Permanent magnetic atom chips

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Summary

This thesis describes the research that was performed for the development of permanent magnetic chips. The goal of magnetic chips is to trap cold atoms and to allow their manipulations (transport, storage, coherent splitting and coherent combining of cold atoms).

An atom in a well-defined angular momentum state has no electric monopole or dipole moment. However, atoms in general have a magnetic dipole moment either due to this angular momentum or the electron spin. Therefore the dominant interaction of an atom with its surrounding is magnetically. This is a relativistic and so a weak effect. As a consequence only for cold atoms the magnetic interaction energy can be larger than the kinetic energy. This leads to the conclusion that in technologically achievable magnetic fields only cold atoms can be trapped and not room-temperature atoms. Note, however, that the low temperature is not only a technical limitation for trapping, but it also an area that leads to new physics, notably due to the coherence properties of cold atoms.

We compare large-scale traps, based on coils, with small-scale traps based on atom chips. In addition, we compare atom chips, based on current-carrying wires with atom chips, based on permanent magnetic material. In this thesis all efforts are focused on atom chips based on permanent magnetic material. The approach we followed has both strong and weak points compared to other approaches. Before we can harvest the benefits (a low price of increasing complexity) we have to learn how to deal with the disadvantages (no combination of position resolution and time dependence), which mostly play a role during the initial loading phase and the final detection phase. We therefore treat the conversion of the atoms from the MOT-phase to the magnetically trapped phase in detail. It turns out that the time-dependence of a global (so position independent) field is sufficient to load a stationary atom chip.

Some preliminary diagnostics of the trapped atoms have been performed. After this thesis work was finished, the research of the group on this subjected is continued. This led to Bose-Einstein condensation of $^{87}\text{Rb}$ atoms on the chip that is described in this thesis. It also led to the development of a next generation chip, on which several hundred traps are realized and loaded. Although these
successes are not part of this thesis, they show the correctness of the choices and the engineering developed and described in this thesis.