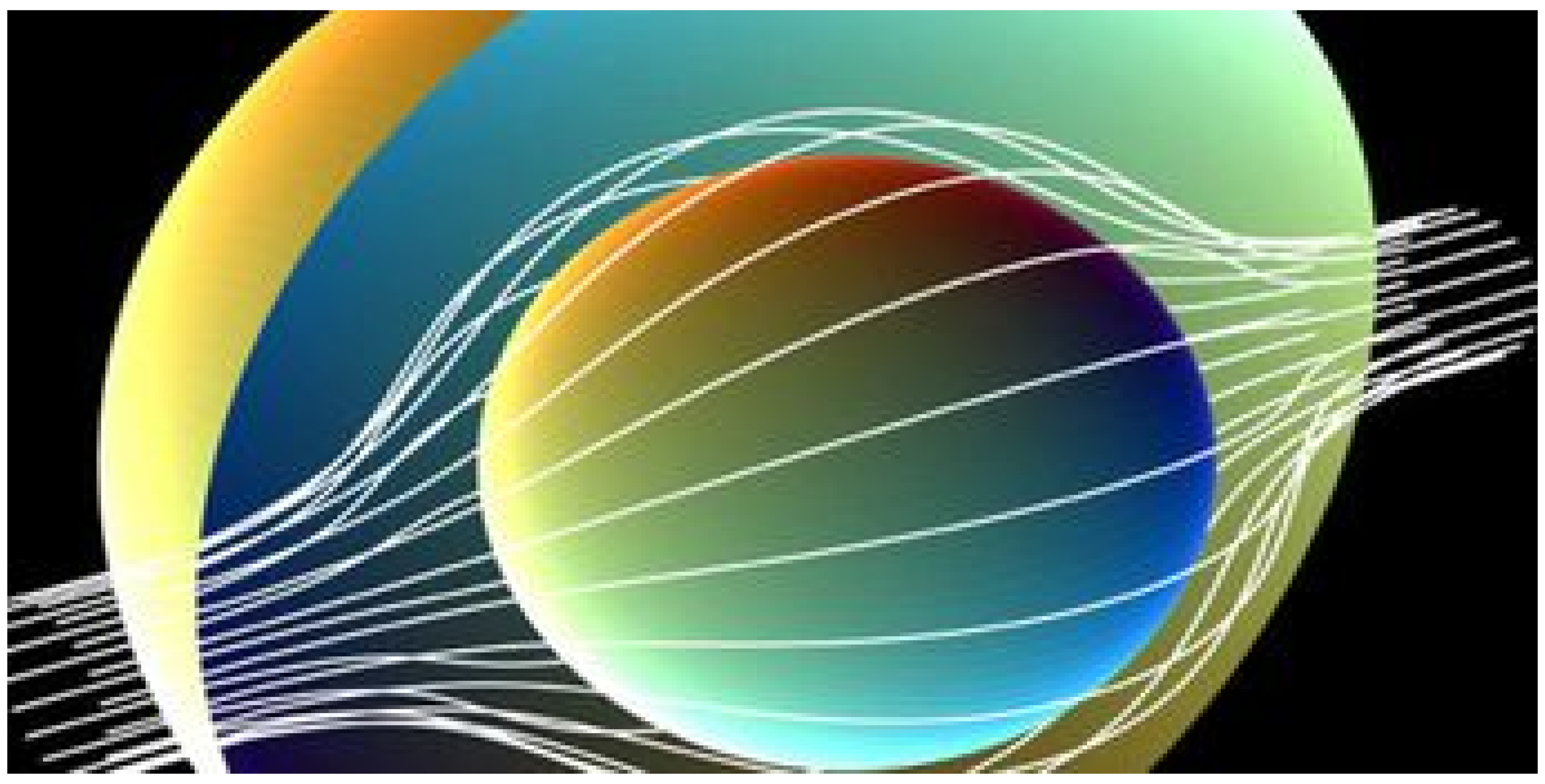
Imperial College London

CONDENSED MATTER THEORY

Condensed matter physics is the study of the immense variety of solids and liquids provided by nature or made by humans. Metals, magnets, ceramics, semiconductors, foams, membranes, superfluids, superconductors, granular systems, polymers, complex liquids, planetary interiors, and graphene are examples of the sorts of things we work on. Solids and liquids are understood to the extent that the Schrödinger equation provides an accurate "grand unified theory" at the atomic scale. However, assemblies of huge numbers of simple objects often show emergent behaviour that could never have been guessed from their individual properties. One atom on its own is a dull thing, but the emergent properties of huge numbers of atoms give the world, and our subject, their astonishing variety and richness. The idea of emergence is not restricted to atoms. Our Complexity and Networks Group studies emergence in social and biological systems. Understanding materials also enables us to develop new ones to perform according to our wish. Our group has world-leading expertise in 'condensed matter optics'. Using nano-photonics and plasmonics, we design 'metamaterials' to manipulate and harvest light with unprecedented control.

