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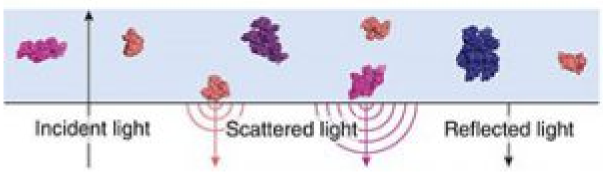
Weighing Biomolecules with Light

From imaging to mass measurement



In the authors' interferometric detection scheme, iSCAMS, the scattering signal scales with the polarizability, which is a function of the refractive index and proportional to the particle volume. That allows users to infer the mass of proteins from the scattering signal.

In existing, fluorescence-based techniques for looking at biomolecular structures and interactions, molecules must first be labeled and excited, and then emission collected from them. Other, static methods involve averaging over many molecules in a sample, and thus can't provide accurate spatiotemporal information or reflect the diversity in a sample. And state-of-the-art mass spectrometry works only in a vacuum, so it isn’t suitable for studying many biological systems in their living state.

The team behind the new research, led by University of Oxford chemists Justin Benesch and Philipp Kukura, sought a different approach—one flexible enough to look at small samples in solution, but without labelling and with improved spatiotemporal accuracy and resolution. They found a potential answer by leveraging interferometry. The researchers had, in fact, first used light scattering to image proteins back in 2014, and since then have improved the sensitivity of their technique to the point where they say it’s competitive with traditional fluorescence measurements.

The team also realized, though, that since the scattering signal scales with polarizability—which is a function of refractive index and is proportional to particle volume—its microscope should be sensitive to mass. More specifically, the researchers observed that there is very little variation (only around 1 percent) in the volumes of amino acids and the refractive indices of proteins. Since single amino acids can be considered as nano-objects, the team reasoned, the scattering signal should be proportional to the number of amino acids in a polypeptide, and thus to its mass.

From links to chains to amyloids

The group led by Benesch and Kukura, which also included other Oxford researchers and scientists from universities in Sweden, the United States, Germany and Switzerland, obtained high-quality images of single proteins diffusing from solution to bind with the interface between the microscope cover slip and solution. The signal-to-noise ratios were such that, by optimizing their data analysis, the scientists could precisely determine the scattering contrast for a single molecular binding event.

From there, the researchers obtained signatures for different oligomers—short macromolecule complexes consisting of a few simpler units—and their relative abundances. They repeated the experiments on eight different proteins to establish a linear relationship between mass and interferometric contrast, and confirmed the precision of the technique.

Once that was done, the researchers moved on to more complex systems. They were able to follow and model the evolution of various oligomeric species, and resolve changes in mass in both space and time; that enabled them, for example, to examine surface-catalyzed nucleation events that may eventually lead to the formation of amyloids, the proteins implicated in some neurodegenerative diseases (such as Parkinson's). In other words, team co-leader Benesch suggested in a press release accompanying the work, the technique allows examination of questions such as whether molecules interact, how tightly, what the composition of a protein is, and how proteins grow or fall apart.

Broadly applicable

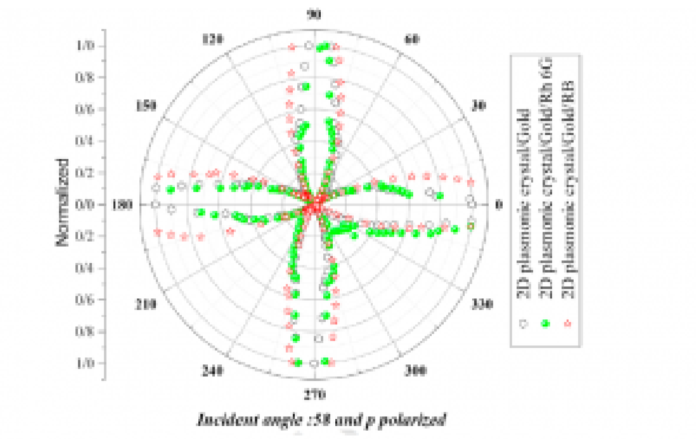
The relationship between volume, optical properties, and mass holds for molecules containing lipids and carbohydrates, as well as proteins, according to the team, so iSCAMS can be applied quite broadly. Indeed, the team finds that general applicability "tremendously exciting," team co-leader Kukura said in a press release. Essentially, the researchers point out, every physiological and pathological process involves biomolecular interactions in solution—and mass is a universal property that reveals a lot about the molecule being investigated. The technique, Kukura says, allows users to see those properties and processes playing out in real time—using a compact, "shoebox-size" instrument that's easy to operate.

