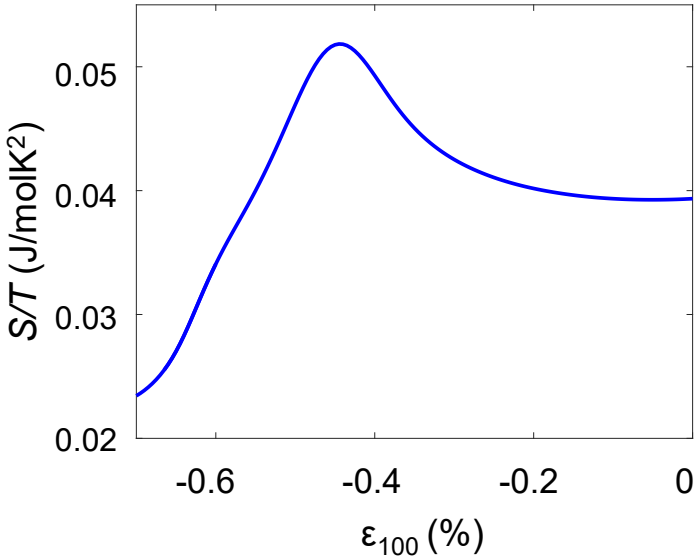
Sr_2RuO_4: elastocaloric effect

Make a precise measurement of the sample temperature as you apply uniaxial pressure



Measurement precision ~ 2 μK/(Hz)$^{1/2}$

Instant phase diagram mapping but much more



Under quasi-adiabatic conditions possible with a.c. piezo-electric excitation the sample entropy can be extracted

Y.-S. Li, A.W. Rost, M. Nicklas, APM et al. (unpublished)

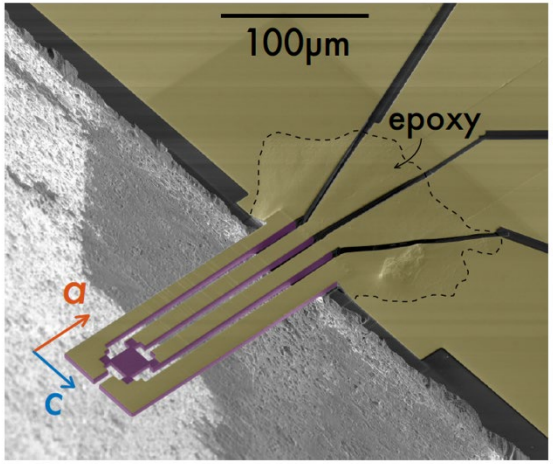
Poster PQM_03

Our Focused Ion Beam ‘micro machine shop’

Our Xe Plasma FIB and Ga-FIB give us rough- and fine-cutting on the microscale.

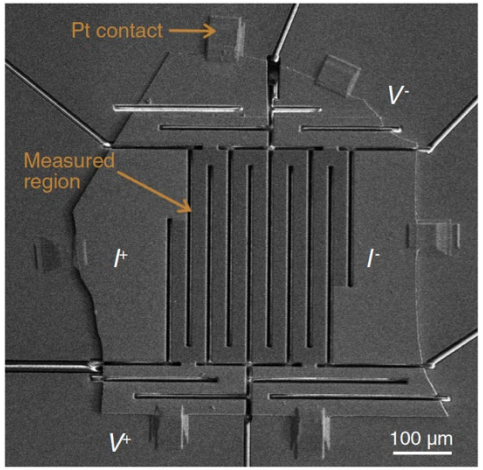
Core technology for our department, enabling experiments not possible by other means.

