The Dressed Photon:
Shining light on the unknown using the unconventional area of off-shell science

The seas of science are unrelenting: researchers have spent lifetimes trying to attain the unattainable – and fallen overboard into obscurity when they were unsuccessful. In the disciplines of Quantum Field Theory and Materials Science, the ability to create light emitting devices from silicon has long been seen as a perpetual unattainable – and fallen into obscurity for years. In the mid-90s, a similar thing happened with video: VHS gave way to DVD and we could now squeeze around four times the data that a record could hold onto a disk taking up less than 16% of the area. In 2004, Professor Motoichi Ohtsu, of Research Origin for Dressed Photon (Japan), has demonstrated, anything can be achieved if you choose the right tools. In his case, an exotic particle known as the Dressed Photon is exactly what was needed to conquer the unconquerable.

When the first Blu-ray was released, the quality of our home entertainment catalogues rocketed, with a whopping 25GB of data now easily stowed on that small disk – that’s 60 times the data that a record can contain. Have you ever wondered what was behind these leaps and bounds in home entertainment? In this particular case, advances in laser technology are what made the difference. Data is etched onto such devices using lasers – and read in the same way. The size that one bit of data takes up on a CD, DVD or Blu-ray depends on one thing only: the wavelength of light used to read and write it. For CDs, a 780 nanometre (nm) laser was used (that’s a laser that produces light with a wavelength of 780 thousand-millionths of a metre). DVDs and Blu-rays used 680nm and 405nm laser light respectively. So why don’t they just create a laser with a wavelength of 1nm and be done with it?

Well, when it comes to light emitting diodes (LEDs) and lasers, scientists have long been struggling with the same problem: the wavelength of light emitted by a device is intrinsically linked to the underlying atomic structure of the materials used. In other words, scientists can’t just decide which wavelengths they want to produce: they have to find materials, or engineer specific combinations of materials, that will give the results they are looking for. That’s why advances in this technology come in apparent sporadic leaps and jumps. Professor Motoichi Ohtsu, of Research Origin for Dressed Photon (Japan), has been able to make another leap forward in this field by creating the first ever Si-LED and laser devices. He has achieved this by exploiting the peculiarities of the recently discovered Dressed Photon.

THE DRESSED PHOTON
To understand what a Dressed Photon is, you first have to understand that the physical world is largely made up of tiny building blocks of matter and energy. Atoms are the most widely known about, but they too have their own constituent parts: neutrons, electrons and protons. In the world of sub-atomic particles such as quarks, muons, pions and bosons (amongst others). You might even have heard of the famous Higgs Boson, the so-called God particle, whose existence was finally proven at CERN in 2012. The fact is that our universe, which is bigger than we could possibly imagine, is absolutely teeming with tiny particles that are so small we can’t even see them. A photon is simply a particle of light (when light behaves to choose like a particle, that is).

Particles, of all shapes and sizes, interact with their environment in very specific ways. For example, photons can – and do – knock electrons out of their orbits on the outskirts of atoms – but only for a limited time: the ousted electron usually returns to send the photon off with a swift kick and a burst of light. Scientists call this process excitation and emission. It is a phenomenon that has been exploited throughout science to produce many of the technological wonders we currently take for granted. How a particle interacts with its surroundings can usually be described in very precise, reliable ways. Sometimes, though, particles behave unexpectedly: they appear to break the laws of conventional physics, having more influence on their surroundings than their size, or other measurable qualities, indicate they should. Scientists call these Dressed Particles and as Professor Ohtsu has demonstrated by exploiting a particularly special case, the Dressed Photon, they are beginning to lead us in completely new directions.

OFF-SHELL SCIENCE: SCOUTING THE HINTERLANDS OF QUANTUM FIELD THEORY
Physics can be divided into many different areas – classical physics, relativistic physics, quantum physics (to name a few) – and one of the great problems of our time is that these areas don’t always play nicely with each other. Quantum Field Theory (QFT) was developed to try and bridge the gap between classical field theory, special relativity, and quantum mechanics and is used to represent the world of sub-atomic particles.

In QFT, when a particle obeys a set of equations from classical physics, we say that it is an example of on-shell science.
The terminology comes from the fact that these specific equations relate to the particle's energy momentum and what physicists like to call its mass-shell (but which can be thought of as plain old mass for our purposes). When a particle doesn't obey these equations of motion, it is an example of off-shell science—an area of physics we still have much to learn about. The Dressed Photon has a lot of unique features which have never been described by the conventional quantum field theories that treat only the phenomena of on-shell science,' explains Professor Ohtsu.

Off-shell science is an extremely fertile area of physics and nobody really knows what secrets it might unlock in the future. Back in the year 1960 when a couple of unassuming physicists built the first laser, it didn’t really have the future. Back in the year 1960 when he did this, Professor Ohtsu has not engineered a new combination of materials to achieve the light emitting devices required but developed a new method for engineering them. His new approach, which he calls Dressed Photon-Phonon Assisted Annealing is a nano-fabrication technique which uses off-shell science to produce light emitting materials in a novel way. Using a technique called Joule-heating, and flooding the material with light during the process, he is able to lock-in specific wavelengths in a way that has never been seen before. The unique feature of the fabricated device is that the wavelength of the emitted light is equivalent to that of the light irradiated during the annealing," explains Professor Ohtsu. "This surprising feature is named the "Photon Breeding", which has never been observed in conventional LED and laser devices.

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