Lasing from a direct bandgap GeSn alloy grown on Si (100) substrates

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The monolithic integration of optoelectronic components into Si technology is a long-lasting effort in semiconductor research [1]. The integration of optical circuitry including all active and passive optical components into Si CMOS offers an intriguing approach to drastically reduce the power consumption and at the same time overcoming the barrier of limited bandwidths of copper interconnects.

The group IV alloy GeSn has been predicted to have a direct fundamental bandgap at Sn concentrations of more than 20%,[2] recently this was reduced to about 10% for relaxed GeSn layers on Si.[3] However, fabrication of high quality GeSn layers with Sn concentrations > 10%, far beyond the solid solubility limit, remains challenging due to Sn precipitation. Using a new reactive gas source epitaxy (RGE) technique, we successfully grew GeSn alloys with Sn concentrations up to 14% on relaxed Ge buffer layers on Si. Optical analysis using PL and transmission spectroscopy unambiguously reveal a fundamental direct bandgap for Sn concentrations > 11%. Optical pumping techniques reveal a modal gain that depends linearly on excitation power and reaches values > 100 cm^{-1} for a pump power of 600 kW/cm^2; optically-pumped lasing was also demonstrated.

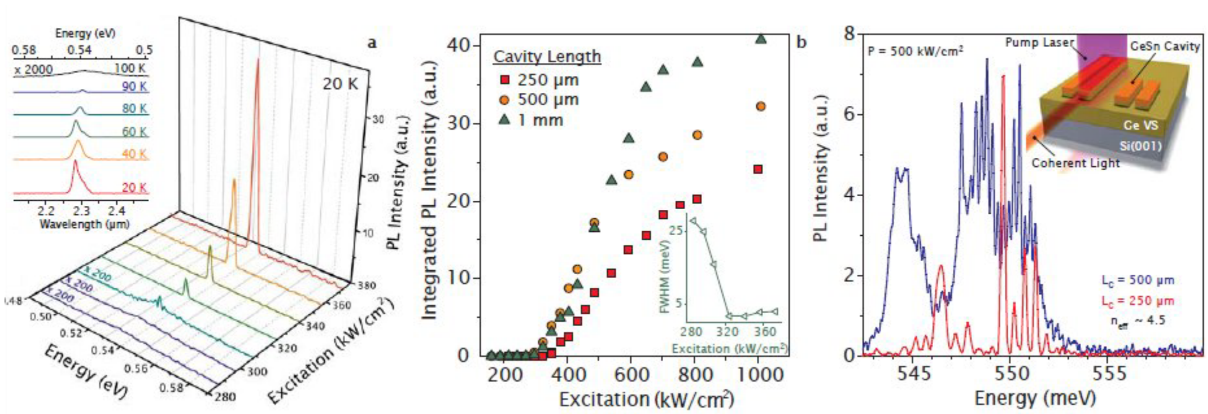

Fig. 1. Optically-pumped direct bandgap GeSn laser: (a) power-dependent PL spectra of a waveguide cavity, with temperature-dependent (20–100 K) PL spectra at 1000 kW/cm^2 excitation density; (b) integrated PL intensity *vs.* optical excitation for waveguide lengths of 250 µm, 500 µm and 1 mm, with FWHM near the lasing threshold for the 1 mm waveguide; (c) high-resolution spectra of 250 and 500 µm waveguides at 500 kW/cm^2 homogeneous excitation taken at one of the etched facets (adapted from [4]).

1. S. S. Iyer and Y.-H. Xie, *Science* **260**, 40 (1993).
2. D. Jenkins and J. Dow, *Phys. Rev. B* **36**, 7994 (1987).
3. K. Lu Low, Y. Yang, G. Han, W. Fan, and Y. Yeo, *J. Appl. Phys.* **112**, 103715 (2012).
4. S. Wirths *et. al.*, "Lasing in direct bandgap GeSn alloy grown on Si (001)", *Nature Photonics* (2014).