Nano-carbon Photonics

Primary Objectives
The objective of this project is to develop a new, environmentally friendly and yet versatile materials technology platform for photonic and optoelectronic devices based on polymer composites of tailored Nanocarbons, targeted specifically to the eye-safe 2 μm near-infrared region, with enormous potential e.g. in industrial processing, free-space communications & medical procedures, but well beyond what is currently widely accessible.

A specific novel objective is to prepare tailored nanoscale optoelectronic materials by noncovalently coupling dye aggregates to carbon nanotubes and graphene. This clean approach is a new pathway to derive transformative functionalities in nanoscale materials. In addition, this particular “bottom-up” approach enables us to correlate the atomic structure of the assembled nanostructures to their optical and optoelectronic properties, facilitating the elucidation of the fundamental mechanism of photosensitisation.

The general logic structure of the project is best shown graphically.
Selected target application demonstrations are:

- Light trapping structures for improved photovoltaic devices
- Near Infrared (NIR) photoemitting structures to demonstrate NIR OLEDs and possible NIR lasers
- Nonlinear optical applications including broadband optical limiters and modelockers, and ultrafast all-optical switches.

Scientific context and ground breaking nature:
Photonics technology has become an important part of our daily life, spanning telecommunications, displays, lighting, renewable energy to biomedical sensors and devices. It has also been identified as one of the main technology driver in the 21st century. Particularly, the current worldwide introduction of Fibre-to-the-Home technologies necessitates components which are efficient, cheap, easy to install and environmentally safe.

Going further into the Near Infrared (NIR), 2 μm technology has the potential to open a whole new area of ICT and industrial applications. The well-known power scaling advantages, from increased core size & higher non-linear thresholds, offer a tenfold increase in “raw laser power” compared with current 1 μm technology. Perhaps more importantly, a host of applications specific to this almost unexplored region of the eye-safe spectrum are obvious; including industrial processing, free-space communications & medical procedures. To date, a lack of suitable components blocks R&D in this field.

Most active photonic devices rely on inorganic semiconducting compounds. The increasing use of nanostructures has created a concomitant increase in complexity and cost of fabrication equipment. Furthermore, the chemicals used in most active devices, e.g. GaInAlAs or InP, contain heavy metals and toxic halides with potential environmental and health hazards.

In this proposal, a novel interdisciplinary approach to deal with all the above issues by employing a range of tailored Nanocarbon doped polymer composites is taken. In addition to 'neat' Carbon Nanotube and Graphene/Graphene Oxide containing materials, dye aggregates, i.e. supramolecular assemblies of dye molecules, with sharp optical absorption bands and large optical cross sections will be used to photosensitise single-walled nanotube (SWNT) and graphene devices with high selectivity and sensitivity.

The aggregates will be assembled on graphene sheets and nanotubes in dispersions and on thin films, in which we can exploit their extraordinary field effect mobility to detect optical absorption
events. Intimate interaction between dye molecules and atomically clean device surfaces enables aggregate assembly.

The following are fundamental scientific issues learnt from dye aggregate-functionalized nanotube and graphene nonlinear optical and light harvesting devices:

- Structure of dye aggregates on nanotube and graphene surfaces.
- Impact of direct interaction between dye molecules and graphitic surfaces.
- Fundamental mechanism of photosensitisation of nanotubes and graphene sheets using tailored dye aggregates, as measured by ultrafast nonlinear optical and photoconduction responses.
- Impact of intense electric field near nanotube surface on dye aggregates with large linear and hyper polarisability.

These results will have a broad impact on nanoscale carbon nanotubes and graphene photonics. In addition, improving the capture efficiency of light by dye aggregates and subsequent translation of the capture event into electronic signals is relevant for solar energy generation.