METAMATERIALS

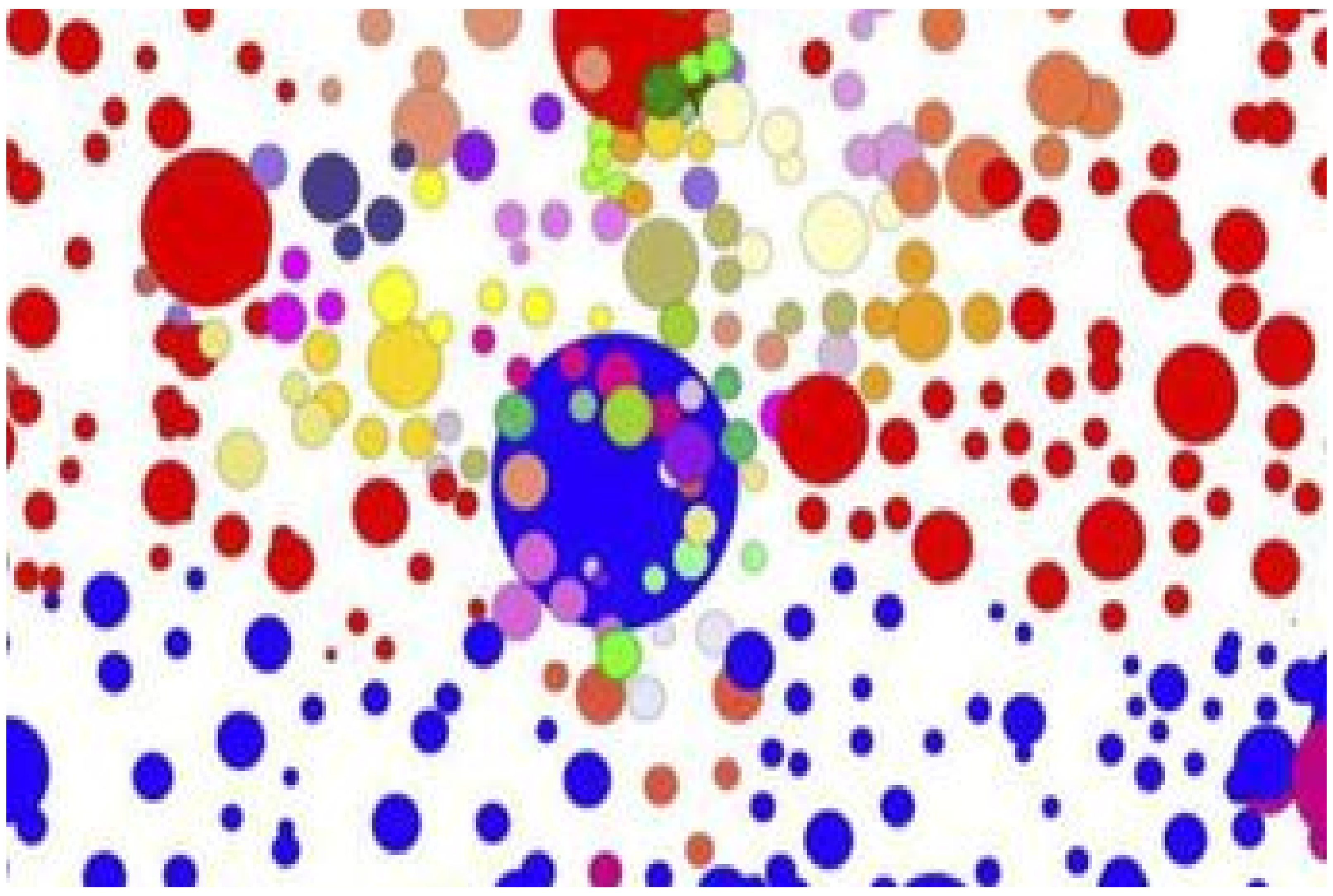
Imperial is the home of Metamaterials. John Pendry's revolutionary ideas are simple but change and expand our understanding of the world in profound ways. Metamaterials exploit the idea that physically structuring on a scale less than the wavelength can dramatically alter a material's property. Using man-made metamaterials, one can construct a perfect lens that, unlike a conventional lens, does not have limitations in the sharpness of the image or one can guide light around an object, rendering it in effect invisible, see Fig. 1. Devices using metamaterials are already finding their way into production and are likely to become common in the future.



John Pendry et al. proposed a way to guide light over or around an object using metamaterials with exotic optical properties. The invisibility cloak deflects microwave beams as they flow around an object hidden inside it, in the same way that water in a river flows around a stick.

