Coherent Back Scattering and Anderson Localization of Ultra Cold Atoms

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Abstract: Ultra cold atoms released in a disordered potential created with a laser speckle, allow one to study Anderson Localization (AL) and Coherent Back Scattering (CBS). Localization has been observed in 1D and 3D, and 2D experiments are promising. Theory supports the conclusion that what is observed is AL, but a smoking gun of the role of coherence is still missing. Recently, it has been possible to observe CBS (see Figure), an indisputable coherent effect in quantum transport, related to the first order manifestation of localization (weak localization). These experiments belong to the very active domain of simulating difficult problems of Condensed Matter Physics with Ultra-Cold Atoms placed in tailored optical potentials.

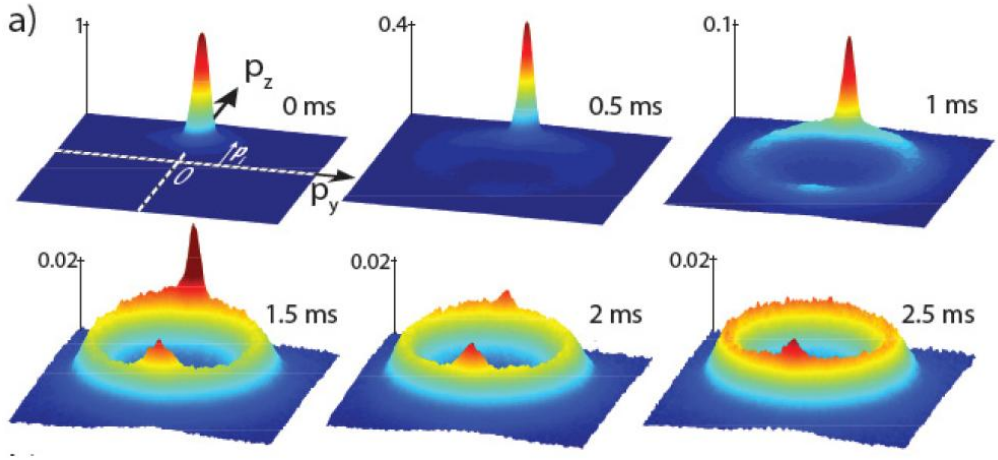

Figure 1: 2D momentum distribution of ultra cold atoms after propagation in a 2D (laser speckle) disordered potential for various propagation times. The first figure shows the initial momentum distribution. One can then see the progressive build up of the ring associated with elastic scattering, and of the Coherent Back Scattering peak still visible after the initial momentum peak has been totally washed out.

1. J. Billy, V. Josse, Z. C. Zuo, A. Bernard, B. Hambrecht, P. Lugan, D. Clement, L. Sanchez-Palencia, P. Bouyer, and A. Aspect, "Direct observation of Anderson localization of matter waves in a controlled disorder," Nature **453** (7197), 891-894 (2008).
2. G. Roati, C. D'Errico, L. Fallani, M. Fattori, C. Fort, M. Zaccanti, G. Modugno, M. Modugno, and M. Inguscio, "Anderson localization of a non-interacting Bose-Einstein condensate," Nature **453** (7197), 895-896 (2008).
3. Aspect and M. Inguscio, "Anderson localization of ultracold atoms," Physics Today **62** (8), 30-35 (2009).
4. S. S. Kondov, W. R. McGehee, J. J. Zirbel, and B. DeMarco, "Three-Dimensional Anderson Localization of Ultracold Matter," Science **333** (6052), 66-68 (2011).
5. F. Jendrzejewski, A. Bernard, K. Muller, P. Cheinet, V. Josse, M. Piraud, L. Pezze, L. Sanchez-Palencia, A. Aspect, and P. Bouyer, "Three-dimensional localization of ultracold atoms in an optical disordered potential," Nature Physics **8** (5), 398-403 (2012).
6. M. Piraud, L. Pezze, and L. Sanchez-Palencia, "Matter wave transport and Anderson localization in anisotropic three-dimensional disorder," Epl 99 (5) (2012).
7. M. Robert-de-Saint-Vincent, J. P. Brantut, B. Allard, T. Plisson, L. Pezze, L. Sanchez-Palencia, A. Aspect, T. Bourdel, and P. Bouyer, "Anisotropic 2D Diffusive Expansion of Ultracold Atoms in a Disordered Potential," Physical Review Letters 104 (22) (2010).
8. F. Jendrzejewski, K. Muller, J. Richard, A. Date, T. Plisson, P. Bouyer, A. Aspect, and V. Josse, "Coherent Backscattering of Ultracold Atoms," Physical Review Letters **109** (19) (2012).

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