Faculty of Natural & Mathematical Sciences
Department of Physics

KING'S College LONDON

Nanostrand

The Photonics & Nanotechnology Research Group

Review of 2018

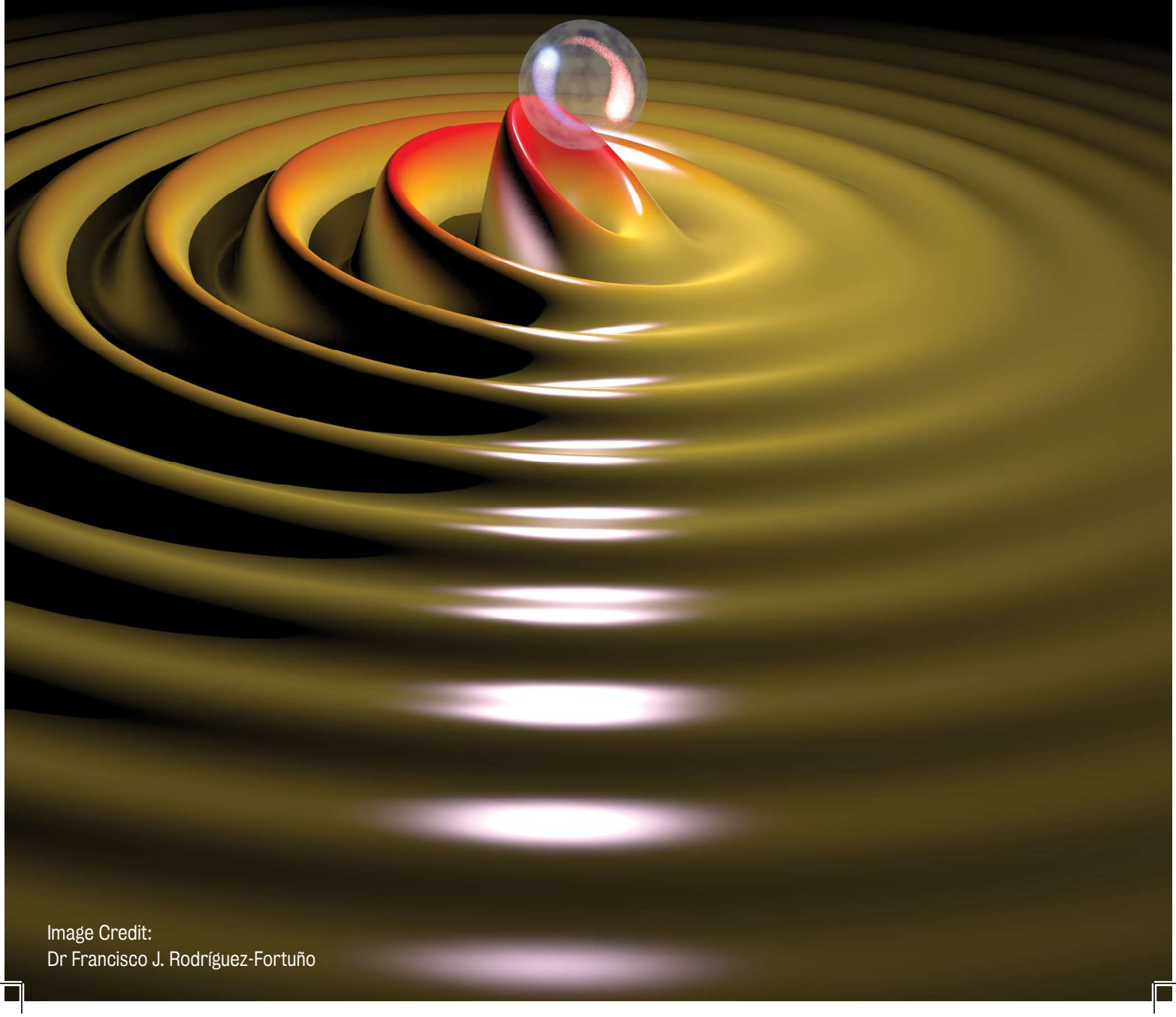
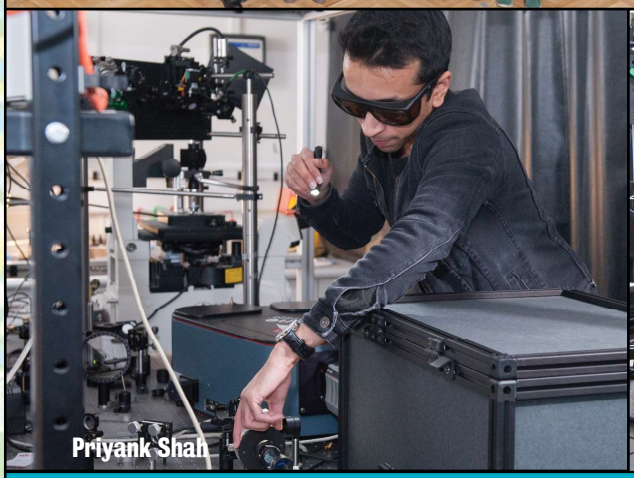


