Atomtronics with Quantum Resonant Tunneling-based Devices

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Current and Future…

- **Atomtronics is an emerging paradigm aimed at storing, guiding and building devices with atomic waves, as electrons in nanostructures, spins in spintronics and photons in photonics**

- **Advantage of using BECs is in achieving better focussed-beams with long coherence length and short "wavelength" (a few tens of nm) and efforts are currently and successfully pursued to put BECs in chips**

- **Applications of atomtronics circuitry are *e.g.* in precision measurements of fundamental constants, tests of fundamental forces (*e.g.* Casimir-Polder) and principles, interferometry, atom lithography (optical litography is bounded to 100 nm), quantum computation**

➢ **Quantum Resonant Tunneling can be the building block to develop a new generation of atomtronic devices, exploiting its (i) multifunctionality, (ii) high control, versatility, and engeneering capability, (iii) all-atomic conception**

➢ **Time-dep. tunnelling has long history and is also relevant for**

➡ ***Applications:***

* *photoinduced dynamics in strong laser fields* [Gavrila 1992]

* *high-frequency field impurity ionization* [Ganichev et al. 2002]

* *transport in superlattices under THz fields* [Guimaraes et al. 1993]

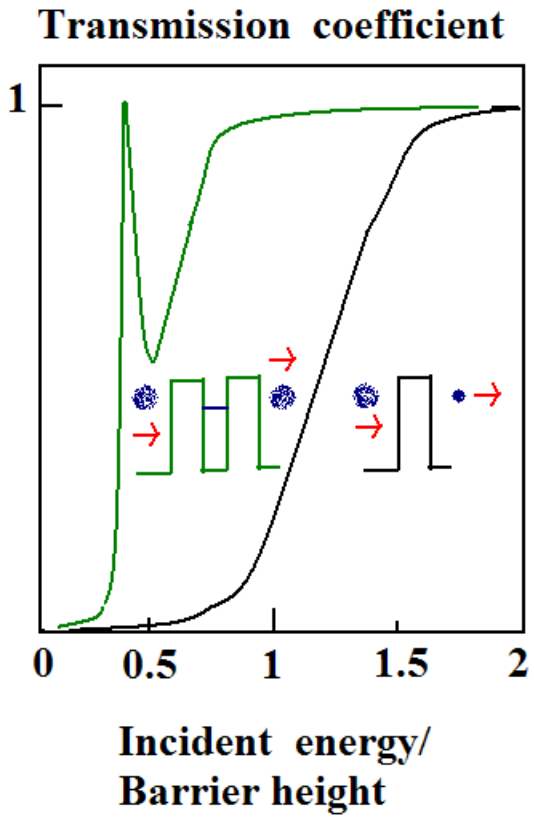
* *quantum chaos* [Hensinger *et al*., Steck *et al*. 2001, Averbukh *et al*. 2002]

* *diffusion and relaxation processes* [Doering-Gadoua 1992].

➡ ***Unravel fundamental concepts in Quantum Mechanics:***

* *the controversial notion of tunnelling time* [Buttiker-Landauer 1982].

❑ Resonant tunnelling across static double barriers manifests as a peak in the transmission of a wavepacket at energies resonant with the quasi-bound state inside the double barrier, well below the threshold for tunneling across the single barrier



❑ Resonant tunnelling is also possible when particles move across time-dependent external potentials. For example

$$V(x,t)=U(x-lf(t))$$

❑ Nearly perfect transparency has been predicted for charged particles in oscillating laser fields [Vorobeichik *et al*. 1998, Pimpale *et al*. 1991, Ge and Zhang 1996] but never observed!!!!!!!!!!!!!!!!!!!!

Goals

We predict that the use of ***ultracold atomic beams*** impinging on repulsive dipole potentials set spatially oscillating at high frequencies, *e.g.* modulated via an oscillating mirror [Anderson and Kasevich 1998, Burger et al. 2001, Cataliotti et al. 2001, Greiner et al. 2002]. yields access to the ***observation*** of :

- ***Almost perfect field-induced transparency at tunable energies*** at high frequencies [Chiofalo, Artoni and La Rocca 2003].
- ***Energy filtering of the atomic beam*** and ***generation of atom-laser sidebands*** in the so-far unexplored ***crossover region*** corresponding to intermediate frequency driving [Chiofalo, Artoni and La Rocca 2004].
- Possibly, useful effects for atom-optical devices such as ***optical limiting*** and ***optical bistability*** after exploiting nonlinear atomic interactions at high frequency driving [Embriaco, Chiofalo, Artoni and La Rocca 2004]