UNIKASSEL VERSITÄT

# Physikalisches Kolloquium

**Thursday, 14.07.2016, 17:15, HS 100**
**Reception with coffee & cookies 16:45**

**Prof. Dr. Kilian Singer**, Experimentalphysik I, Universität Kassel :

## *Antrittsvorlesung*

## *Light matter interaction with single ions for basic research and modern quantum technologies*

**Abstract**

I will present pioneering experiments where light-matter interaction with single ions [1] is used in order to ask fundamental questions of nature and implement modern quantum technologies. I will describe experiments where laser-cooled single ions are employed to realize an atomic nano-assembler, capable of placing single atoms with nanometer resolution into solid state systems [2,3]. The motivation is to implement a new production technique for scalable solid state quantum devices, potentially enabling nitrogen vacancy color centres in diamond to be used as long-lived quantum memory and a scalable quantum information processing platform at room temperature. Trapped ions can be also used within a tapered ion trap to realize thermodynamic machines reduced to the ultimate atomic limit [4], using a single ion as the working agent. The confinement in a linear Paul trap with tapered geometry allows for coupling axial and radial modes of oscillation. The heat-engine is driven thermally by coupling it alternately to hot and cold reservoirs, using the output power of the engine to drive a harmonic oscillation [5,6]. From direct measurements of the ion dynamics, the thermodynamic cycles for various temperature differences of the reservoirs can be determined and the efficiency compared with analytical estimates. This system will provide valuable information for future experiments with heat engines working in the quantum regime relevant to nanoscale quantum technologies. Trapped ions are also a formidable model system to verify theoretical predictions. Towards this goal I will present an experiment where we have observed of the Kibble-Zurek scaling law for defect formation in ion crystals [7]. This universal mechanism played an important role in cosmic string formation of the early Universe.

[1] K. Singer, U. G. Poschinger, M. Murphy, P. A. Ivanov, F. Ziesel, T. Calarco, F. Schmidt-Kaler, "Colloquium: Trapped ions as quantum bits: Essential numerical tools", Review of Modern Physics 82, 2609 (2010).
[2] W. Schnitzler, N. M. Linke, R. Fickler, J. Meijer, F. Schmidt-Kaler, K. Singer, "Deterministic Ultracold Ion Source Targeting the Heisenberg Limit", Physical Review Letters 102, 070501 (2009).
[3] G. Jacob, K. Groot-Berning, U. G. Poschinger, F. Schmidt-Kaler, K. Singer, "Maximizing the information gain of a single ion microscope using bayes experimental design", arxiv 1605.05071 (2016).
[4] J. Roßnagel, S. T. Dawkins, K. N. Tolazzi, O. Abah, E. Lutz, F. Schmidt-Kaler, K. Singer, "A single-atom heat engine", Science 352, 325 (2016).
[5] O. Abah, J. Roßnagel, G. Jacob, S. Deffner, F. Schmidt-Kaler, K. Singer, E. Lutz, "Single-Ion Heat Engine at Maximum Power", Phys. Rev. Lett. 109, 03006 (2012).
[6] J. Roßnagel, O. Abah, F. Schmidt-Kaler, K. Singer and E. Lutz, "A nano heat engine beyond the Carnot limit", Phy. Rev. Lett. 112, 030602 (2014). (spotlight article on physics.org)
[7] S. Ulm, J. Roßnagel, G. Jacob, C. Degünther, S. T. Dawkins, U. G. Poschinger, R. Nigmatullin, A. Retzker, M. B. Plenio, F. Schmidt-Kaler and K. Singer, "Observation of the Kibble-Zurek scaling law for defect formation in ion crystals", Nature communications 4, 2290 (2013).

All of you interested in physics are cordially invited!

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