NAIST® Research Highlights

Nara Institute of Science and Technology | **Ultrafast Photonics Laboratory** www.naist.jp/en

Optical memory

Laser switchable across waveguides

Optical buffer memories may be improved with a vertical-cavity surface-emitting laser that can switch light into different waveguides

A design of a semiconductor laser that emits light into different sets of waveguides depending on the polarization of the lasing beam has been theoretically investigated by NAIST researchers[1].

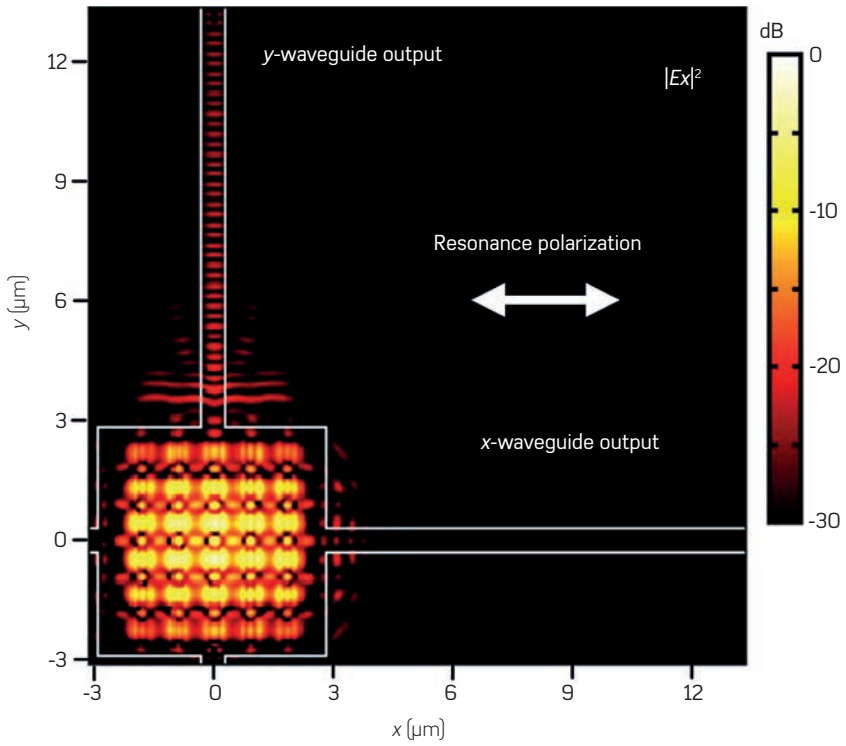
Hitoshi Kawaguchi's team at NAIST used three-dimensional finite-difference time-domain modelling to study the behaviour of a vertical-cavity surface-emitting laser (VCSEL) coupled to two sets of silicon waveguides arranged in orthogonal directions to each other (see figure). The coupling takes place via a square-shaped, polarization-independent, high-index-contrast subwavelength grating (HCG) that is also made in silicon and forms the bottom mirror of the VCSEL.

"For applications requiring a larger waveguide output power, the reflectivity of the DBR will be increased by increasing the number of the DBR layers."

When employed with a polarization bistable VCSEL, such an arrangement may prove useful for creating compact and efficient all-optical buffer memories on a silicon chip that can temporarily switch and store optical data streams without the need for free-space optics.

"We found that the output waveguide can be switched by changing the lasing polarization of the VCSEL with an extinction ratio of 11.9," says Kawaguchi. The light coupled more strongly to the waveguide when it was perpendicularly orientated to the polarization of the resonant mode, rather than parallel. The strongly coupled mode was found to be transverse electric, or perpendicular to the propagation direction of the beam.

The modelling assumes a VCSEL operating at 1.55 micrometres in wavelength, consisting of an active gain region composed of a series of InGaAsP (indium gallium arsenide phosphide) quantum wells sandwiched between the HCG below, and a Distributed Bragg Reflector (DBR) above. The DBR is made from an alternating stack of 32 pairs of thin layers of InP (indium phosphide) and InGaAsP.



Simulation showing light exiting the VCSEL via the y waveguide only. By changing the lasing polarization, the output light switches to the x waveguide.

The HCG has a greater than 99 per cent reflectivity for wavelengths around 1.55 micrometres, while the DBR has a reflectivity of around 90 per cent. The HCG is bonded to the rest of the VCSEL structure using benzocyclobutene. According to the researchers, the output power coupled to the waveguide is similar to the emission from a conventional VCSEL, which is less than 1 per cent of optical power inside the laser cavity.

"This output will be sufficient for all-optical memory applications because the memory works with a very low input power of 80 nanowatts," explains Kawaguchi. "For applications requiring a larger waveguide output power, the reflectivity of the DBR will be increased by increasing the number of the DBR layers."

Their simulations also suggest that the output power of the waveguide is roughly proportional to the waveguide width.

Reference

1. Tsunemi, Y., Ikeda, K. & Kawaguchi, H. Lasing-polarization-dependent output from orthogonal waveguides in high-index-contrast subwavelength grating vertical-cavity surface-emitting laser. *Applied Physics Express* **6**, 092106 (2013).

More information about the group's research can be found at the Ultrafast Photonics Laboratory webpage:
http://mswebs.naist.jp/LABs/kawaguchi/index-e.html