

Helmholtz - OCPC - Programme 2017-2021 for the Involvement of Postdocs in Bilateral Collaboration Projects with China

PART A

Title of the project:

Novel quantum phases in helimagnetic transition-metal monpnictides

Helmholtz Centre and institute:

Karlsruhe Institute of Technology (KIT), Institute for Solid-State Physics (IFP)

Project leader:

Dr. Michael Merz and Dr. Amir-Abbas Haghighirad

Web-address:

www.ifp.kit.edu

Description of the project (max. 1 page):

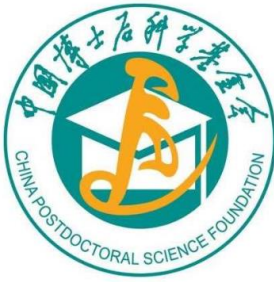
Motivation:

The transition-metal monpnictide CrAs as well as the doped/substituted variants $\text{Cr}_{1-x}\text{Mn}_x\text{As}$ and $\text{CrAs}_{1-x}\text{P}_x$ are promising systems to display novel quantum phases along with strong electron-lattice interactions. The interplay between structural and electronic degrees of freedom in these systems will be studied in detail and provides guidelines for the rational design of novel quantum critical transition-metal monpnictides.

State-of-the-art

The tunability of many correlated electron materials is rooted in rich phase diagrams containing almost degenerate electronic states. Transitions between these states can be achieved, even down to the lowest reachable temperatures, by tuning the interplay between the structural and electronic degrees of freedom by, e.g., varying the electronic bandwidth or the band filling, for instance via chemical substitutions. This has been pivotal in unveiling some of the key properties of unconventional superconductors.

Recently, superconductivity (SC) was reported in the strongly correlated material CrAs. This compound shows a first-order transition to a non-collinear helimagnetic double spiral structure below $T_N \sim 270$ K, accompanied by a strong structural anomaly [$\Delta b/b \sim 4\%$ and $\Delta V/V \sim 2.2\%$, space group (*Pnma*) is preserved] indicating strong magneto-elastic coupling [1-6]. SC emerges with the suppression of the magnetic order under pressure (hydrostatic or chemical), yielding a phase diagram similar to those of Fe-pnictide and heavy-fermion systems [2]. The electrical resistivity of CrAs becomes quasi-linear at low temperatures, and the carrier mass diverges, providing evidence for quantum criticality which in turn suggests unconventional SC [1]. The nature of the coupling between structural, magnetic and electronic degrees



of freedom and of the microscopic mechanisms underpinning the appearance of SC remains to be clarified.

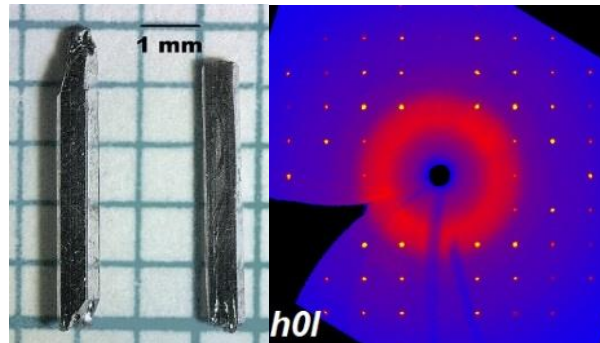


Figure 1: *left*) CrAs single crystals grown by chemical vapour transport, *right*) reciprocal lattice plane $h0l$, as derived from single-crystal x-ray diffraction.

A detailed understanding of the interaction parameters governing the electronic state of the selected materials can be achieved by combining detailed crystallographic x-ray & neutron diffraction studies (i.e., temperature, and doping-dependent changes of the lattice parameters, interatomic distances [7]) with spectroscopic experiments, which probe the electronic structure, such as x-ray absorption and core-level photoemission (XAS & XPS).

References:

- [1] M. Matsuda et al., Phys. Rev. X 8, 031017 (2018).
- [2] W. Wu et al., Nature Comm. 5, 5508 (2014).
- [3] H. Kotegawa et al., J. Phys. Soc. Jpn 83, 093702 (2014).
- [4] T. Suzuki et al., J. Appl. Phys. 73, May, 5686 (1993).
- [5] Q. Niu et al., Nature Comm. 8, 15358 (2017).
- [6] H. Kotegawa et al., Phys. Rev. Lett. 114, 117002 (2015).
- [7] M. Merz et al., J. Phys. Soc. Jpn 85, 044707 (2016).

Description of existing or sought Chinese collaboration partner institute (max. half page):

We would like to establish a bilateral scientific exchange with the International Center for Quantum Materials, Peking University. Ass.-Prof. Dr. Yuan Li works at the International Center for Quantum Materials, Peking University. His research involves implementing state-of-the-art scattering methods, in particular neutron and photon (Raman, X-ray) scattering, to study the structure and dynamics of correlated electron systems and quasiparticle excitations. Topics of current interest include mechanism of high-temperature superconductivity in copper- and iron-based materials, phenomenology and mechanism of charge order in metals and insulators, spin-orbital physics in transition-metal compounds, frustrated quantum magnets, and band topology of bosonic excitations in crystalline materials.

There is an existing collaboration between Yuan Li's group and the Institute of Solid-State Physics at KIT. Through this collaboration both parties will benefit mutually from scientific interaction with Dr. M. Merz and Dr. A. A. Haghighirad (and the wider Solid-State Physics at



KIT) with a well-established track record in exploring experimentally a variety of correlated electron materials. The candidate will benefit from having access to well-established laboratory infrastructure for sample synthesis and physical properties measurements (single crystal x-rays, magnetic measurements, and significant capabilities in crystal growth). Our group at the Institute for Solid-State Physics will benefit from the candidate's expertise in advanced experimental techniques, which will bring new possibilities and enable new materials to be studied.

Required qualification of the post-doc:

- PhD in Condensed Matter Physics
- Experience in Solid-State Physics, Materials Growth and/or Crystallography
- Additional skills in materials synthesis and characterisation

PART B

Documents to be provided by the post-doc, necessary for an application to OCPC via a postdoc-station in China, which is affiliated to a research institution like a university:

- Detailed description of the interest in joining the project (motivation letter)
- Curriculum vitae, copies of degrees
- List of publications
- 2 letters of recommendation
- Proof of command of English language

PART C

Additional requirements to be fulfilled by the post-doc:

- Max. age of 35 years
- PhD degree not older than 5 years
- Very good command of the English language
- Strong ability to work independently and in a team