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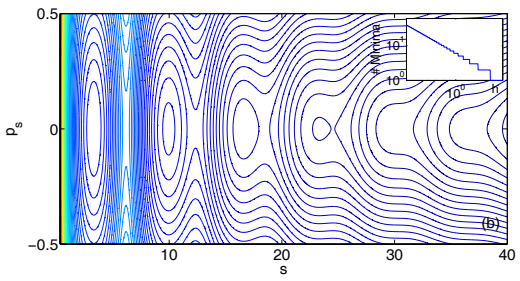
Highlights from the previous volumes

Effective long-range interactions in confined curved dimensions

Fundamental forces of Nature such as the gravitational or Coulomb force mediated by the mass and charge of particles, respectively, decay according to universal laws with increasing distance between the particles. Still, these simple laws lead to the enormous beauty and amazing complexity of matter surrounding us. In ultracold atomic physics the three-dimensional motion of neutral atoms or charged particles can be confined to a lower-dimensional, typically one- or two-dimensional, trap by employing electromagnetic forces. If these traps are of curved character which is possible, *e.g.*, in evanescent fields surrounding optical nanofibers, they confine the motion to a curved low-dimensional manifold. This opens the perspective of designing novel effective finite-range and possibly also long-range interactions since the dynamics is constrained to the curved geometry but the interaction takes places via the dynamically forbidden dimensions. The corresponding forces can now become oscillating with increasing distance between the particles and are widely tunable via the parameters of the confining curved manifold. Exploring as a prototype example the one-dimensional helix, it can be immediately shown that a plethora of local equilibrium configurations and consequently bound states emerge already for two particles even if the particles were repelling each other in free space. The number and depths of the local minima and wells can be tuned by modifying the pitch or curvature of the helix thereby establishing bound state configurations of different symmetries. With an increasing number of interacting particles an ever increasing wealth of symmetry-adapted and symmetry-distorted configurations create a very complex energy landscape exhibiting a dense spectrum of local equilibria. It can be anticipated that the thermodynamical properties and quantum physics of the many-body interacting helical chain show novel structural properties such as enriched phase diagrams as well as an intriguing dynamical behaviour.

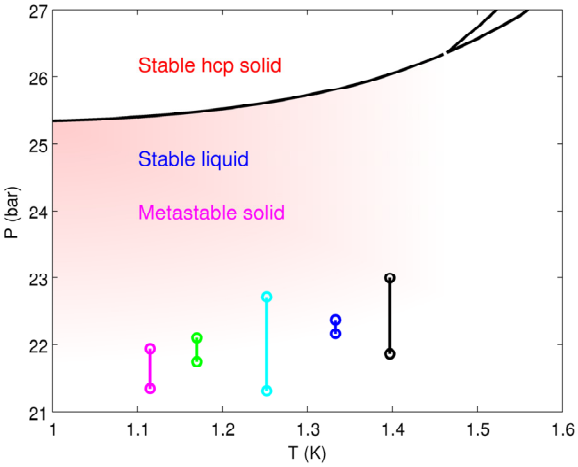


Phase space picture of the effective long-range interactions indicating many local equilibria (inset: number of minima as a function of the pitch of the helix).

Original article by Schmelcher P.
EPL, **95** (2011) 50005

Observation of metastable hcp solid helium

Crystalline solids can be brought into metastable state with respect to fusion only if surface melting is avoided. Overheated metals have indeed been observed by embedding small samples in carefully chosen matrices. Because of its constant melting pressure at low temperatures, hcp solid helium offers a unique possibility to achieve a metastable solid via pressure variations. Intense positive and negative pressure swings far from any interface can be achieved using focused sound waves. In hcp solid helium, the sound velocity is anisotropic and a dedicated non-spherical sound emitter has to be used. The wave amplitude is small enough not to melt the crystal at its interface with the emitter. As it propagates, its amplitude increases and pressures below the static melting line are obtained in the solid bulk. The pressure is measured via the refraction index changes of the medium using an interferometric imaging technique. The main result of this work is shown in the figure below: hcp solid helium between -2 and -4 bars below the melting line has been produced and observed. A side result is that the crystal seems to become unstable beyond this value. We feel that the stretched quantum solid is an interesting new system to be understood in detail.



Partial phase diagram of helium and minimum pressures achieved at different temperatures between 1.1 K and 1.4 K. The metastable domain is below the melting line.

