Using Matter-waves and optical disorder to study coherent transport and Anderson Localisation

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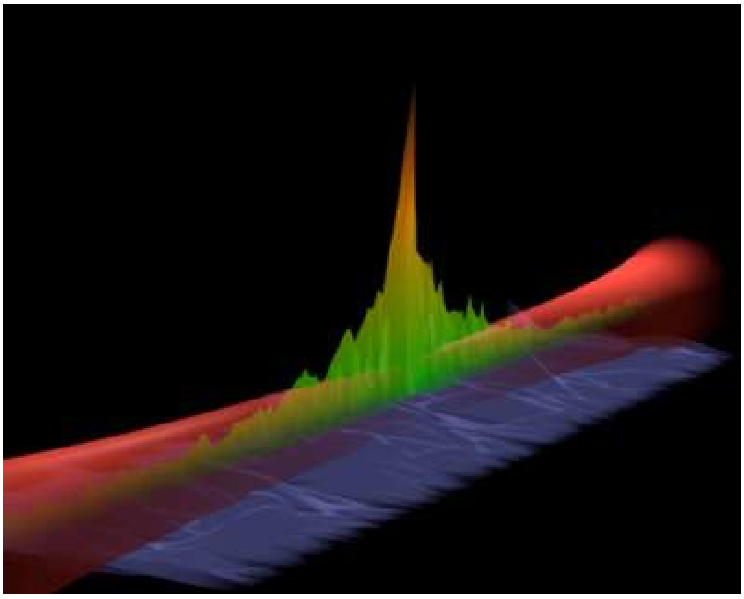

Figure 1: *Observation of Anderson localisation in 1D with an expanding Bose-Einstein Condensate in the presence of a 1D speckle disorder.*

Disorder has long proven to be a crucial ingredient to understand coherent transport properties. The most prominent example is the weak localization phenomenon in mesoscopic physics, which has been studied extensively for electrons and for classical waves. Weak localization arises from interference between multiply scattered waves in a random medium. This interference survives the configuration average over many realizations of disorder and reduces the conductivity that enters the Drude model for electron transport and the diffusion constant of classical radiative transport theory. Disorder can even induce a metalinsulator transition, known as the strong (or Anderson) localization transition. In 1958, P.W. Anderson predicted the exponential localization[1] of electronic wave functions in disordered crystals and the resulting absence of diffusion. It has been realized later that Anderson localization (AL) is ubiquitous in wave physics[2] as it originates from the interference between multiple scattering paths, and this has prompted an intense activity. Experimentally, localization has been reported in light waves , microwaves, sound waves, and electron gases.

Recent progress in ultracold atomic systems has triggered a renewed interest in quantum disordered systems where several effects such as localization. Ultracold atoms in optical and magnetic potentials provide an isolated, defectless and highly controllable system and thus offer an exciting (new) laboratory in which quantum many-body phenomena at the border between atomic physics and condensed matter physics can be addressed. We present here the observation of Anderson localization[3] of a Bose-Einstein condensate (BEC) released into a one-dimensional waveguide in the presence of a controlled disorder created by laser speckle. We also show that, in our one-dimensional speckle potentials whose noise spectrum has a high spatial frequency cut-off, exponential localization occurs only when the de Broglie wavelengths of the atoms in the expanding BEC are larger than an effective mobility edge corresponding to that cut-off. In the opposite case, we find that the density profiles decay algebraically[4].

[1]Anderson, P.W., Phys. Rev. 109, 1492-1505 (1958)
[2]Van Tiggelen, B. , In Wave diffusion in complex media, edited by J.P. Fouque, (Kluwer, Dordrecht, 1999).
[3]Billy, J., *el al.*, to appear in Nature.
[4]Sanchez-Palencia, L., , *et al.*, Phys. Rev. Lett. 98, 210401 (2007).