

Mathematics and Physics of Anderson Localization: 50 years after

14 July to 19 December 2008

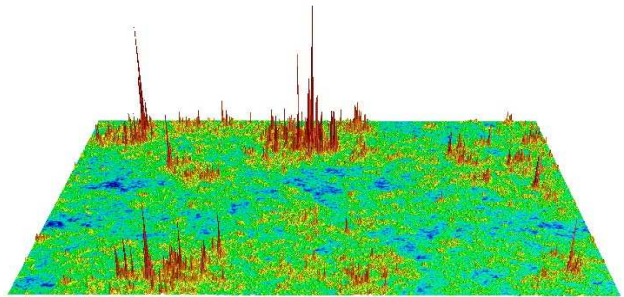
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Although on a cloudy day there is no direct view of the sun, the light is still there: it is the diffuse light scattered by tiny drops forming the clouds and reaching us from all directions. For a long time it was considered to be natural to describe the light intensity propagation through a random medium as a simple diffusion process. This approximation successfully explains many important phenomena. However, it neglects the wave nature of light which may be essential in more delicate experiments. Interference is one of such intrinsic wave phenomena. It is responsible for the increase of the strength of two in-phase waves overlapping at the same point of space ('constructive' interference), as well as for reduction of wave intensity when overlap involves two out-of-phase waves ('destructive' interference).

Interference effects play a particularly important role in the quantum world since Quantum Mechanics teaches us that all particles may demonstrate wave properties. In particular, interference effects play an essential role in understanding electric conductivity in disordered solids. Most real-life solids do have imperfections in their structure and this fact motivated pioneers like PW Anderson and NF Mott in their effort to develop the theory of quantum wave propagation in the presence of randomly placed scatterers.

One of the most striking and far-reaching discoveries of this theory is the phenomenon of Anderson localization. In 1958, Anderson conjectured that strong enough disorder (e.g. high concentration of defects in crystals) can essentially halt propagating waves and stop the diffusion of wave intensity through the random medium. In the context of electric properties of disordered solids, this leads to the possibility of electron localization, converting good conductors into insulators. The transition from the pattern of waves randomly spread over the whole available volume to the regime when the wave intensity is confined to a relatively small spatial region, is believed to occur in an abrupt manner and is known under the name of 'the Anderson localization transition'.

Precisely at the point of the transition, one expects a very non-trivial wave intensity pattern with intriguing 'multi-fractal' properties (see the figure below). Being related to interference between multiply scattered waves, Anderson localization also applies to the transport of many types of waves: quantum, electromagnetic, acoustic, and even ocean waves propagating over a random seabed. It also proved to be crucial for an understanding of such important phenomena as the Integer Quantum Hall effect and mesoscopic fluctuations in small conductors.



Multifractal wave function at the critical point (courtesy of F Evers, A Mildenberger, and A Mirlin, unpublished)

Over the years, both physicists and mathematicians contributed greatly to the understanding of various features of Anderson Localization. So far, however, many heuristic predictions made by physicists resisted rigorous mathematical understanding, and this despite many non-trivial insights obtained by mathematicians over the years. The program will bring together the world leaders in the spectral theory of random Schrödinger operators and theoretical physicists successfully working on the problem of Anderson localization, to review the state of the art in both communities, to discuss conceptual as well as technical difficulties and to map new directions of research. This mixture of expertise should provide a unique environment for fruitful collaboration between physicists and mathematicians, and ensure further progress in this fascinating area of mathematical physics.