SUSTAINABILITY

Controlling Light with Nanostructures

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Quantum physics has come a long way, and the advent of nanostructures has enabled researchers to observe experiments once relegated to textbooks. Chee Wei Wong is at the forefront of examining the control of light with nanostructures, with interesting results.

"When you can trap light in a confined space and bounce it back-and-forth for a time equivalent to one million optical cycles, its intensity gets really strong," said Wong. This intensity, when tuned to resonances, such as atomic transitions or mechanical radio-frequency vibrations, can speed up or cool down the other process. An exciting subset is laser cooling of nanomechanical beams to its fundamental quantum mechanical ground state, "the coolest state of its eigenmodes," he said. With the discovery of nanostructures and coherent lasers, researchers can now explore mechanics of quantized structures, "where it's mind-boggling that so many atoms can act in such a coherent way."

Wong focuses on the physics and engineering of nanoscale optics, e.g. optical interconnects and ultrafast lasers for infrastructures, and photovoltaics for sustainability. His team can not only trap light in a small box, but also use nanostructures to slow light down, forcing increased interactions with its surroundings. Wong is compressing light pulses at 100-femtosecond timescales and generating new frequencies for next-generation optical networks.

Wong notes that even the single photon has many properties not yet fully understood. It can encode much information in its many degrees-of-freedom (vortices, timing, polarization, etc.). It can interact with a single quantum dot for new computational ways. It can interact with, or generate, another photon in non-classical distributions. It can interact with a phonon for metrology purposes. Trapped in a confined nano-space for one million cycles, many of these effects are enhanced. These have fundamental security implications because, Wong observed, "with the newly discovered ability to artificially engineer materials for negative refraction, people are fantasizing that one day we can cloak objects, hiding objects from the enemy's electromagnetic radar."

Understanding photon-material interactions has implications for next-generation photovoltaics. "The sun is our most abundant energy source and in an hour floods our planet with sufficient energy for one year, if we know how to collect it efficiently," said Wong. "We used to think each photon gives one electron (or less), and hence there is a glass ceiling on the performance and cost effectiveness of photovoltaics. It turns out that, with new materials and a better understanding of the dynamical processes, we can develop photovoltaics that are better and cheaper, trapping light longer for more electricity. This is our challenge."

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