Physics Department Colloquia Speakers 2021/22

Prof Mark Dennis (University of Birmingham)

How to tie an optical field into knots and links

Friday 26 November 2021

Tying a knot in a piece of string can be a hard practical problem. It seems even harder to tie a field into a knot – say a function from real 3-dimensional space to the complex numbers such that the function is zero on a curve which is a given knot or link. Nevertheless, several ways of doing this have been proposed in recent years, linking several areas in modern optics such as optical vortices, position-dependent polarisation, optical helicity and tightly-focused beams. I will discuss recent progress in this area, including creating laser beams containing a variety of different knots and links, detecting knottedness in random speckle fields and relations with knots in other systems such as fluids, nuclear physics and quantum chaos. I will conclude with some comparisons with 3D topological textures and skyrmions.

Prof Corentin Coulais (University of Amsterdam)

Non-orientable order and non-Abelian response in frustrated metamaterials

Friday 10 December 2021

From atomic crystals to bird flocks, most forms of order are captured by the concept of spontaneous symmetry breaking. This paradigm was challenged by the discovery of topological order, in materials where the number of accessible states is not solely determined by the number of broken symmetries, but also by spacetopology. Until now however, the concept of topological order has been linked to quantum entanglement and has therefore remained out of reach in classical systems. Here, we show that classical systems whose global geometry frustrates the emergence of homogeneous order realise an unanticipated form of topological order defined by non-orientable order-parameter bundles: non-orientable order. We validate experimentally and theoretically this concept by designing frustrated mechanical metamaterials that spontaneously break a discrete symmetry underhomogeneous load. While conventional order leads to a discrete ground-state degeneracy, we show that non-orientable order implies an extensive ground-state degeneracy–in the form of topologically protected zero-nodes and zero-lines. Our metamaterials escape the traditional classifi-cation of order by symmetry breaking. Considering more general stress distributions, we leverage non-orientable order to engineer robust mechanical memory and achieve non-Abelian mechanical responses that carry an imprint of thebraiding of local loads. We envision this principle to open the way to designer materials that can robustly process information across multiple areas of physics, from mechanics to photonics and magnetism. https://arxiv.org/abs/2111.13933

Prof Hendrik Ulbricht (University of Southampton)

Testing quantum mechanics and gravity with levitated mechanical systems

Friday 4 March 2022

I will introduce the general context of macroscopic quantum physics, discuss a few concrete proposals to measure gravity of quantum systems, to test wavefunction collapse models as well as effects on quantum systems in non-inertial reference frames. I will then report on our focused experimental progress to probe into macroscopic quantum mechanics and gravity, as well as the theoretically predicted interplay of both theories in the low-energy regime. The illustration of quantum optomechanics and magnetomechanics experiments, as performed at Southampton, will be the core topic of my talk.

Prof Peter A. Bobbert (Technische Universiteit Eindhoven)

Thermodynamic theory for light-induced halide segregation in mixed halide perovskites

Friday 18 March 2022

Mixed halide perovskites that are thermodynamically stable in the dark demix under illumination. This is problematic for their application in solar cells. We present a unified thermodynamic theory for this light-induced halide segregation that is based on a free energy lowering of photocarriers funnelling to a nucleated phase with different halide composition and lower band gap than the parent phase. We apply the theory to a sequence of mixed iodine-bromine perovskites. The spinodals separating metastable and unstable regions in the composition-temperature phase diagrams only slightly change under illumination, while light-induced binodals separating stable and metastable regions appear signalling the nucleation of a low-band gap very iodine-rich phase. We find that the threshold photocarrier density for halide segregation is governed by the band gap difference of the parent and very iodine-rich phase. Partial replacement of organic cations by cesium reduces this difference and therefore has a stabilizing effect. We predict that three-phase coexistence should occur of an I-rich phase, a Br-rich phase, and a light-induced very I-rich phase around the critical point for halide demixing in the dark. Experimental verification of this three-phase coexistence is of fundamental interest and will help unravel the mechanism behind light-induced halide segregation in mixed halide perovskites.

Prof Jonathan Reid (University of Bristol)

SARS-COV-2: Respiratory aerosols, droplets and airborne transmission

Friday 25 March 2022

Aerosols of respirable size (<10um diameter) are exhaled when breathing, speaking and coughing and can transmit respiratory pathogens. Improved quantification of number and mass exhalation rates could support estimates of viral shedding and assessments of transmission risk. Previous studies report aerosol concentrations in an exhaled plume; we will present absolute exhalation rates from measurements of minute ventilation using cardiopulmonary exercise testing with exhaled particle concentrations. Measurements are made in a zero-background space to ensure all aerosols detected originate from the participant, reporting mass exhalation rates for children (aged 12-14) and adults (19-72) when breathing, speaking, singing and exercising. We will also report measurements of hygroscopic response of exhaled aerosol along with studies of evaporation rates and phase behaviour. Aerosol and droplet size, composition and moisture content are dynamic with both drying rapidly once exhaled from the highly humid respiratory tract and we will review the interplay of dynamic and equilibrium properties in governing the distance of transmission of droplets. We will also report new measurements of the survival of SARS-COV-2 in aerosol using a novel single particle approach in a CL-3 laboratory, examining the dependence of infectivity on relative humidity and temperature.