COMPLEXITY SCIENCE

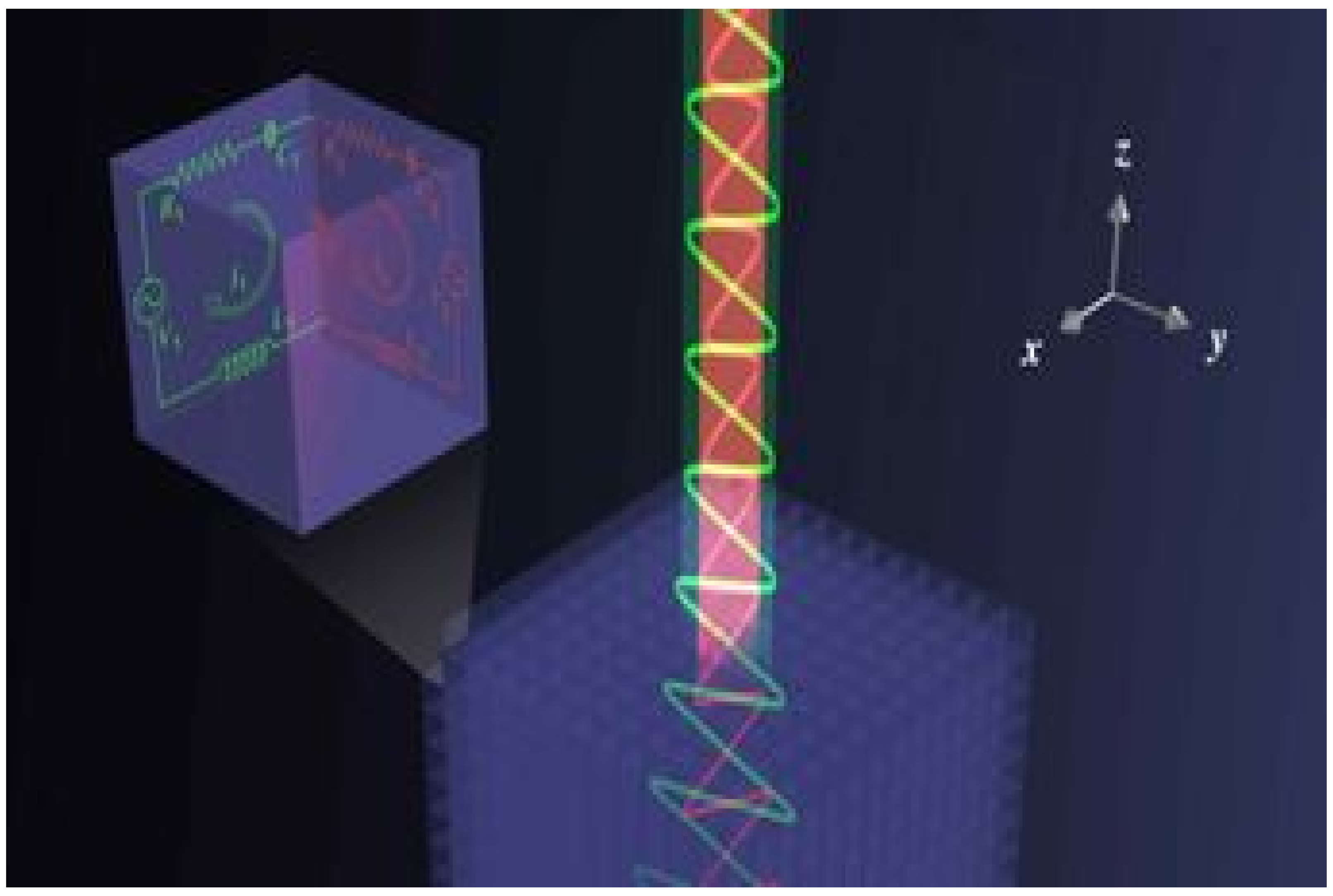
The K richness and complexity in condensed matter physics reflects the fact that new organised behaviour emerge from the collective behaviour of simple interacting objects, whether they are electrons in a metal or agents in a social network. The study of emergent phenomena is a central theme of modern condensed matter physics. We are part of the Complexity and Networks Group at Imperial which focus on the interdisciplinary application of these principles to a variety of stochastic phenomena, ranging from ant colonies to cardiovascular biology, from sandpiles to earthquakes.



An ant-colony is the prime example of a complex system in Nature. The colony is a self-organized adaptive society who's macroscopic (colony-level) properties originate from interactions at the microscopic level among the individual ants themselves and between individuals and the environment. Without a blue-print, the self-organizing bottom-up structure can accomplish incredible feats that are impossible to complete for ants in isolation.

