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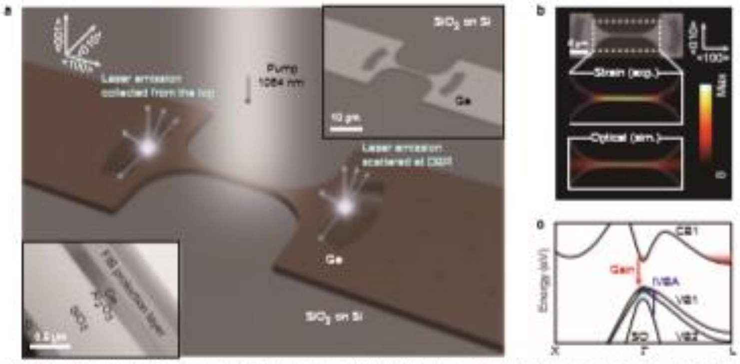
COEB PHOTONICS
COEB - Centre for OptoElectronics and Biophotonics

Low-threshold optically pumped lasing in highly strained germanium nanowires

Abstract

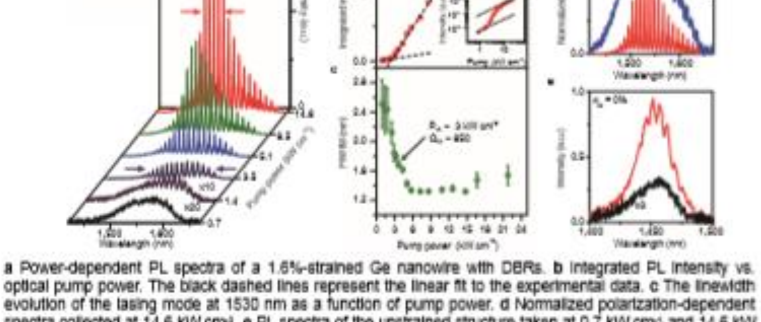
The integration of efficient, miniaturized group IV lasers into CMOS architecture holds the key to the realization of fully functional photonic-integrated circuits. Despite several years of progress, however, all group IV lasers reported to date exhibit impractically high thresholds owing to their unfavourable bandstructures. Highly strained germanium with its fundamentally altered bandstructure has emerged as a potential low-threshold gain medium, but there has yet to be a successful demonstration of lasing from this seemingly promising material system. Here we demonstrate a low-threshold, compact group IV laser that employs a germanium nanowire under a 1.6% uniaxial tensile strain as the gain medium. The amplified material gain in strained germanium can sufficiently overcome optical losses at 83 K, thus allowing the observation of multimode lasing with an optical pumping threshold density of ~3.0 kW cm^{-2}. Our demonstration opens new possibilities for group IV lasers for photonic integrated circuits.

Design of strained Ge nanowire lasers



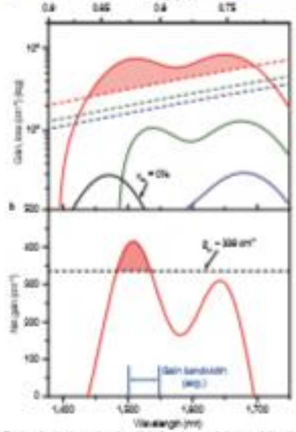
a A typical Ge nanowire laser consisting of a strained nanowire surrounded by a pair of distributed Bragg reflectors (DBRs) on the stressing pads. The strained nanowire is photo-excited with a 1064-nm pulsed laser, and the stimulated emission is collected at a DBR. b A strong spatial overlap between strain and optical fields is achieved in our unique design. c Calculated band structure of 1.6% uniaxial strained Ge.

Lasing characteristics (83 K)



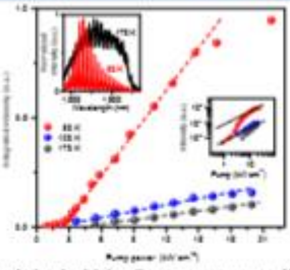
a Power-dependent PL spectra of a 1.6%-strained Ge nanowire with DBRs. b Integrated PL intensity vs. optical pump power. The black dashed lines represent the linear fit to the experimental data. c The linewidth evolution of the lasing mode at 1530 nm as a function of pump power. d Normalized polarization-dependent spectra collected at 14.6 kW cm^{-2}. e PL spectra of the unstrained structure taken at 0.7 kW cm^{-2} and 14.6 kW cm^{-2} pump powers, showing no lasing action.

Theoretical modelling (83K)



a Calculated gain (solid line) and loss (dashed line) for 1.6% strained Ge at different injection densities. The gain for unstrained Ge at an injection density of 8×10^{18} cm^{-3} (black solid line) is overwhelmed by the loss. b Calculated net gain spectrum for an injection density of 8×10^{18} cm^{-3}.

Temperature-dependent emission



Integrated output intensity vs. pump power. While the data set for 83 K manifests a nonlinear lasing behaviour, no superlinear output increase is clearly observed for 123 K and 173 K.

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