Original article by Souris F. *et al.*
EPL, **95** (2011) 66001

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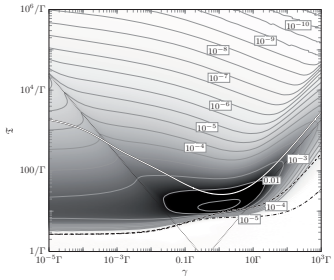
Interference-induced energy transport for biomolecular networks

Recent experimental demonstrations of long-lived quantum coherence in certain photosynthetic light-harvesting structures has launched a flurry of controversy over the role of coherence and non-classical correlations in biological function. Indeed, an ongoing investigation into the cause of the astonishingly high energy transport efficiency of these structures increasingly suggests that Nature takes advantage of quantum-mechanical coherent dynamics.

Currently, theoretical research explores the following two main areas: First, one would like to understand how, at room temperature, quantum coherent oscillations can survive in a large, noisy macromolecular structure. Secondly, the potential impact of quantum effects on the functioning of biomolecules is to be clarified.

The work presented here addresses the latter. We inquire on the fundamental principles of quantum coherent energy transport in ensembles of spatially disordered molecular networks subjected to a continuous distribution of environmental dephasing noise. Dephasing reduces the coherence between individual network nodes and has already been shown to assist transport substantially provided that quantum coherence is detrimental by reason of destructive interference, *e.g.* in the presence of disorder and quantum localization. In a large-scale statistical survey, we map the probability landscape of transport efficiency for the whole ensemble of disordered networks, in search of specially adapted molecular conformations that Nature may select in order to facilitate energy transport: *We thus find certain optimal molecular configurations that by virtue of constructive quantum interference yield the highest transport efficiencies in the absence of dephasing noise.* Moreover, the transport efficiencies realized by these optimal configurations are systematically higher than the noise-assisted efficiencies mentioned above. As discussed in the article, this defines a clear incentive to select configurations for which quantum coherence can be harnessed.



Grey-scale encoded probability density of the average energy transfer time $\mathfrak{T}$ as a function of the dephasing rate γ (exponentially increasing from left to right). As indicated by the median (white line), for a typical configuration, the transfer time is reduced by the dephasing up to an optimal rate γ, where the transfer becomes most efficient. However, these noise-assisted transfer times are still notably longer than the minimum transfer time achieved by an optimized configuration for vanishing dephasing (minimum of the dot-dashed line on the left).

Original article by Scholak T. *et al.*
EPL, **96** (2011) 10001

Stable p-type conductivity in ZnO —A step towards oxide-based optoelectronics

Zinc Oxide (ZnO) has potential applications in varistors, light-emitting diodes and photo-detectors. The primary obstacle in preventing its use in optoelectronic devices is the lack of a stable p-type material. In ZnO the majority carriers are electrons and minority carriers are holes. So ZnO is naturally an n-type material. It must have majority carriers as holes to have p-type conductivity. Most p-type dopants in ZnO introduce either deep acceptors or shallow acceptors and so the resulting materials are unstable p-type conductors with either very low carrier concentration or unstable conductivity. There have been a number of previous efforts to synthesize p-type ZnO by using N, As and P as dopants. In the current study bismuth was chosen as the p-type dopant in ZnO.

Thin films of bismuth-doped ZnO were grown using a pulsed-laser deposition system employing a homogeneous target. The thickness of the samples was around 150 nm. XRD results confirmed the wurtzite structure of the resulting thin films and XPS confirmed the presence of bismuth in the ZnO lattice. No evidence of secondary phases was found. Hall measurement data taken over repeated cycles confirmed p-type conductivity in *in situ* annealed 3% bismuth-doped ZnO samples and 5% bismuth-doped ZnO samples. It was interesting to note that as-grown 3% Bi-doped ZnO samples showed unstable p-type conductivity. These results for 3% doped samples suggest that some form of activation of bismuth in ZnO occurs during post growth annealing which leads to the p-type conduction. In the 5% doped samples it appears that the concentration of bismuth is sufficiently high to produce p-type conduction in the as-grown samples. Bismuth substitution in ZnO lattice is known to produce acceptors and this has been confirmed in our photoluminescence experiments. Carrier concentration was 5.36×10^{18} and 4.76×10^{19} in annealed 3% and 5% bismuth-doped samples, respectively. The temperature-dependent photoluminescence study shows that the acceptor energy level of bismuth is about 0.13 eV above the valence band. The results indicate that bismuth-doped ZnO thin films exhibit stable p-type conductivity in oxygen-rich or post-annealed conditions. Thus, this study suggests a possible pathway for developing ZnO-based optoelectronic devices.

Original article by Lee J. W. *et al.*
EPL, **95** (2011) 47002