CORRELATED QUANTUM SYSTEMS

On the microscopic scale, strongly correlated quantum systems exhibit emergent phenomena in terms of exotic quantum phases of matter in equilibrium or novel dynamical behaviour out of equilibrium. This can lead to systems exhibiting novel exchange statistics which allow for quantum computing, to materials that have additional speeds of sound with a rich and complex set of dynamics, or to materials which exhibit chirality in the presence of disorder. Our work encompasses a wide variety of quantum mechanical systems such as nano-electromechanical devices, liquid helium films and ultracold atomic clouds.



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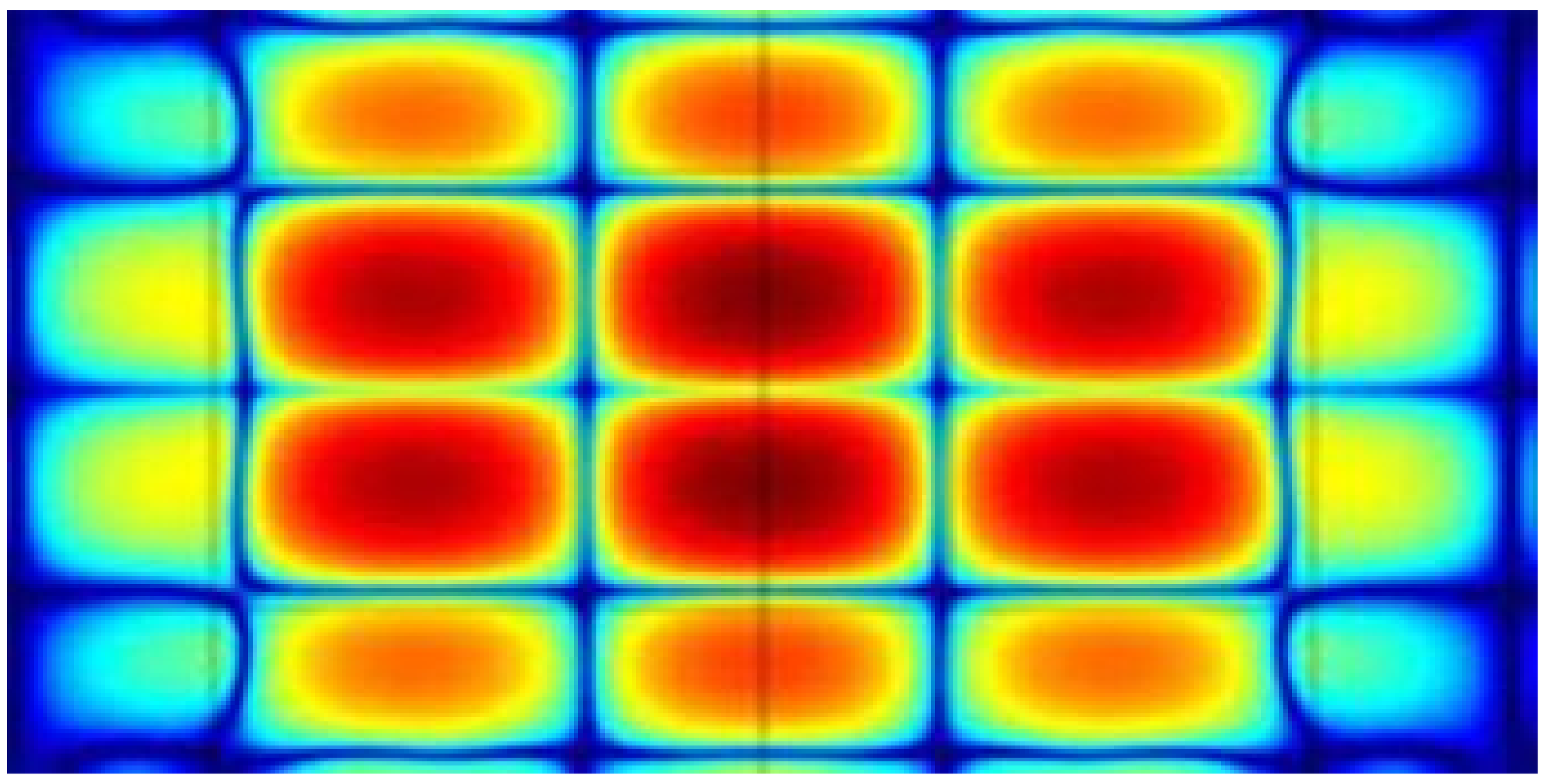
PHYSICS OF MATERIALS

New materials have played a central role in the development of civilisation from the Bronze Age to the Semiconductor Age. We have developed widely used computational codes to solve the equations of quantum mechanics to predict the electronic behaviour at the nanoscale, structural properties at the microscale, or material behaviour on macroscopic length and time scales.



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