Image Credit:
Dr Francisco J. Rodríguez-Fortuño

Welcome to Nanostrand, the newsletter for the Photonics & Nanotechnology Group at King's College London

The P&N Group

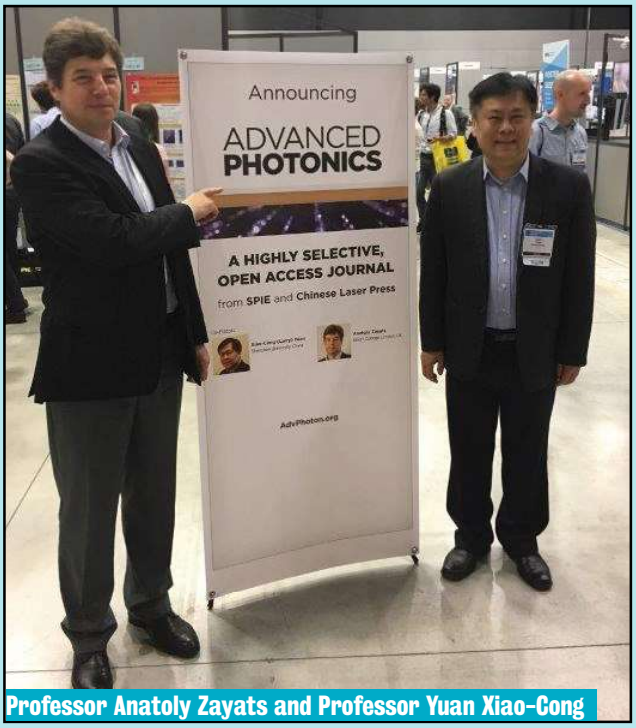
Installation by Dara Rigal - exhibited at the London Light launch



Priyank Shah

Dr Sasha Rakovich

New Journal - Advanced Photonics



Professor Anatoly Zayats and Professor Yuan Xiao-Cong

A new open access journal that will cover high-impact advances in fundamental and applied research in optics and photonics will be publised in 2019. Published by SPIE and Chinese Laser Press, the journal will be edited by Anatoly Zayats, Head of Photonics and Nanotechnology Group, and King's Alumni, Xiao-Cong Yuan (Larry), Changjiang Scholar, Director of the Nanophotonics Research Center at Shenzhen University, China.

Anatoly Zayats said 'We aim to make Advanced Photonics a trusted source of groundbreaking research in optics and optical technologies. With the benefits provided by open access, we hope the journal will be on a reading list of all researchers interested in new trends in photonic sciences.'

