# Combining solid-state physics with quantum optics

October 19 2007, By Miranda Marquit

One of the more interesting advances in science is the use of the atom chip. As the demands of technology require smaller and smaller components, studying the fundamentals of physics at the quantum level will become increasingly important. The Munich Atom Chip Group, under the direction of Theodor Hänsch at the University of Munich and the Max-Planck-Institute of Quantum Optics is working to find ways to learn more about physics at the most fundamental levels.

“We have studied in detail whether it is possible to prepare cold atoms close to a solid state chip surface without losing coherence properties,” Philipp Treutlein, a member of the research group, tells *PhysOrg.com*. “We showed that it is possible to prepare coherent superpositions of atomic quantum states at only a few micrometers distance from a solid surface.” The next step, he says, is to “put something interesting on the surface and see how it will interact with the atoms, and whether the interaction reveals quantum effects.”

The result? A hybrid quantum system that would allow physicists to explore interactions between solid state systems and quantum optical systems – and possibly lead to other, more specific applications. Treutlein and his coauthors, David Hunger, Stephan Camerer and Theodor Hänsch from the University of Munich, as well as Jakob Reichel at the Kastler Brossel Laboratory in Paris, discuss their theory in a piece titled, “Bose-Einstein Condensate Coupled to a Nanomechanical Resonator on an Atom Chip,” published in *Physical Review Letters*.

Treutlein emphasizes that right now this hybrid quantum system is at the theoretical stage. “We are experimentalists, though,” he says, “and we are working with the solid-state physics group of Professor [Jörg] Kotthaus to get it to work in the laboratory.”

The hybrid system the group is investigating is composed of Bose-Einstein condensed atoms and a nanomechanical cantilever resonator. “We take a small cantilever, a nano-sized cantilever, and put a small magnet on the tip. When the cantilever vibrates, it shakes the magnet, and thus generates an oscillatory magnetic field. This oscillatory field couples to the spin of the atoms which are hovering above the cantilever tip, inducing spin flips,” Treutlein explains. “The spin flips are the signal which we will detect, and they give us information about the coupling” between the solid-state cantilever and the atoms.

Treutlein believes there is potential for future applications of this work. “We’re only at the very beginning of exploring this system experimentally,” he points out. “When we see what the fundamental dynamics are, and whether it works, we can decide on specific applications.” But he does think that such hybrid systems could be useful sensors for magnetic fields.

He also thinks that there is some potential for quantum information processing. “An atomic system has very good coherence properties, but the dynamics are slow. In solid state systems, the dynamics are faster, but the coherence is washed out in a shorter time. Maybe atoms could be used as quantum memory and the solid state system as a fast quantum processor.” Treutlein pauses and then laughs. “But I’m not sure yet if that would work. Our main focus isn’t really on building a quantum computer.”

But what he and his colleagues *are* building is interesting enough on its own. “This hybrid quantum system, if it works like we think it will, would give us great insight into fundamental physics." In an email, Treutlein expounds: "For example, we would like to see whether one can use the Bose-Einstein condensate, composed of a few thousand atoms, to engineer the quantum state of the resonator, composed of several billions of atoms, and how such a large quantum system behaves."

The work has its challenges, though. "We have to be able to prepare the mechanical oscillator at very low temperatures to see quantum effects. And we have to combine the state of the art technology from quantum optics and solid-state physics, which is very challenging," Treutlein admits. "We are looking into the long-term here."

"Even though we've proposed a theory," he explains, "we mostly work experimentally, so we see both sides. We know how difficult this might be to realize in the laboratory. But it also means that we try very hard to make realistic assumptions."

He continues: "It seems to us that we could make such a hybrid quantum system a reality. But it doesn't mean it's easy."

Visit the Munich Atom Chip Group at [www.munichatomchip.de/](www.munichatomchip.de/)