Engineering and Physical Sciences Research Council

Engineering and Physical Sciences Research Council Doctoral Landscape Award

PROJECT TITLE: Novel Weyl metasurfaces

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Co-Supervisors: Eros Mariani

Webpage: https://physics-astronomy.exeter.ac.uk/people/profile/index.php?username=meportno

Project details: Summary: This theoretical project aims at unveiling the electronic and optical properties of novel Weyl metasurfaces hosting exotic quasiparticles with unusual "designer" dispersion, including tilted Dirac cones in the band structure. Project: Developing novel materials and metamaterials with "designer" spectra for electrons, photons, magnons and phonons is the growing trend in contemporary condensed matter physics. The tide of research is turning towards theoretical predictions followed by experimental observations of exotic quasiparticles in solid state systems such as Weyl and Majorana fermions. Since the 1980's, two-dimensional (2D) systems provided a particularly rich playground for the discovery of new quasiparticles, including fractionally charged anyons in quantum Hall systems and massless Dirac fermions in graphene and topological insulators as the most spectacular examples. Simultaneously, the most recent advances in nanotechnology include the development of van der Waals heterostructures (artificial few-layer materials held by van der Waals forces) and finding a way of producing carbon nanotubes of selected chirality. The proposed theoretical PhD research will start by addressing the electronic and optical properties of novel designer 2D van der Waals materials formed by a planar arrays of single-walled carbon nanotubes. We will then extend the core ideas from this setup to other 2D Weyl metasurfaces (two-dimensional metamaterials with energy spectrum described by Weyl equation), including Borophene and spatially modulated graphene layers. Single-walled carbon nanotubes are long cylindrical molecules with electronic properties defined entirely by the way they are rolled from a graphene sheet. Namely, they can be semiconducting with a band gap up to several electron-volts, metallic without any band gap or quasi-metallic with a tiny band gap of a few meV induced by curvature effects. Combining the tubes in a regular planar array should result in a strongly anisotropic dispersion of the emerging 2D quasiparticles. The most interesting results are expected for arrays of metallic and quasi-metallic nanotubes for which the motion normal to the nanotube axis will result in the most dramatic changes in the electronic properties. In particular, a band gap may be opened in an array of metallic tubes or collapse for quasi-metallic nanotubes. The motion normal to the tube axis will also result in lifting the valley degeneracy in highly-symmetric zigzag nanotubes leading to tilted Dirac cones supporting a new type of 2D Weyl fermions with hyperbolic equipotential lines. An analytical description of the peculiar low-energy electronic dispersion in this system will be at the core of the proposed research. We will study a plethora of unique physical effects stemming from this dispersion including unusual magneto-transport phenomena and inter-band dipole transitions, which are expected to be in the highly sought-after terahertz frequency range.

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Project Specific requirements: In addition to the standard PhD in Physics requirements, strong mathematical skills and a keen interest in theoretical physics are desirable. Completing an integrated master's degree or MSc project in theoretical physics would be advantageous.

Potential PhD programme of study: PhD in Physics

Department: Physics and Astronomy

Location: Physics building, Streatham campus

Please direct project specific enquiries to: Please contact Prof Mikhail Portnoi (m.e.portnoi@exeter.ac.uk) or Dr Eros Mariani (e.mariani@exeter.ac.uk) for additional information.

Please ensure you read the entry requirements of programme to which you are applying.

To apply for this project please click here.