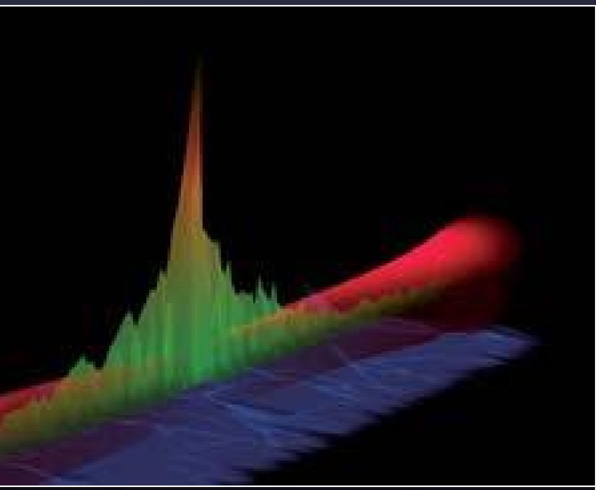
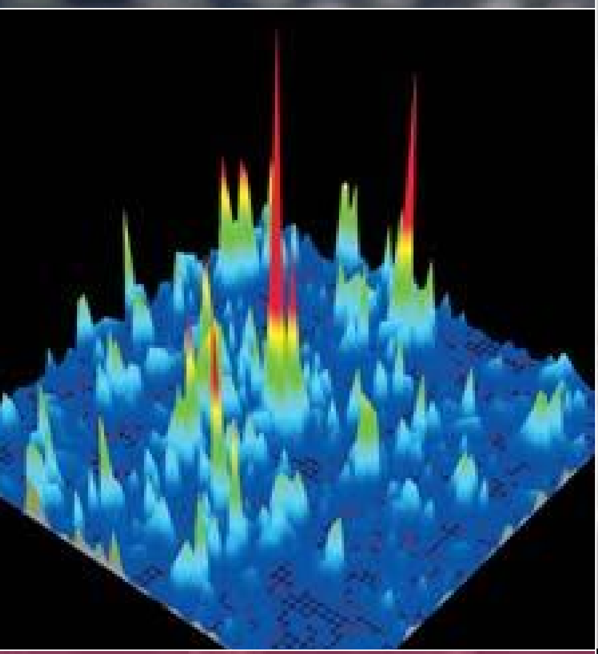
Understanding matter

Why do alloys age prematurely? How do amorphous materials flow? Under what conditions does a metal suddenly become an insulator? The properties of matter are studied from every angle, right down to the very heart of the atom.



> Observation of Anderson localization in one dimension for atomic waves. In green, the localization of atomic waves, brought to a halt by a slight optical disorder (shown in blue). In red, the light axis along which the atoms moved.



> Spatial distribution of sound intensity transmitted through a sample of aluminium beads. Very sharp peaks are characteristic of the Anderson localization regime.

Quantum physics

ELECTRONS HATE DISORDER

Three results have confirmed experimentally what Philip Anderson had predicted in 1958, and which won him the 1977 Physics Nobel Prize. When impurities are introduced into certain conducting metals they suddenly become insulating. Anderson considered that it was the disorder introduced by the impurities that stopped the movement of electrons. On a macroscopic scale, that's a bit like saying that a few blades of grass scattered haphazardly over a golf course could stop a full-speed golf ball in its tracks. It seems hard to believe. But that's what happens on microscopic scales, where matter can also behave like a wave. In a perfectly ordered solid, an electron moves freely without being disturbed by the underlying regular crystal structure. In disordered solids, however, any flaw will diffuse the matter wave in multiple directions. Combining all these disorder-generated waves can lead to a wave that does not propagate and remains frozen within the crystal. The electrons (or the atoms) stop moving which, in the case of electrons, turns the material into an insulator. The first experiment made it possible to directly observe the phenomenon in one dimension, and showed that sufficient disorder led to the complete immobilization of waves of ultra-cold atoms. Then, by using acoustic waves, the researchers observed this phenomenon, known as Anderson localization, in three dimensions. Finally, a third team was able to show how an increase in disorder leads to a gradual increase in resistivity. It has taken fifty years for the Anderson localization to be observed directly, making France one of the world leaders in this field.

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> Sample made up of aluminium beads 4.11 mm in diameter, used to study Anderson localization in three dimensions with acoustic waves.