Advanced Photonics will also incorporate a personal approach to science, with interviews and the personal views of authors and how their new ideas emerge. Speaking about this approach, the editors said 'We hope this will make an exciting mixture of scientific and general material for our readers'

King's joins London Centre for Nanotechnology

King's College London has joined the London Centre for Nanotechnology (LCN), a London-based research group that is harnessing the power of nanotechnology to confront global healthcare, energy and environmental challenges.

Speaking about the partnership, Professor Anatoly Zayats, Head of the Photonics & Nanotechnology Group and Co-Director of the LCN: 'We are delighted to be adding the world-leading expertise of King's College London to the LCN. The combination of facilities and expertise in complimentary fields will allow the LCN to address a range of new challenges, which would not be possible for any one institution. King's, UCL and Imperial will now be able to plan and develop new facilities and capabilities to promote multidisciplinary research and develop new partnerships with industry. This partnership will help ensure that London continues to set the pace in this incredibly exciting area of research.'


LCN @ KCL Launch Event

Anatoly Zayats and Rajesh Agrawal

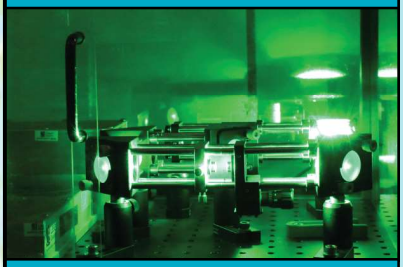
Whilst giving a speech at the lauch event, the Deputy Mayor of London for Business, Rajesh Agrawal, said: 'London has the world's leading cluster of teaching, research and innovation excellence. No other city in the world brings together the quality and range of highly ranked institutions. The LCN brings together three of the world's best universities making London a global research powerhouse in Nanotechnology.'

P&N scientist takes her research to Parliament

P&N researcher Margoth Cordova Castro is a PhD student at King's College London. She attended Parliment in March 2018 to present her physics research to a wide range of politicians as part of STEM for BRITAIN 2018. Her poster was shortlisted from hundreds of applicants to appear in Parliament. On presenting her research in Parliament, she said, 'It's an honor be part of this multidisciplinary event and meet brilliant young researchers and know about the very interesting research all around the UK. Sharing with politicians some of the results we achieved with our everyday hard work with the same motivation: push the boundaries of knowledge and try to bring new ideas and solutions to the real problems we are currently facing.'

Distinguished Lecture at Nanjing University

Head of P&N Professor Anatoly Zayats was honoured to be invited to travel to Nanjing University in Spring 2018 to deliver the distinguished lecture in Transformative Science and Engineering at the College of Engineering and Applied Science. His talk was entitiled Optical Spin-Hall Effects in Nanophotonic Technolgies



London Institute for Advanced Light Technologies launches

The London Institute for Advanced Light Technologies (London Light) launched at King's College London in May 2018 with an afternoon of installations, exhibits and talks organised to coincide with the International Day of Light. A virtual institute uniting optics and photonics research, this multidisciplinary research network brings together scientists and industries in London who work on emerging photonic technologies.

The event built around The International Day of Light, which is a global initiative that provides an annual focal point for the continued appreciation of light and the role it plays in science, culture, art, education, and sustainable development, in fields as diverse as medicine, communications, and energy.

The afternoon began with an exhibition in the King's Anatomy Museum featuring light experiments and light art, including work from artists Shelley James, Dara Rigal and Nedyalka Panova, and demonstrations by scientists and groups from King's College London and Imperial College London.

Opening talks followed in the Anatomy Lecture Theatre, with a keynote lecture from Professor Vahid Sandoghdar, Director of the Max Planck Institute for the Science of Light: 'Nano-Quantum-Optics with Organic Molecules'.

Members of the King's Nano-Optics demonstrated an all-optical sensing system based upon a nanostructured array of metallic nanorods. Dr James Millen and research student Francesco Lotti, whose experiment showed dust particles levitated by focussed laser beams. Dr Eva Philippaki with research student Michela Picardi, who showcased their research with some examples of controlling light with simple geometrical optics.