The team is working on commercializing the technology and feels iSCAMS has the potential to "revolutionize how we study biomolecules and their interactions."

more information on: doi: 10.1126/science.aar5839

Our New Paper in Optical Materials

Congratulations for the publication of paper"Exciton-Plasmon Coupling in Two-dimensional plexitonic nano Grating", in journal of optical materials by N. Asgari and S. M. Hamidi.



Opto-thermoelectric nanotweezers

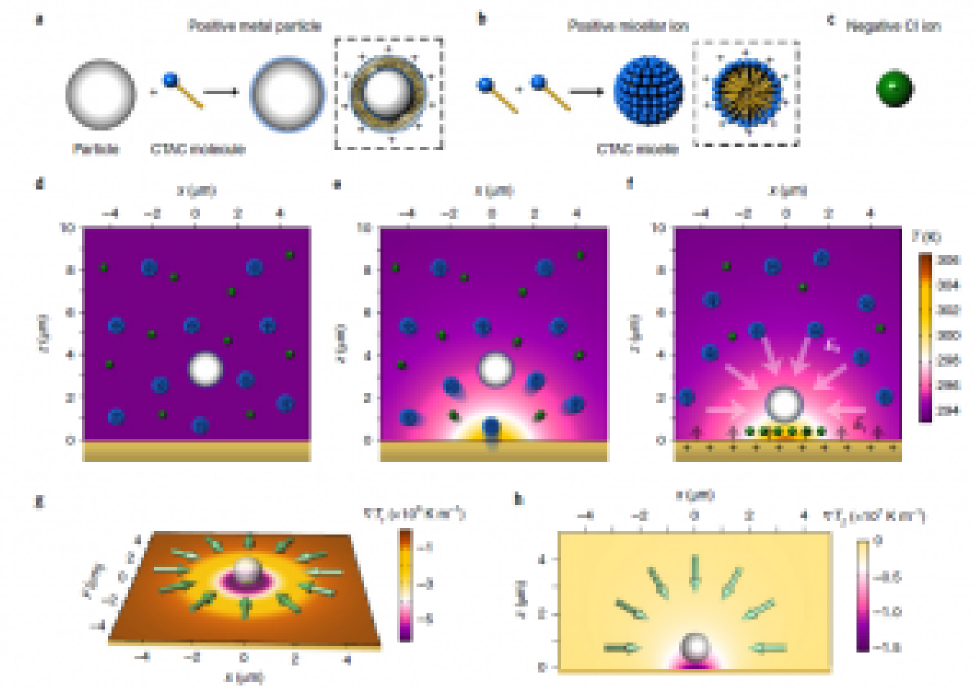


Fig. 1 | Working principle of OTENT. **a**, Surface charge modification of a metal nanoparticle by CTAC adsorption. **b**, Formation of CTAC micelles. **c**,Schematic view of a Cl− ion. **d**, Dispersion of a single metal particle and multiple ions in the solution without optical heating. **e**, Thermophoretic migrationof the ions under optical heating. **f**, Steady ionic distribution under optical heating generates a thermoelectric field E_T for trapping the metal nanoparticle.The repulsive electric field E_r arises from the positive charges of thethermoplasmoic substrate and balances E_T. **g**, Simulated in-plane temperature gradient ∇T_r and direction of the corresponding trapping force. **h**, Simulated out-of-plane temperature gradient ∇T_z and direction of the corresponding trappingforce. The incident laser beam in **e**–**h** has a diameter of 2 μ m and an optical power of 0.216 mW. The green arrows in **g** and **h** show the direction of the trapping force.

