

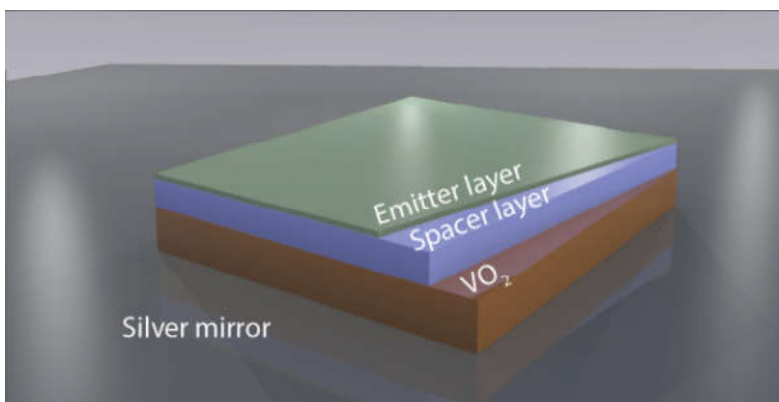
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Quick change Vanadium dioxide, a phase-change material, makes it possible to modulate phosphorescent light at unprecedented speed. *Image: Zia Lab/Brown University*

Researchers transform slow emitters into fast light sources

October 22, 2015 Media contact: [Kevin Stacey](#) 401-863-3766

Phosphors are efficient light emitters but they're not optimal for high-speed communications because they turn on and off slowly. Researchers from Brown and Harvard have now found a way to modulate light from phosphor emitters orders of magnitude faster using phase-change materials, which could make phosphors useful in a range of new optoelectronic applications.

PROVIDENCE, R.I. [Brown University] — Researchers from Brown University, in collaboration with colleagues from Harvard, have developed a new way to control light from phosphorescent emitters at very high speeds. The technique provides a new approach to modulation that could be useful in all kinds of silicon-based nanoscale devices, including computer chips and other optoelectronic components.

“Our results demonstrate relatively fast modulation from fundamentally slow phosphorescent light emitters,” said Rashid Zia, associate professor of engineering and physics at Brown and senior author of a new paper describing the work. “We think this could help make phosphors useful in a variety of new systems and settings.”

The paper is published today in [Nature Communications](#).

Phosphors are common light emitters used in light bulbs, LEDs and elsewhere. They are extremely efficient because much of the energy pumped into them is converted to light as opposed to heat. But they have a slow optical lifetime, meaning it takes a relatively long time for them to return to the ground state after being excited. As a result, phosphors can't be turned on and off very quickly. Glow-in-the-dark toys, for example, take advantage of this property.

That property is bad, however, for optical modulation, a process that often involves flipping the light on and off to encode information. Because of their slow lifetimes, phosphors have traditionally been a non-starter for applications that require high-speed modulation.

But in this latest work, Zia and collaborators, including researchers from Shriram Ramanathan's group at Harvard University, took a different approach to modulation.

“Instead of changing how much light is coming out, which can only be done slowly in phosphor emitters, we came up with a system that changes another quality of that light, namely the color or spectrum of light emission, by rapidly changing the environment around the emitter,” Zia said.

The work was led by Sébastien Cuffe, a postdoctoral researcher in Zia's lab. Cuffe started with an emitter made of erbium ions, an important phosphor that is widely used in fiber-optic telecommunication networks. He combined that with a material called vanadium dioxide (VO₂). VO₂ is a phase-change material that, when pumped with energy, changes very quickly from a transparent insulating state to a reflective metallic state. This change in reflectivity, in turn, switches how nearby erbium ions emit light. As the VO₂ changes phase, the erbium emissions go from being generated mostly by magnetic dipole transitions (the rotational torque push and pull of magnetic forces), to being generated mostly by electric dipole transitions (the linear push and pull of electric forces). Those two emission pathways have distinct spectra, and the modulation back and forth between the two can be used as a means to encode information.

The researchers showed that this direct modulation of light emission could be done as quickly as the VO₂ phase could be changed, which is much faster than the speed at which erbium can be turned on and off. The test system used in these initial experiments showed that the system could be switched three orders of magnitude faster than the optical lifetime of erbium.



Experimental data comparing traditional lifetime (top) with new modulation approach (below).

While the curves may look similar, the time scales are very different. The lifetime curve is plotted in milliseconds, whereas the observed modulation is plotted in microseconds (one thousand times faster than the lifetime). "Phosphorescent emitters have been considered impractical for high speed applications because of their intrinsically long lifetimes," Zia said. "Our results provide a simple way to circumvent this limitation and modulate their emission at high speeds."

And that could enable the use of phosphors in new applications. One example could be optical communications networks on computer chips.

Prototype on-chip networks have used semiconductor lasers as light emitters. They can modulate very quickly, but they have downsides. Semiconductors can't be grown directly on a silicon chip, so fabrication can be difficult. Using indirect means of modulation — interferometers, for example — makes for bulky systems that take up a lot of real estate on a chip. What's more, semiconductor lasers are not particularly efficient. They produce a lot of heat along with light, which is a problem on a silicon chip.

Erbium and other phosphors, on the other hand, can be deposited directly on silicon, making fabrication easier. And phosphors are highly efficient, so heat is less of a concern. There's still more work to be done to get such a system up to a speed that would be useful on a chip, but Zia and his colleagues think it's possible.

In this initial experiment, the researchers used a laser to zap the VO₂ and cause it to change phase. A faster means of changing the VO₂ phase — perhaps using electricity instead of a laser — could make the system much faster still.

Zia and his group plan to continue to refine the technique, but they describe this first set of experiments as an important proof of concept. "We ... hope that the device and concept presented here will engage both academic and industrial researchers working on optoelectronics and nanophotonics," the researchers write.

Other authors on the paper were Dongfang Li (Brown), You Zhou (Harvard), Franklin J. Wong (Harvard), Jonathan A. Kurvits (Brown), and Shriram Ramanathan (Harvard). The work was supported by the Air Force Office of Scientific Research (FA9550-10-1-0026 and FA9550-12-1-0189), Army Research Office (W911NF-14-1-0669), Department of Education (P200A090076) and National Science Foundation (EECS-0846466 and EECS-1408009).

Note to Editors:

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