Stream Bio win Institute of Physics Award

Stream Bio, a company which developed its product at King's College London, has won the Institute of Physics Business Start-Up Award 2018 for Outstanding Innovative Work.

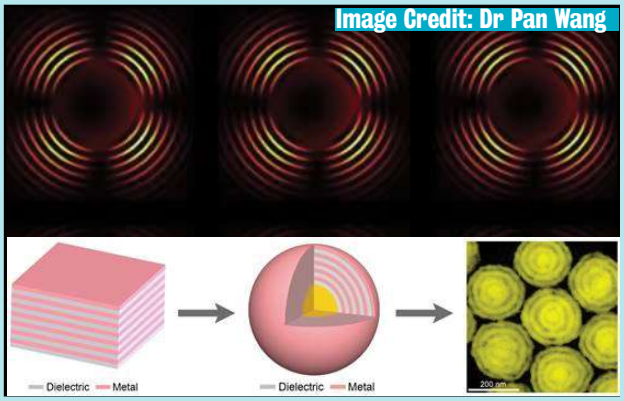
P&N Professor Mark Green is the Director of Research at Stream Bio. The company develops and manufactures a range of revolutionary bioimaging molecular probes. Their Conjugated Polymer Nanoparticles (CPNs™) were invented at King's College London. These highly fluorescent, non-toxic nanoparticles are set to transform the bioimaging market with their unique brightness, exceptional stability, magnetic capability and suitability to be conjugated with a range of molecules. They currently have diagnostics and therapeutics applications, and can potentially be used for imaging tumours and fluorescence-guided surgery.

Stream Bio collecting their award

New hyperbolic metamaterial fabricated by researchers at King's College London

Hyperbolic Metamaterials are artificial subwavelength-structured media that exhibit unusual optical properties and display indefinite dispersion. They are usually fabricated as metal nanorod assemblies or multilayers on substrates. Researchers in the Department of Physics at KCL have now developed a version of a hyperbolical metamaterial in colloidal form. Published in Laser & Photonics Reviews these hyperbolic metaparticles are dispersed in a solution and may find applications in plasmon enhanced spectroscopy, nanolasers, design of nonlinear phenomena, photothermal conversions, and hot electron generation.

Dr Pan Wang was able to make hyperbolic metaparticles using a wet chemistry method coating nano-objects with alternating silica and gold multishells. The highly anisotropic silica/gold multishells display a hyperbolic dispersion and allow the engineering of refractive index on demand, providing great flexibility in the design of the optical properties of the metaparticles. Compared with traditional bulk hyperbolic metamaterials, metaparticles in the colloidal form show many interesting advantages such as high flexibility in use (e.g., can be dispersed in a solvent, self-assembled on a surface, or embedded in a bulk



matrix) and easy excitation of hyperbolic modes by direct illumination, making them promising for many applications. For example, they can be used as optical antennas for the enhancement of spontaneous emission rate of emitters by directly dispersing them into an active solution or spreading them on an active surface. It is also possible to make metaparticles active by incorporating optical gain, such as dye molecules or quantum dots, directly into the silica shells, which is attractive for developing ultra-small nanolasers. In addition, single metaparticles can work as building blocks for the creation of complex hyperbolic structures via self-assembly, which are difficult to realize using existing fabrication methods.

P&N takes tech on the road

In 2018, the Nano-Optics team from the Photonics & Nanotechnology Group took device demonstrations to SPIE Photonics Europe 2018 in Strasbourg, participating in the Photonics Innovation Village which aimed to showcase the research and innovative products from universities, nonprofits, and research centres. One of the items on show was an ultrasensitive metamaterial sensor for the optical detection of gases. The sensor is made up of an LED light source and a photodetector. When hydrogen is present, there is a change in the reactive index of the palladium nanorods in the metamaterial which can be plotted and detected. The team believes that this set up could be miniaturised and reproduced relatively cheaply and could be useful to the chemical industry.