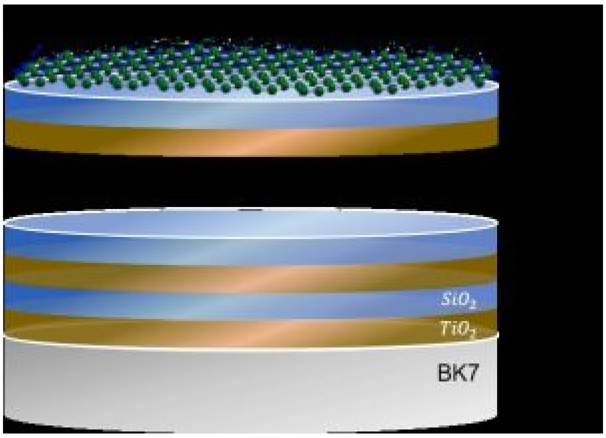
Optical manipulation of plasmonic nanoparticles provides opportunities for fundamental and technical innovation in nanophotonics.Optical heating arising from the photon-to-phonon conversion is considered as an intrinsic loss in metal nanoparticles, which limits their applications. this group show that this drawback can be turned into an advantage, by developing an extremely low-power optical tweezing technique, termed opto-thermoelectric nanotweezers. By optically heating a thermoplasmonic substrate, a light-directed thermoelectric field can be generated due to spatial separation of dissolved ions within the heating laser spot, which allows us to manipulate metal nanoparticles of a wide range of materials, sizes and shapes with single-particle resolution. In combination with dark-field optical imaging, nanoparticles can be selectively trapped and their spectroscopic response can be resolved in situ. With its simple optics, versatile low-power operation, applicability to diverse nanoparticles and tunable working wavelength, opto-thermoelectric nanotweezers will become a powerful tool in colloid science and nanotechnology.

more information on:

[1]	M. W. X. P. E. N. L. Z. M. Linhan Lin1, “Opto-thermoelectric nanotweezers,” *nature photonics,* vol. 12, pp. 195-201, 2018, https://doi.org/10.1038/s41566-018-0134-3.

Our new paper in Optical and Quantum electronics

Congratulations for the publication of paper” Demonstration of tunable complex refractive index of graphene covered one dimensional photonic crystals”, in journal of optical and quantum electronics, by S. M. Hamidi, M. Mahboubi, S. M. Mohseni, B. Azizi, A. Ghaderi, S. Javadi.



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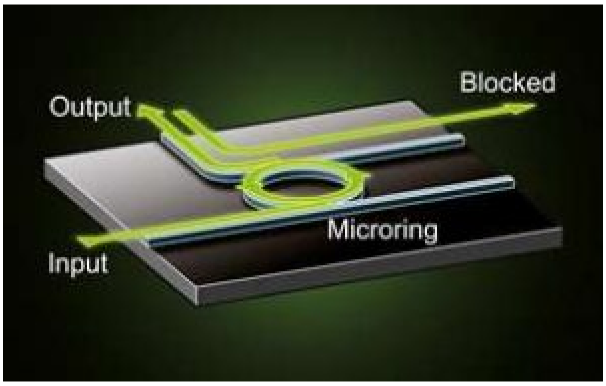
[Scientists create diodes made of light]



Photonics researchers at the National Physical Laboratory (NPL) have achieved the extra-ordinary by creating a diode consisting of light that can be used, for the first time, in miniaturised photonic circuits, as published in Optica.

Dr. Pascal Del'Haye and his team at NPL have created an optical version of a diode that transmits light in one direction only, and can be integrated in microphotonic circuits. This small-scale integration has been a major challenge in photonics because existing optical diodes require bulky magnets.

NPL’s ground-breaking work has overcome the limitation of diodes based on bulky magnets, by using light stored in tiny chip-based glass rings to form a diode.

Diodes are well known in electronic circuits. They transmit electric current in one direction but block the current in the backward direction. Diodes are essential components of nearly every electronic circuit and are used, for example, in battery chargers.

The novel technique was created by sending lots of light into a microresonator – a glass ring on a silicon chip, about the width of a human hair – and harnessing the circulating optical power to generate the diode effect.