Posters PQM_01, PQM_09, COLL_02, PUMAS_01



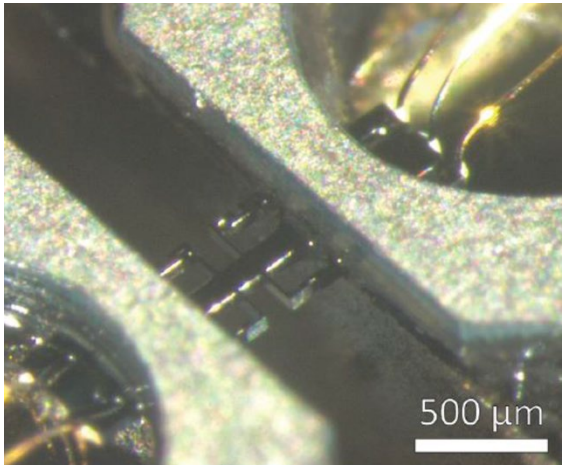
Superconductivity in $CeIrIn_5$

*M.D. Bachmann, (..), APM, (..) & P.J.W. Moll, Science **366**, 221 (2019)*



$PtCoO_2$ capable of surviving 2.5 MeV electron irradiation

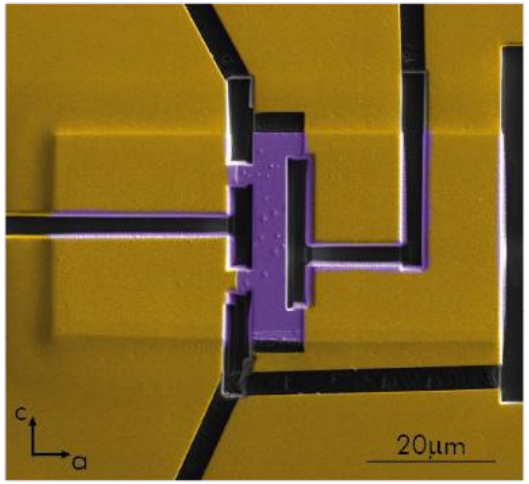
*V. Sunko, P.M. McGuinness, (..) & APM, PRX **10**, 021018 (2020)*



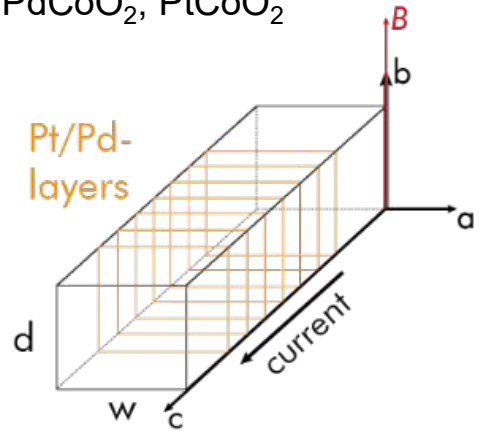
Sr_2RuO_4 as an example of next-generation uniaxial pressure technology development

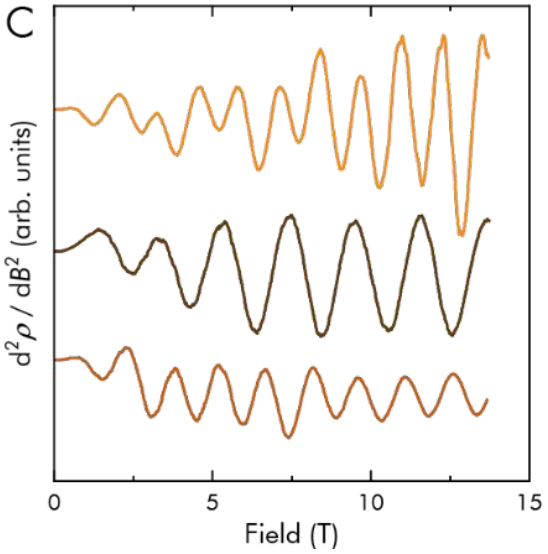
P.-Y. Yang, unpublished

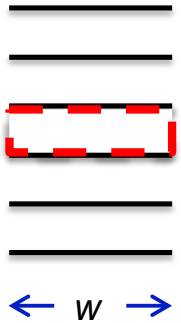
Quantum coherence in delafossite microstructures