Later on in the year, the team travelled to Southampton


Members of the Nano-Optics team

to exhibit at the Future Photonics Hub Industry Day. Speaking of the events, Head of P&N, Anatoly Zayats said ' This technology emerged from our very basic research on metamaterials. The exhibits and live demonstration of sensing capabilities were crucial for bringing it to the attention of relevant industries and prove that it works outside laboratory environment. We are always committed to working with our industrial partners to further develop these sensors for real world'

London Plasmonics Forum 2018

The 4th annual London Plasmonics Forum was held at King's College London on the 8th June 2018. Almost 100 scientists joined the event that took place the historic Anatomy Lecture Theatre at the Strand Campus.
Professor Richard Catlow from University College London & Cardiff University gave the keynote lecture talking about Structure and Reactivity in Nano- and Oxide Catalysts. Other talks given that day came from researchers from King's College London, Imperial College London, Gothenburg University & University of Bath. The talks covered a wide range of topics branching physics, chemistry and biology.

A poster session was held during the lunchtime session in the Anatomy Museum. Many congratulations to Will Hart from the Department of Physics at Imperial College London who won with his poster 'From graphene plasmon hotspots to low-loss hyperbolic metamaterials: Applications and techniques for super-resolution imaging in the mid-infrared'.

Professor Anatoly Zayats, Will Hard & Dr Nina Meinzer

Summer Science Exhibition Lates at the Royal Society

In July, researchers form the Photonics & Nanotechnology group at King's College London made the short trip down the Strand to showcase their high quality research to members of the public at the Summer Science Exhibition Lates at the Royal Society. The demonstrations revolved around the control of light for applications in imaging metrology, sensing, quantum technologies and advanced materials for nanophotonics.

Royal Society Research Fellow Dr Sasha Rakovich's demonstration was aimed at highlighting the significance of spatial control of light for sensing applications and why nanomaterials, such as nanorods, can form the basis of next generation sensing devices.

Dr James Millen showed particles levitated by an optical trap. Used as optical tweezers in single-molecule atomic force microscopy, this demonstration enables him to explore the limits of quantum physics to build mind-bending new technology.

Dr Eva Philippaki, along with research student Michela Picardi showcased how to create real-life invisibility cloaks. Previous research in metamaterials enabled them to change optical properties and bend light, which demonstrates how cloaking can work in one dimension with simple geometrical optics.

Dr Diane Roth and Luke Nicholls demonstrated an all-optical sensing system based upon a nanostructured array of metallic nanorod. These nanorods are extremely sensitive to changes in their environment and therefore make a great optical sensor. In their demo, they used this sensing capability to detect hydrogen.

P&N Researchers Propose Two-face Dipole

Combinations of magnetic and electric dipoles are often used to generate directional electromagnetic emission in devices like nanoantennas or on-chip light emitters. Current approaches control directionality by separately manipulating the electric and magnetic fields generated by the dipoles. These approaches, however, ignore effects due to relative phase and amplitude differences between the electric and magnetic fields. P&N's Michela Picardi has proposed a new type of dipole source that can control these differences. The scheme could lead to a broad array of photonic devices such as nanorouters and polarimeters.

By taking the phase and amplitude of both electric and magnetic fields into account, the researchers developed a general theoretical framework that describes the emission of an ensemble of dipoles as well as all possible ways to couple the dipoles' emission into a waveguide. Such a framework allowed them to introduce the Janus-dipole source, consisting of two perpendicularly oriented electric and magnetic dipoles oscillating with a 90· phase difference. The source, like its namesake Roman god Janus, has two faces. One face can excite electromagnetic waves in a nearby waveguide, while the second cannot. The authors suggest that a Janus dipole could be realized using a single nanoparticle that can be simultaneously

Image Credit: Michela Picardi

polarized magnetically and electrically.
Using numerical simulations, the team analyzed a scheme in which the Janus dipole sits between two parallel waveguides. They showed that one could select which of the waveguides carries the emitted signal by switching the orientation of the dipole's two faces. This switching could be achieved by changing the polarization or wavelength of a laser beam shined on the nanoparticle.