Dr. Jonathan Silver, Higher Research Scientist at NPL, explains: “To create the optical diodes we used microrings that can store extremely large amounts of light. This meant that, even though we were only sending small amounts of light into these glass rings, the circulating power was comparable to the light generated by the flood lights in a whole football stadium–but confined into a device smaller than a human hair. The light intensities enable the formation of a diode via a light-with-light interaction called the Kerr effect.”

In their experiments, they have shown that the electromagnetic field of clockwise circulating light in these glass rings effectively blocks any counterclockwise circulating light.

Pascal Del’Haye, Principal Research Scientist of the project emphasises: “These diodes will, for the first time, open the door to cheap and efficient optical diodes on microphotonic chips, and will pave the way for novel types of integrated photonic circuits which could be used for optical computing.

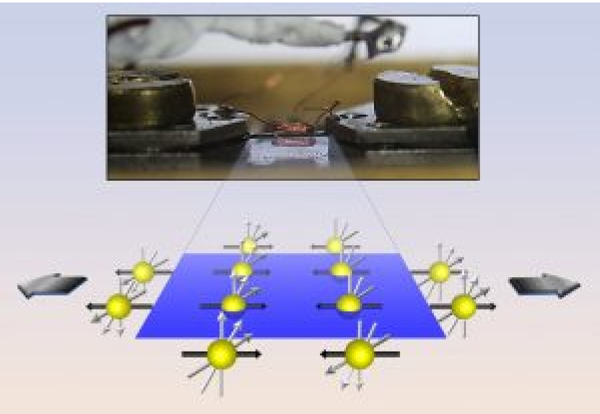
“They could also have significant impact on future optical telecommunication systems, for more efficient use of telecom networks.”

Leonardo Del Bino, Doctoral Student on the project, said: “A remarkable property of this novel diode is that the performance improves if the forward propagating light field is increased. This is very important, for example, when using the diode to protect chip-integrated laser diodes from back reflections.”

Beyond the use for optical diodes, NPL’s research on interaction of counterpropagating light can enable new types of optical rotation sensors and optical memories.

More information: Leonardo Del Bino et al. Microresonator isolators and circulators based on the intrinsic nonreciprocity of the Kerr effect, Optica (2018). DOI: 10.1364/OPTICA.5.000279

Piezomagnetic material changes magnetic properties when stretched



Piezoelectric materials, which generate an electric current when compressed or stretched, are familiar and widely used: think of lighters that spark when you press a switch, but also microphones, sensors, motors and all kinds of other devices. Now a group of physicists has found a material with a similar property, but for magnetism. This “piezomagnetic” material changes its magnetic properties when put under mechanical strain.

“Piezomagnetic materials are rarely found in nature, as far as I’m aware,” said Nicholas Curro, professor of physics at UC Davis and senior author of a paper on the discovery published March 13 in the journal Nature Communications.

Curro and colleagues were studying a barium-iron-arsenic compound, BaFe2As2, that can act as a superconductor at temperatures of about 25 Kelvin when doped with small amounts of other elements. This type of iron-based superconductor is interesting because although it has to be kept pretty cold to work, it could be stretched into wires or cables.

BaFe2As2 is what is called a “nematic” crystal because its structure goes through a phase transition before it becomes superconducting. In the case of BaFe2As2, its crystal structure goes from a square to a rectangular configuration.

Curro and graduate students Tanat Kissikov and Matthew Lawson were attempting to study the material by nuclear magnetic resonance (NMR) imaging while stretching it, to see if they could force it into the rectangular configuration. To their surprise, the magnetic properties of BaFe2As2 changed as they stretched it.

The material is not a bulk magnet — the spins of its atoms point in alternating opposite directions, making it an antiferromagnet. But the direction of those magnetic spins does change in a measurable way when under stress, they found.

“The real surprise is that it appears that the direction of magnetism can change and come out of plane,” Curro said.

