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Physicists Shed Light on Precise Shape of Single Photon

"The geometry and optical properties of the environment has profound consequences for how photons are emitted, including defining the photons shape, color, and even how likely it is to exist," said University of Birmingham's Professor Angela Demetriadou.

The team's new work shows how photons are emitted by atoms or molecules and shaped by their environment.

The nature of this interaction leads to infinite possibilities for light to exist and propagate, or travel, through its surrounding environment.

This limitless possibility, however, makes the interactions exceptionally hard to model, and is a challenge that quantum physicists have been working to address for several decades.

By grouping these possibilities into distinct sets, the authors were able to produce a model that describes not only the interactions between the photon and the emitter, but also how the energy from that interaction travels into the distant far field.

At the same time, they were able to use their calculations to produce a visualization of the photon itself.

The work was published in the journal *Physical Review Letters*.

https://www.sci.news/physics/photon-shape-13438.html

Improved spin and density correlation simulations give researchers clearer insights on neutron stars

When a star dies in a supernova, one possible outcome is for the remains to become a neutron star. Inside a neutron star, the protons and electrons combine into uncharged neutrons. This substance is called neutron matter.

A team of researchers from the United States, China, Turkey, and Germany has performed ab initio (i.e., from the most fundamental principles) simulations to calculate spin and density correlations in neutron matter. They used realistic nuclear interactions at higher densities of neutrons than previously explored. Spin and density are the probability of finding a neutron in a particular position with a particular direction of spin. These correlations determine key aspects of how neutrinos scatter and heat up in a core-collapse supernova. The research is published in the journal *Physical Review Letters*.

To perform the calculations, the researchers introduced a new algorithm called the "rank-one operator method" that greatly reduces the computational effort needed to calculate observables involving several particles.

https://phys.org/news/2024-11-density-simulations-clearer-insights-neutron.html

Spin-powered crystals dramatically improve water splitting process for clean hydrogen production

Water splitting—breaking water molecules into hydrogen and oxygen—is a promising pathway to sustainable energy. However, this process has long been challenged by the slow chemical kinetics of the oxygen evolution reaction that make hydrogen production inefficient and costly.

An international research team has now uncovered a solution. By using special crystals with unique intrinsic "chiral" structures—meaning they have a distinctive left or right-handed atomic arrangement—researchers have dramatically improved the water splitting process.

The findings are published in the journal *Nature Energy*.

The topological chiral crystals, composed of rhodium and elements like silicon, tin, and bismuth, possess an extraordinary ability to manipulate electron spin. This quantum mechanical property allows electron transfer to oxygen generation in a highly efficient manner, significantly accelerating the overall chemical reaction.

https://phys.org/news/2024-11-powered-crystals-hydrogen-production.html

Novel AI algorithm captures photons in motion

Close your eyes and picture the iconic "bullet time" scene from "The Matrix"—the one where Neo, played by Keanu Reeves, dodges bullets in slow motion. Now imagine being able to witness the same effect, but instead of speeding bullets, you're watching something that moves one million times faster: light itself.

Computer scientists from the University of Toronto have built an advanced camera setup that can visualize light in motion from any perspective, opening avenues for further inquiry into new types of 3D sensing techniques.

The researchers developed a sophisticated AI algorithm that can simulate what an ultra-fast scene—a pulse of light speeding through a pop bottle or bouncing off a mirror—would look like from any vantage point.

The work is published on the *arXiv* preprint server.

David Lindell, an assistant professor in the department of computer science in the Faculty of Arts & Science, says the feat requires the ability to generate videos where the camera appears to "fly" alongside the very photons of light as they travel.

https://phys.org/news/2024-11-ai-algorithm-captures-photons-motion.html

Scientists gain new insights into how mass is distributed in hadrons

Scientists can determine the mass of subatomic particles that are built from quarks by looking at the particles' energy and momentum in four-dimensional spacetime. One of the quantities that encode this information, called the trace anomaly, is linked to the fact that physical observables from high-energy experiments depend on the energy/momentum scales involved.

Researchers believe that the trace anomaly is crucial for keeping quarks bonded in subatomic particles.

In a study published in *Physical Review D* scientists calculated the trace anomaly for both nucleons (protons or neutrons) and pions (a subatomic particle made of one quark and one antiquark).

The calculations show that in the pion, the mass distribution is similar to the charge distribution of the neutron, while in the nucleon, the mass distribution is similar to the charge distribution of the proton.

Understanding the origin of the nucleon mass is one of the major scientific goals of the Electron-Ion Collider (EIC). Scientists also want to understand how the mass from quarks and gluons is distributed in hadrons. These are subatomic particles such as protons and neutrons that are made up of quarks and held together by the strong force.

https://phys.org/news/2024-11-scientists-gain-insights-mass-hadrons.html

Theoretical model explains the anomalous properties of water in extreme conditions

Water, a molecule essential for life, has unusual properties—known as anomalies—that define its behavior. However, there are still many enigmas about the molecular mechanisms that would explain the anomalies that make the water molecule unique. Deciphering and reproducing this particular behavior of water in different temperature ranges is still a major challenge for the scientific community.

Now, a study presents a new theoretical model capable of overcoming the limitations of previous methodologies to understand how water behaves in extreme conditions. The paper, featured on the cover of *The Journal of Chemical Physics*, is led by Giancarlo Franzese and Luis Enrique Coronas, from the Faculty of Physics and the Institute of Nanoscience and Nanotechnology of the University of Barcelona (IN2UB).

The study not only broadens our understanding of the physics of water, but also has implications for technology, biology and biomedicine, in particular for addressing the treatment of neurodegenerative diseases and the development of advanced biotechnologies.

https://phys.org/news/2024-11-theoretical-anomalous-properties-extreme-conditions.html

New design for photonic time crystals could change how we use and control light

An international research team has for the first time designed realistic photonic time crystals—–exotic materials that exponentially amplify light. The breakthrough opens up exciting possibilities across fields such as communication, imaging and sensing by laying the foundations for faster and more compact lasers, sensors and other optical devices.

"This work could lead to the first experimental realization of photonic time crystals, propelling them into practical applications and potentially transforming industries. From high-efficiency light amplifiers and advanced sensors to innovative laser technologies, this research challenges the boundaries of how we can control the light-matter interaction," says Assistant Professor Viktar Asadchy from Aalto University, Finland.

The study is published in the journal *Nature Photonics*.

Photonic time crystals represent a unique class of optical materials. Unlike traditional crystals, which have spatially repeating structures, photonic time crystals remain uniform in space but exhibit a periodic oscillation in time. This distinctive quality creates "momentum band gaps," or unusual states where light pauses inside the crystal while its intensity grows exponentially over time.

https://phys.org/news/2024-11-photonic-crystals.html

Thank you!

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