Michaela said ' We expect novel ideas to emerge from the application of Janus dipoles in quantum optics, photonic nano-routing, photonic logical circuits, optical forces and torques of particles in near-field environments, inverse and reciprocal scenarios for polarization synthesis, integrated polarimeters, and other unforeseen devices throughout the whole electromagnetic spectrum.'

PlusAlliance Workshop On 'Nanoscale Optical Structures For High Efficiency Photovoltaic Solar Power Conversion'

P&N Researchers are part of a new project that aims to improve the efficiency of solar cells. Solar photovoltaic electricity is a ubiquitous and readily available source of power, capable of delivering electricity at vast utility scale to industrialised cities or on a small, individual scale for recharging portable lamps for use in regions of the planet that do not presently have access to electricity. As the cost of manufacturing solar cells is now extremely low, the challenge is to improve the efficiency.

Last year a workshop was organised by the PLuS Alliance to discuss emerging approaches to better solar cells. The goal of the Alliance is to empower global communities to address their local needs to create a sustainable future for all.

The workshop brought together researchers from Arizona State University (ASU), King's College London (KCL), UNSW Sydney (UNSW) and Sharp Laboratories Europe to meet at the Kavli Royal Society International Centre at Chicheley Hall.

The project 'Nanoscale optical structures for high efficiency photovoltaic solar power conversion' is led by Professor Stephen Goodnick (ASU), Professor Ned Ekins-Daukes (UNSW) and Professor Anatoly Zayats (KCL). It aims to fuse together practical techniques and computational methods that have been developed independently at ASU, KCL & UNSW to establish the next generation of highly efficient solar cells.

A selection of our recent publications

Wang, P., Krasavin, A. V., Nasir, M. E., Dickson, W., & Zayats, A. V. (2018). Reactive tunnel junctions in electrically driven plasmonic nanorod metamaterials. Nature Nanotechnology. https://doi.org/10.1038/s41565-017-0017-7

Krasavin, A. V., Segovia, P., Dubrovka, R., Olivier, N., Wurtz, G. A., Ginzburg, P., & Zayats, A. V. (2018). Generalization of the optical theorem: Experimental proof for radially polarized beams. Light: Science and Applications. https://doi.org/10.1038/s41377-018-0025-x

Wang, P., Krasavin, A. V., Viscomi, F. N., Adawi, A. M., Bouillard, J. S. G., Zhang, L., Roth, D. J., Tong,L, Zayats, A. V. (2018). Metaparticles: Dressing nano-objects with a hyperbolic coating. Laser and Photonics Reviews. https://doi.org/10.1002/lpor.201800179

Li, G., Sartorello, G., Chen, S., Nicholls, L. H., Li, K. F., Zentgraf, T., Zhang, S., Zayats, A. V. (2018). Spin and geometric phase control four-wave mixing from metasurfaces. Laser and Photonics Reviews. https://doi.org/10.1002/lpor.201800034

Picardi, M. F., Zayats, A. V., & Rodríguez-Fortuño, F. J. (2018). Janus and huygens dipoles: near-field directionality beyond spin-momentum locking. Physical Review Letters. https://doi.org/10.1103/PhysRevLett.120.117402

Gür, F. N., McPolin, C. P. T., Raza, S., Mayer, M., Roth, D. J., Steiner, A. M., Löffler, M., Fery, A., Brongersma, M. L., Zayats, A. V., Schmidt, T. L. (2018). DNA-assembled plasmonic waveguides for nanoscale light propagation to a fluorescent nanodiamond. Nano Letters. https://doi.org/10.1021/acs.nanolett.8b03524

