

Electrically driven nanocavity lasers on silicon with photonic-crystal cavity and ultra small buried heterostructure

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3 Nanophotonics Center, NTT Corporation, Japan The performance of CMOS chips has continuously improved as they have been scaled down. However, electrical interconnects are becoming a bottleneck to further improvement, because small-size and narrow-pitch wires have large resistance and capacitance, which results in large energy consumption. There have been many attempts to realize on-CMOS-chip optical interconnects with small energy consumption and large band width. Considering the allowable power supply for CMOS chips and communications bandwidth, light sources should be operated with energy consumption on the order of 10 fJ/bit or 0.01 mW/Gbit/s.

In this context, we are studying photonic crystal (PhC) lasers. Reducing the size of the active region is an effective way to reduce the energy consumption of directly modulated semiconductor lasers. However, since this reduces optical confinement in the active region, we have employed PhC cavities to maintain large optical confinement. After these important features, we named our PhC lasers lambda-scale embedded active region PhC(LEAP) lasers.

We have used oxygen-plasma-assisted bonding to integrate InP-based III-V material on Si substrate. InGaAsP three-quantum-well active layers were formed on thermally oxidized Si substrates, followed by buried heterostructure regrowth with dimensions of $2.5 \times 0.3 \times 0.15 \text{ mm}^3$. Lateral p-i-n junctions were formed by ion implantation of Si and thermal diffusion of Zn for n and p doping, respectively. We formed the PhC cavity by electron-beam lithography and dry etching, followed by electrode formation.

We achieved continuous-wave operation of LEAP lasers on Si substrate at room temperature, with a threshold current of 57 μA and a maximum output power of 3.5 mW. The lasing wavelength was determined by the lattice constant of the PhC, and it was 1554.2 nm. Although the output power from the device was not large enough to evaluate dynamic characteristics, LEAP lasers on InP substrate showed direct modulation at a bit rate of 10 Gbit/s with very small energy consumption of 5.5 fJ/bit. From the potential small-energy device performance and integrability on Si substrates, we believe LEAP lasers are very promising for future on-chip optical interconnects.

Biography:

Koji Takeda received the B.S., M.S., and Ph.D. degrees in electronics engineering from the University of Tokyo, Tokyo, Japan, in 2005, 2007, and 2010, respectively. From 2008 to 2010, he received a research fellowship for young scientists from the Japan Society for the Promotion of Science. He joined NTT Photonics Laboratories in 2010. His current research interests include ultralow-power optical interconnects, InP photonic integrated circuits, and photonic crystal lasers. He is now with NTT Device Technology Laboratories.

Dr. Takeda is a member of the IEEE Photonics Society, Japan Society of Applied Physics (JSAP), and the Institute of Electronics, Information and Communication Engineers (IEICE). He received the Best Student Paper Award from the IEEE Photonics Society in 2009, the Outstanding Student Presentation Award from the JSAP in 2010, and the Best Paper Award from the IEICE in 2013.