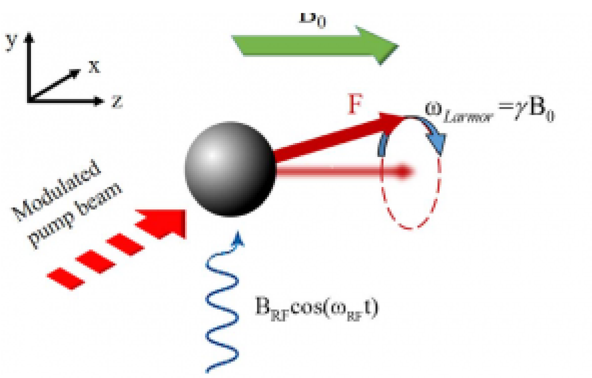
At this point, there’s no theory to explain these results, Curro said. His lab is looking to see if other materials can show the same behavior and if mechanical strain can affect the superconducting properties of the material (these experiments were not carried out at temperatures where BaFe2As2 is a superconductor).

The discovery could have applications in new ways to look for strain within materials such as aircraft components, Curro said.

More information: T. Kissikov et al, Uniaxial strain control of spin-polarization in multicomponent nematic order of BaFe2As2, Nature Communications (2018). DOI: 10.1038/s41467-018-03377-8

Our new paper in physica C

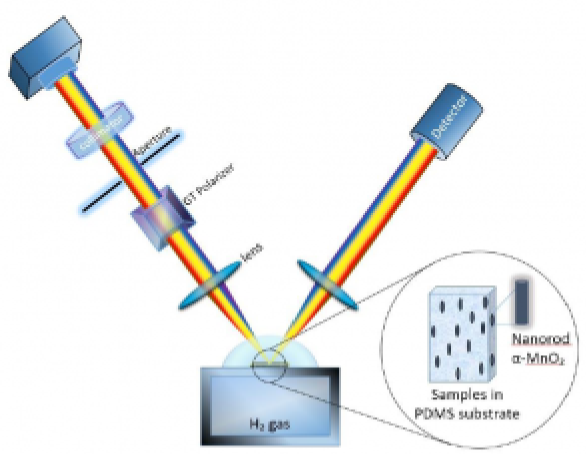
Congratulations for the publication of paper”Sensitivity optimization of Bell-Bloom magnetometers by manipulation of atomic spin synchronization”, in journal of Physica C, by Malihe Ranjbaran, Mohammad Mehdi Tehranchi, Seyedeh Mehri Hamidi, Mohammad Hossein Khalkhali.



Read more at:

https://www.sciencedirect.com/science/article/pii/S0921453417302460

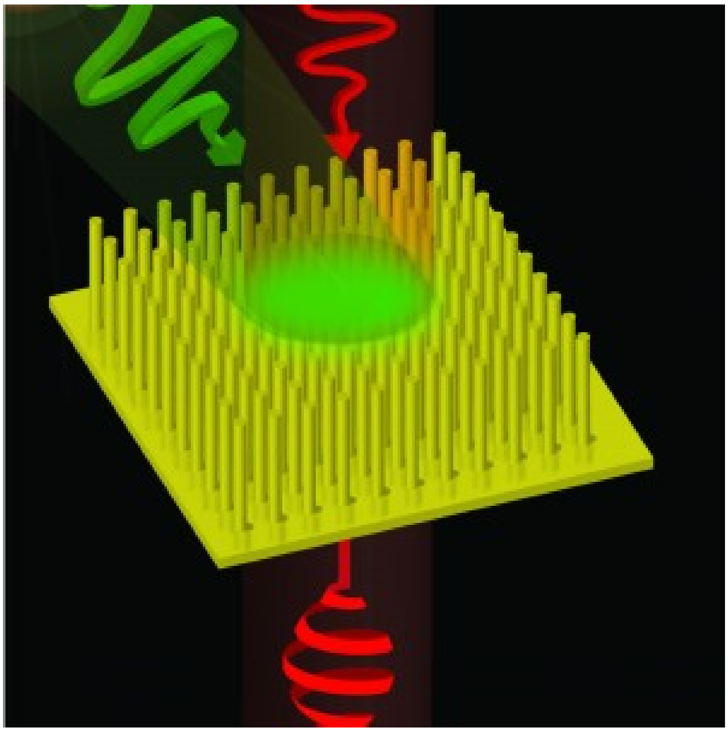
[Our new paper in Applied Physics A]



Congratulations for the publication of paper"New generation of α-MnO2 Nanowires @PDMS composite as a Hydrogen gas sensor", in journal of Applied Physics A, by Seyedeh Mehri Hamidi1, Alireza Mosivand1, Mina Mahbobi1, Hadi Arabi, Narin Azad, Murtada Riyadh Jamal.