Zhang, Y., Shen, J., Min, C., Jin, Y., Jiang, Y., Liu, J., Zhu, S., Sheng, Y., Zayats, A. V. Yuan, X.C. (2018). Nonlinearity-induced multiplexed optical trapping and manipulation with femtosecond vector beams. Nano Letters. https://doi.org/10.1021/acs.nanolett.8b01929

Marino, G., Segovia, P., Krasavin, A. V., Ginzburg, P., Olivier, N., Wurtz, G. A., & Zayats, A. V. (2018). Second-harmonic generation from hyperbolic plasmonic nanorod metamaterial slab. Laser and Photonics Reviews. https://doi.org/10.1002/lpor.201700189

Krasavin, A. V., Ginzburg, P., & Zayats, A. V. (2018). Free-electron optical nonlinearities in plasmonic nanostructures: A review of the hydrodynamic description. Laser and Photonics Reviews. https://doi.org/10.1002/lpor.201700082

Wells B, Bykov AY, Marino G, Nasir ME, Zayats AV, Podolskiy VA. (2018). Structural second-order nonlinearity in plasmonic metamaterials. Optica. https://doi.org/10.1364/OPTICA.5.001502

Rodríguez-Fortuño, F. J., Picardi, M. F., & Zayats, A. V. (2018). Repulsion of polarized particles from two-dimensional materials. Physical Review B. https://doi.org/10.1103/PhysRevB.97.205401

Minovich, A. E., & Zayats, A. V. (2018). Geometric-phase metasurfaces based on anisotropic reflection: Generalized design rules. ACS Photonics. https://doi.org/10.1021/acsphotonics.7b01363

McPolin, C. P. T., Marino, G., Krasavin, A. V., Gili, V., Carletti, L., De Angelis, C., Leo, G., Zayats, A. V. (2018). Imaging electric and magnetic modes and their hybridization in single and dimer AlGaAs nanoantennas. Advanced Optical Materials. https://doi.org/10.1002/adom.201800664

Roth, D. J., Nasir, M. E., Ginzburg, P., Wang, P., Le Marois, A., Suhling, K., Richards, D., Zayats, A. V. (2018). Förster resonance energy transfer inside hyperbolic metamaterials. ACS Photonics. https://doi.org/10.1021/acsphotonics.8b01083

Rakovich, A., & Rakovich, T. (2018). Semiconductor: Versus graphene quantum dots as fluorescent probes for cancer diagnosis and therapy applications. Journal of Materials Chemistry B. https://doi.org/10.1039/c8tb00153g

Abdelrahman, Z., Khokhlova, M. A., Walke, D. J., Witting, T., Zair, A., Strelkov, V. V., Marangos, J. P., Tisch, J. W. G. (2018). Chirp-control of resonant high-order harmonic generation in indium ablation plumes driven by intense few-cycle laser pulses. Optics Express. https://doi.org/10.1364/OE.26.015745

Stickler, B. A., Papendell, B., Kuhn, S., Schrinski, B., Millen, J., Arndt, M., & Hornberger, K. (2018). Probing macroscopic quantum superpositions with nanorotors. New Journal of Physics. https://doi.org/10.1088/1367-2630/aaece4

Córdova-Castro, R. M., Zayats, A. V, Dickson, W., Nasir, M. E., & Krasavin, A. V. (2018). Nanocone-based plasmonic metamaterials. Nanotechnology. https://doi.org/10.1088/1361-6528/aaea39

Wei, L., Zayats, A. V., & Rodríguez-Fortuño, F. J. (2018). Interferometric evanescent wave excitation of a nanoantenna for ultrasensitive displacement and phase metrology. Physical Review Letters. https://doi.org/10.1103/PhysRevLett.121.193901