

# Synchrotron based investigations of quantum critical materials

## PhD position 3/4 E13 or PostDoc 1 E13

### Institute of Physics II, University of Cologne, Cologne Germany

We investigate the quantum states of materials in the proximity of quantum critical points (QCP). Here so called *heavy fermion* compounds have been chosen because the samples are clean and well characterized and because the quantum critical behavior occurs at very low temperatures where phonons are frozen out. In these heavy fermion compounds the QCP marks the zero temperature transition between a magnetically ordered on one side and more itinerant state on the other. The transition is driven by the exchange interaction  $J_{ex}$  which again can be manipulated by external parameters as pressure, field or substitution. In the proximity of the QCP many heavy fermion compounds exhibit unconventional superconductivity.

In the last years we have established soft-x ray absorption spectroscopy (XAS) as a tool for investigating crystal-field ground state wave functions in cerium based heavy fermion compounds. At the example of the substitution series  $CeRh_{1-x}Ir_xIn_5$  we could show that the crystal-field wave function correlates with the ground state properties [1]. Here  $CeRhIn_5$  orders antiferromagnetically and  $CeIrIn_5$  has a superconducting ground state and in-between are regions of phase coexistence. Such correlation had been theoretically suspected quite some time and we were able to confirm it experimentally due to the unprecedented accuracy of the soft-XAS technique.

The candidate will perform soft x-ray absorption measurements at various synchrotron sources (ESRF in Grenoble, SOLEIL close to Paris, NSRRC in Taiwan, Spring-8 in Japan....) and determine valences and crystal-field wave function. More substitution phase diagrams shall be investigated and thanks to the improvement of sample environment experiments in the low temperature, quantum critical region (mK) of heavy fermion compounds will be possible.

The candidate should have some experimental sensitivity and enthusiasm since the soft x-ray range requires ultra high vacuum, the measurements are fast and the single crystalline samples which we handle can be very small ( $<1\text{mm}^3$ ). The candidate should further be interested in modeling the data on the basis of a complex full multiplet routine (code by A. Tanaka from Hiroshima University) and of course he/she should enjoy travelling.

Contact: A. Severing [severing@ph2.uni-koeln.de](mailto:severing@ph2.uni-koeln.de) or 0221 470 2608

[1] Correlation between the phase diagram and the crystal-field wave functions of  $CeRh_{1-x}Ir_xIn_5$

T. Willers, F. Strigari, Z. Hu, V. Sessi, N. B. Brookes, E. D. Bauer, J. D. Thompson, J. L. Sarrao, A. Tanaka, S. Wirth, L. H. Tjeng, and A. Severing, [arXiv:1309.3409](https://arxiv.org/abs/1309.3409)

## Some Publications

*Correlation between the phase diagram and the crystal-field wave functions of  $CeRh_{1-x}Ir_xIn_5$*

T. Willers, F. Strigari, Z. Hu, V. Sessi, N. B. Brookes, E. D. Bauer, J. D. Thompson, J. L. Sarrao, A. Tanaka, S. Wirth, L. H. Tjeng, and A. Severing  
Submitted to PRL (2013)

*Crystal-field ground state of the orthorhombic Kondo semiconductors  $CeOs_2Al_{10}$  and  $CeFe_2Al_{10}$*

F. Strigari, T. Willers, Y. Muro, K. Yutani, T. Takabatake, Z. Hu, S. Agrestini, C.-Y. Kuo, Y.-Y. Chin, H.-J. Lin, T. W. Pi, C.T. Chen, E. Weschke, E. Schierle, A. Tanaka, M. W. Haverkort, L. H. Tjeng, and A. Severing  
Phy. Rev. B 87, 125119 (2013)

*Crystal-field ground state of the orthorhombic Kondo insulator  $CeRu_2Al_{10}$*

F. Strigari, T. Willers, Y. Muro, K. Yutani, T. Takabatake, Z. Hu, Y.-Y. Chin, S. Agrestini, H.-J. Lin, C. T. Chen, A. Tanaka, M. W. Haverkort, L. H. Tjeng, and A. Severing  
Phys. Rev. B 86, 081105(R) (2012)

*Determining the In-Plane Orientation of the Ground-State Orbital of  $CeCu_2Si_2$*

T. Willers, F. Strigari, N. Hiraoka, Y. Q. Cai, M.W. Haverkort, K.-D. Tsuei, Y. F. Liao, S. Seiro, C. Geibel, F. Steglich, L. H. Tjeng, and A. Severing  
a) Phys. Rev. Lett 109, 046401 (2012)  
b) Scientific highlight in the annual report 2012 of the National Synchrotron Radiation Research Centre (NSRRC) in Taiwan.

*Spectroscopic determination of crystal-field levels in  $CeRh_2Si_2$  and  $CeRu_2Si_2$  and of the  $4f^0$  contributions in  $CeM_2Si_2$  with  $M = (Cu, Ru, Rh, Pd, \text{ and } Au)$ .*

T. Willers, D.T. Adroja, B.D. Rainford, Z. Hu, N. Hollmann, P. O. Körner, Y.-Y. Chin, D. Schmitz, H. H. Hsieh, H.-J. Lin, C. T. Chen, E.D. Bauer, J.L.Sarrao, K.J. McClellan, D. Byler, C. Geibel, F. Steglich, H. Aoki, P. Lejay, A. Tanaka, L. H. Tjeng, and A. Severing  
Phys. Rev. B 85, 035117 (2012)

*Magnetic field induced orbital polarization in cubic  $YbInNi_4$ : determining the quartet ground state using x-ray linear dichroism."*

T. Willers, J.C. Cezar, N.B. Brookes, Z. Hu, F. Strigari, P. Körner, N. Hollmann, D. Schmitz, A. Bianchi, Z. Fisk, A. Tanaka, L. H. Tjeng and A. Severing  
a) Phys. Rev. Lett. . 107, 236402 (2011)  
b) Scientific highlight in the annual report 2012 of the European Synchrotron Radiation Facility (ESRF) in Grenoble, France.

*Crystal-field ground state of the non-centrosymmetric superconductor  $CePt_3Si$ : a combined polarized soft X-ray absorption and polarized neutron study*

T. Willers, B. Fak, N. Hollmann, P.O. Körner, Z. Hu, A. Tanaka, D. Schmitz, M. Enderle, G. Lapertot, L.H. Tjeng, A. Severing  
Phys. Rev. B 80, 115106 (2009)

*Determining the crystal-field ground state in rare earth Heavy Fermion materials using soft-x-ray absorption spectroscopy*

P. Hansmann, A. Severing, Z. Hu, M.W. Haverkort, C.F. Chang, S. Klein, A. Tanaka, H.H. Hsieh, H.-J. Lin, C.T. Chen, B. Fak, P. Lejay, and L.H. Tjeng,  
Phys. Rev. Lett. 100, 066405 (2008)