Abstract—New hydrogen gas sensor has been prepared by α-MnO2 nanowires in polydimethylsiloxane matrix. For this purpose, the high aspect ratio α-MnO2 nanowires has been prepared by the aid of Hydrothermal method and then dispersed into Poly-dimethyl siloxane polymer media. In order to gas sensing, the samples have been exposed under different gas concentrations from 0 to 5%. The sensor responses have been examined by normalized ellipsometric parameter with respect to the chamber fill with N2 Gas. Our results indicate linear behavior of resonance wavelength in ellipsometric parameter as a function of gas concentrations which can open the new insight for the sample's capability to hydrogen gas sensing applications.

Scientists develop ultra fast method of changing fundamental property of light



Researchers from the Reactive Plasmonics team at King's College London have developed a new method for rapidly changing the polarisation of light, one of its fundamental properties. The research, published in Nature Photonics, could lead to much faster data transfer and advance research into nano-materials.

A light wave undulates in different ways – known as its polarisation. The polarisation of light is changed by the material it passes through, so we can use it to learn about unseen nano-scale worlds such as drug chemistry and quantum electronics. Switching polarisation is also used to transfer digital information along fibre optic cables.

The electronic methods currently used to control the light polarisation in such applications is reaching its physical speed limit. Researchers at King’s have overcome this problem, allowing polarisation to be switched at timescales of less than a millionth of a millionth of a second – hundreds of times faster than current electronic methods.

This will allow us to ‘see’ very fast nano-scale processes such as chemical reactions for the first time, by illuminating them with rapidly changing light. This helps us to understand the difference in formation of nasty chemicals and life-saving drugs, and allows us to study new materials that will bring about the next technological revolutions. This will also represent a major advance in data transfer speeds. By rapidly changing the polarisation of light – to represent a one or a zero – data can be passed along fibre optic cables and into your living room more rapidly. This will help meet growing data sharing demands driven by streaming and cloud services.

The team designed nano-structured materials that can control light polarisation using light itself – a technique known as ‘all-optical polarisation control’. These nano-structures are known as metamaterials: materials with optical properties not available in nature. These thin, lightweight materials are constructed from elements smaller than a thousandth of a millimetre in order to create exotic optical effects.

In this case, the metamaterial is constructed of gold nano-particles. A high intensity light pulse is fired into the metamaterial, injecting energy into electrons in gold particles, which in turn changes the refractive index of the material.

A second pulse is fired at the metamaterial at the same time. As this pulse passes through the material, the change in refractive index changes its polarisation. This all happens instantaneously, allowing polarisation to be changed trillions of times per second. By simply shining two beams of light through the material, one beam is able to control the polarisation of the other at ultrafast speed.

The effect can be observed even with one beam. In this case, the polarisation of the light transmitted through the metamaterial changes with the intensity. It is like polaroid sunglasses which adjust themselves to remove glare whenever it is too much sunlight.

Luke Nicholls, the PhD student who carried out these experiments, said, “With everybody using more and more data, streaming videos, music and sharing pictures, we are fast approaching a point where the current internet infrastructure will not be able to cope. All-optical control provides an answer to this looming problem and hopefully sees an end to staring at the infuriating buffer wheel.”

This research also has potential beyond how many box sets we can download. Control of light at such short time scales could also feed into quantum information processing, where controlling the polarisation of light is integral for building successful quantum computing devices.

Reactive Plasmonic’s PI Anatoly Zayats of King’s College concludes: “This effect opens up many opportunities for new applications which can directly impact everyday life. The faster you can control light polarisation, the faster you can use light to transmit data and make measurements.”

more information:

- *Nature Photonics* **volume 11**, pages 628–633 (2017)
- doi:10.1038/s41566-017-0002-6