Better 'photon loops' may be key to computer and physics advances

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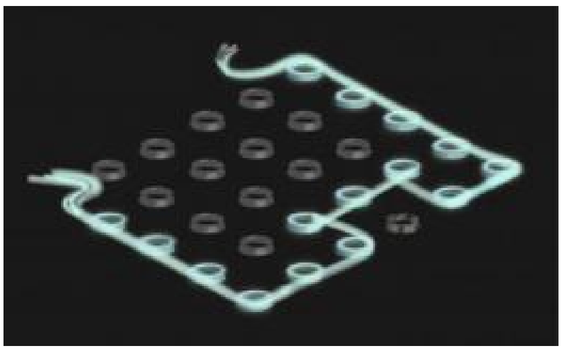

Artist's rendering of the proposed JQI fault-tolerant photon delay device for a future photon-based microchip. The devices ordinarily have a single row of resonators; using multiple rows like this provides alternative pathways for the photons to travel around any physical defects. Credit: JQI

Surprisingly, transmitting information-rich photons thousands of miles through fiber-optic cable is far easier than reliably sending them just a few nanometers through a computer circuit. However, it may soon be possible to steer these particles of light accurately through microchips because of research performed at the Joint Quantum Institute of the National Institute of Standards and Technology (NIST) and the University of Maryland, together with Harvard University.

The scientists behind the effort say the work not only may lead to more efficient information processors on our desktops, but also could offer a way to explore a particularly strange effect of the quantum world known as the quantum Hall effect in which electrons can interfere with themselves as they travel in a magnetic field. The corresponding physics is rich enough that its investigation has already resulted in three Nobel Prizes, but many intriguing theoretical predictions about it have yet to be observed.

The advent of optical fibers a few decades ago made it possible for dozens of independent phone conversations to travel long distances along a single glass cable by, essentially, assigning each conversation to a different color-each narrow strand of glass carrying dramatic amounts of information with little interference.

Ironically, while it is easy to send photons far across a town or across the ocean, scientists have a harder time directing them to precise locations across short distances-say, a few hundred nanometers-and this makes it difficult to employ photons as information carriers inside computer chips.

"We run into problems when trying to use photons in microcircuits because of slight defects in the materials chips are made from," says Jacob Taylor, a theoretical physicist at NIST and JQI. "Defects crop up a lot, and they deflect photons in ways that mess up the signal."

These defects are particularly problematic when they occur in photon delay devices, which slow the photons down to store them briefly until the chip needs the information they contain. Delay devices are usually constructed from a single row of tiny resonators, so a defect among them can ruin the information in the photon stream. But the research team perceived that using multiple rows of resonators would build alternate pathways into the delay devices, allowing the photons to find their way around defects easily.

As delay devices are a vital part of computer circuits, the alternatepathway technique may help overcome obstacles blocking the development of photon-based chips, which are still a dream of computer manufacturers. While that application would be exciting, lead author Mohammad Hafezi says the prospect of investigating the quantum Hall effect with the same technology also has great scientific appeal.

"The photons in these devices exhibit the same type of interference as electrons subjected to the quantum Hall effect," says Hafezi, a research associate at JQI. "We hope these devices will allow us to sidestep some of the problems with observing the physics directly, instead allowing us to explore them by analogy."

More information: M. Hafezi, E.A. Demler, M.D. Lukin and J.M. Taylor. Robust optical delay lines with topological protection. *Nature Physics*, Aug. 21, 2011, DOI: 10.1038/NPHYS2063

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