Magnetic interactions of cold atoms with surfaces: Material engineering meets atom optics

Experiments with ultra-cold neutral atoms trapped in potentials generated by micro-structures integrated on a nearby surface (atom chips) are evolving rapidly and may soon enable robust quantum devices. This decade has seen atom chip based coherent manipulation (interferometry) of both internal and external atomic degrees of freedom.

The promise of the atom chip platform may, however, be hindered by thermal noise originating from the nearby "classical environment", specifically the motion of finite-temperature electrons present in the surface. The coupling of this noise radiation to the atoms results in atom loss, heating and decoherence. Slight imperfections in the fabrication of this nearby environment also lead to static corrugations of the trapping potential, which can cause a variation of the atoms' density in traps, as well as lead to localization in guides and perturb quantum phase evolution in interferometry. This paper describes the implications of using novel materials on the atom chip for the micro-structures creating the trapping and guiding potentials and specifically electrically anisotropic materials. Using such materials, decoherence and heating rates can be significantly reduced, even for room temperature atom chips. In addition, the amplitude of the static potential corrugation can be reduced, as typical electron scattering patterns within the imperfect wires can be controlled. Materials, fabrication, and experimental considerations are discussed. ■

T. David, **Y. Japha**, **V. Dikovsky**, **R. Salem**, **C. Henkel** and **R.Folman**, 'Magnetic interactions of cold atoms with anisotropic conductors', *Eur. Phys. J. D* **48**, 321 (2008)

Time-independent theory of ionization and breakup reactions

Under the stimulus of advances in experimental techniques and methods of numerical calculation, numerous theoretical investigations have recently been undertaken of the process of single ionization of an atom (or breakup of a nuclear target) by impact of a charged projectile. Encouraged by such advances, more ambitious programs, involving multiple ionization and nuclear breakup reactions, are now being undertaken. The theoretical basis for such calculations is rather less firm than it is for single ionization. One looks for refinements in the basic formulation of the problem to allow for more effective numerical investigations.

A rigorous theory of non-relativistic time-dependent multiparticle collisions was developed (by J. D. Dollard) quite some time ago, in which the effect of long-range Coulomb forces was accounted for by a modification of the standard wave operator, describing propagation of particles in initial and final states, that appears in treatments of neutral-particle scattering. While it establishes the existence of the scattering matrix, that theory provides no specific procedure to be used for the calculation of the transition probability.

In order to have available a method more amenable to numerical calculation, this time-dependent theory is converted, in the present work, to a time-independent form, with the wave-operator modification replaced by the use of Coulomb-modified plane waves in the construction of the wave packets that appear in the formalism. This provides a convenient basis for the development of approximation techniques in configuration space, including the use of variational methods of calculation, based on integral identities for the transition amplitudes. In many cases oscillatory divergences appear in integrals representing the ionization or breakup amplitudes; this disturbing feature is intrinsic to the theory. A rigorously justified method for removing such divergences by an averaging of the integrand at great distances is here defined. ■

L. Rosenberg, 'General time-independent theory of ionization and breakup reactions', *J. Phys. B: At. Mol. Opt. Phys.* **41**, 155203 (2008)

The "footprints" of irreversibility

The reversibility paradox stated by Loschmidt in response to Boltzmann's H-theorem illustrates the apparent incompatibility of the time reversal symmetry governing the dynamics of microscopic processes and the second law of thermodynamics ruling their macroscopic behaviour. One century later, exact equalities, referred to as work and fluctuation theorems, reveal that the very same time-reversal-symmetry puts strong constraints on the *probability distributions* of work, heat and entropy in non-equilibrium experiments involving small scale devices. These equalities are compatible with the second law of thermodynamics, but provide no extra information on the actual value of the entropy increase. Even more recently, Kawai, Parrondo, and Van den Broeck [*Phys. Rev. Lett.* **98**, 080602 (2007)] have derived from Hamiltonian dynamics the exact value of the entropy production, relating the mean work dissipated in an arbitrary non-equilibrium experiment directly to the statistical difficulty of distinguishing whether a snapshot of the microstate of the system pertains to an experiment carried out forward or backward in time.

This statistical indistinguishability is quantified through a concept from information theory: the relative entropy or Kullback-Leibler distance between two probability distributions.

Now, Gomez-Marin, Parrondo, and Van den Broeck have extended the previous result to the relative entropy between the distributions of paths or trajectories. Furthermore, by combining the mathematical properties of the relative entropy with the work theorem, they have been able to identify the relevant information to exactly evaluate the entropy production along an arbitrary process connecting two equilibrium states. Their conclusion is striking: the only relevant variables are those containing the statistical information about the work performed in the experiment. Any further information does not improve the discrimination of the arrow of time. Therefore, such variables provide, without the need of other microscopic information, the "footprints" of irreversibility. ■

A. Gomez-Marin, **J.M.R. Parrondo** and **C. Van den Broeck**, 'The "footprints" of irreversibility', *EPL* **82**, 50002 (2008)