

New Horizons for Nanophotonics

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The current progress in nanophotonics is explained by the excitement of achieving enhanced near-field effects and breaking the diffraction limit for light localization and imaging. Recent years have witnessed a growing research interest in the study of plasmonic structures made of the noble metals gold and silver. The resonant light-matter interaction in such structures has multiple applications ranging from bio-imaging and thermotherapy to solar cells and information storage. However, up to now only a small fraction of these promised applications has progressed to commercial products, mainly due to high losses of metals at visible frequencies and their incompatibility with advanced fabrication processes. Further progress calls for the development of novel breakthrough concepts by merging different interdisciplinary approaches and techniques, and expanding towards novel directions such as quantum physics.

The meeting ‘New Horizons for Nanophotonics’ was organized by the Royal Society and held at the Kavli Royal Society International Center, Chicheley Hall, on 23-24 May 2016. The meeting attracted an impressive international line-up of participants. We believe this meeting boosted the development of new directions in the field of nanophotonics that will lead to ground-breaking discoveries in the coming years, and that it provided novel avenues for the development of important applications. The proceedings presented on the following pages represent a snapshot of some of the topics discussed during the meeting, and also reflect on some recent trends in the fields of nanophotonics, plasmonics, and metamaterials.

The concepts of optical metamaterials penetrate actively into different fields of physics and nanotechnology and merge with material science. The important task of this merger is to incorporate new developments in the physics of metamaterials, plasmonics, and resonant dielectric structures with quantum and nonlinear optics to facilitate new discoveries. This meeting brought together leading researchers from different areas of nanoscale physics to explore the confluence of subwavelength photonics, metamaterials, quantum physics, graphene physics, and nonlinear optics. Whilst a number of breakthroughs can be already anticipated, e.g. energy-saving metadevices for optical technologies and quantum metamaterials, one of the primary objectives of the meeting was to catalyze the creation of exciting new areas of research.

Broadly, the meeting addressed one of the most significant challenges of modern photonics: the development of novel materials and devices where light is controlled at the level of subwavelength constituents with the main goal of achieving unique properties and functionalities not available in Nature. This will lead to the development of important breakthrough concepts and practical applications based on low-loss metamaterials, graphene physics, and the flexible manipulation of light in space and time with the help of nanostructures, which will enable switching, redirecting, and processing of parallel information flows by all-optical means. Importantly, a majority of those fundamental problems are not yet solved, and solving them requires the development of innovative

approaches and the development of new numerical and experimental techniques. In addition to technological applications, the theoretical methods discussed at this meeting and developed after it could benefit many other areas of nanoscale physics where the study of the properties of composite systems is required, e.g. semiconductor hetero-structures and quantum-well arrays.

One of the highlights of the meeting was the discussion of the newly developing branch of nanophotonics aimed at manipulating strong optically-induced *electric* and *magnetic* resonances in high-refractive index dielectric and semiconductor nanostructures. A unique advantage of dielectric nanostructures over plasmonic structures is their low dissipative losses which provide new and competitive alternatives for nanoantennas and optical metamaterials. This new field of nanophotonics also demonstrates that resonances in semiconductor nanostructures can be exploited to boost performance of many photonic devices such as photodetectors, solar cells, and light sources operating in the visible and near-IR spectra.

In addition, many of the implementations of the nanoscale plasmonics require strong and fast nonlinearities for controlling light with light. However, the field of photonics is based on the premise that controlling light signals with light requires intense laser fields to facilitate beam interactions in nonlinear media, where the superposition principle can be broken. This premise was recently challenged with the help of plasmonic metamaterials: it was demonstrated that two coherent beams of light of arbitrarily low intensity can interact on a metamaterial layer of nanoscale thickness in such a way that one beam modulates the intensity of the other. Applications of this phenomenon may lie in ultrafast all-optical pulse-recovery devices, coherence filters and terahertz-bandwidth light-by-light modulators. Enhancement of ultrafast nonlinearities with metamaterials arguably offers the brightest and fastest nonlinear media with potential ground-breaking applications for terahertz-rate all-optical data processing as well as ultrafast optical limiters and laser saturable absorbers.

From its very birth, nanophotonics has exhibited the potential for disruptive technological applications, aiming to complement or even replace the existing semiconductor and metallic photonic platforms. The results discussed at the Royal Society meeting and selectively presented in this special issue bring an excellent overview of the activity currently being conducted in several fields of modern nanophotonics and may boost potential interesting applications—such as active optical elements, bio- and chemical-sensors, highly sensitive Raman detection, lasing, and switching or frequency multiplexing. Importantly, the current status of the photonics industry requires quick development of new ideas and concepts, and the special issue is expected to attract attention from researchers in different fields, also bringing some educational material not available so far in the original publications and research papers. This issue also includes a review article from one of the organizers that may help in the merger of several different directions through the study of multipolar interference effects.

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