Confining light for use in nanophotonic devices

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"There is a strong drive to make smaller and smaller devices," Hui Cao tells PhysOrg.com. "However, there are limitations to what we can do. We want faster devices than what we can get from electronics, so we are looking to photonics. Unfortunately, photonics, while having the potential to be much faster, are larger in size. Devices using electrons are smaller, on the nanoscale, while photonic devices are still on the microscale-defined by the wavelength of light."

Cao is a scientist at Yale University, and she explains that the biggest issue with creating nanoscale photonic devices to replace electronic devices, as in optical interconnects, is that the light won't stay confined on the nanoscale. "The photons leak out quickly, so there has to be a way to keep them in place so that there is enough time for them to perform functions. It is also necessary to make small light sources, such as nanolasers on chips," she says.

In an effort to move nanophotonic devices a step closer to realization, Cao and Q.H. Song, also at Yale, worked out a way that it might be possible to confine light in nanostructures. Their work is described in Physical Review Letters: "Improving Optical Confinement in Nanostructures via External Mode Coupling."

"Consider two modes, both of which are pretty leaky," Cao explains. "There is an A mode and a B mode. These two modes can be couple so that mode A gives part of its leakiness to mode B. Mode A becomes less leaking, while mode B becomes more leaky. As a result, you have efficiently increased the lifetime of mode A."

The increase in the lifetime of one of the modes in this coupling provides just what is needed to create a situation in which the light is confined. "It is no longer leaking out as much for light in mode A, and there is more time for functions to be performed," Cao says. She also points out that this type of external coupling has been successful in other fields. "It's somewhat fundamental, and once you have the ability to keep light in a nanostructure, it becomes possible to contemplate smaller photonic devices with speed capabilities beyond our current electronic devices."

So far, Cao and Song have only presented their ideas in the form of numerical simulations. "We don't have experimental results yet, but our extensive numerical calculations indicate that this should be possible, and a similar concept has been used in other fields, such as resonance trapping in atomic and molecular physics. However, this approach has not been used in nanophotonics yet."

Cao thinks that the main obstacles to experiments with this idea include fine control over nanostructures, as well as access to the proper facilities. "There is a challenge in fine control of nanostructures, but the technology does exist to overcome this," Cao says. "Mainly we are looking for access to the kinds of facilities that can fabricate the type of structure we propose. I think this kind of structure can be made using nanofabrication technology, with the right set up."

As long as an experiment can be performed to back up the numerical simulations performed by Cao and Song, there is a chance that this technique could help advance the use of nanophotonic devices. "It's kind of novel, the way we use fundamental physics to solve this problem," Cao says. "It's also realistic, and something that could be used practically in the advance of nanotechnology."

More information: Q.H. Song and H. Cao, "Improving Optical Confinement in Nanostructures via External Mode Coupling," Physical Review Letters (July 2010). DOI:10.1103/PhysRevLett.105.053902 .