$PdCoO_2$, $PtCoO_2$



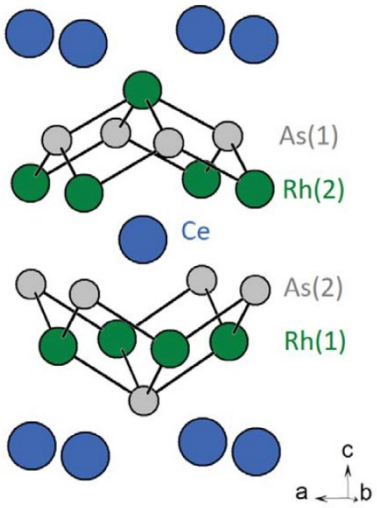


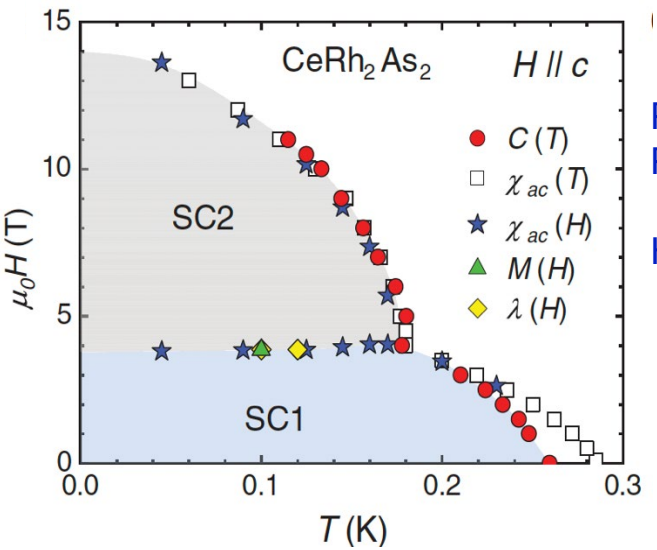


Width *w* can be > 5 x 10^4 lattice spacings: macroscopic coherence in a metal!

*C. Putzke, M.D. Bachmann, (..), R. Moessner, (..), APM & P.J.W. Moll, Science **368**, 1234 (2020)*

Local Rashba superconductivity in $CeRh_2As_2$





Posters PQM_05
PUMAS_01

Hassinger talk

2017: S. Khim, C. Geibel: investigate $CeRh_2As_2$ motivated by the unusual Ce environment

Local inversion symmetry breaking in a globally inversion symmetric structure

2018-2021: Collaboration with MPRG of Elena Hassinger, group of Manuel Brando and Daniel Agterberg of U Wisconsin

Fully establish and explain rare two-phase superconductivity and huge critical field

*S. Khim, J.F. Landaeta, J. Banda, N. Bannor, M. Brando, P.M.R. Brydon, D. Hafner, R. Küchler, R. Cardoso-Gil, U. Stockert, APM, D.F. Agterberg, C. Geibel & E. Hassinger, Science **373**, 1012 (2021)*

Physics of Quantum Materials Posters

Poster PQM_01	Novel developments in uniaxial pressure tuning of quantum materials	Elena Gati and Clifford Hicks
Poster PQM_02	Modelling structure-property relationships in quantum magnets	Helge Rosner
Poster PQM_03	Towards simultaneous spectroscopy and thermodynamics under uniaxial pressure	Andy Mackenzie and Veronika Sunko
Poster PQM_04	$YbAlO_3$: a Tomonaga-Luttinger liquid	Manuel Brando
Poster PQM_05	Tuning the magnetic Weyl semimetal CeAlSi by hydrostatic pressure	Michael Nicklas
Poster PQM_06	The new heavy-fermion superconductor $CeRh_2As_2$	Seunghyun Khim and Christoph Geibel
Poster PQM_07	Yb delafossites $NaYbCh_2$ (Ch:O,S,Se): unique J_{eff} = 1/2 spin liquids on a triangular lattice	Michael Baenitz
Poster PQM_08	Observation of a Rashba-driven anomalous Hall effect (AHE) in an antiferromagnetic crystal	Haijing Zhang and Ashley Cook
Poster PQM_09	Directional ballistics in delafossite microstructures	Philippa McGuinness and Elina Zhakina