STRAIN ENGINEERING FOR GeSn/SiGeSn MULTIPLE QUANTUM WELL LASER STRUCTURES

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Optically pumped GeSn laser have been realized, thus alloying of group IV elements germanium (Ge) and tin (Sn) has a large potential to be a solution for Si-photonics, since a direct bandgap for Sn incorporations above ~9 at.% is obtained [1]. The value of the bandgap can further be controlled by adding Si into the mix, which can be exploited for the formation of heterostructures for carrier confinement [2]. However, a sufficiently large difference in energy ΔE between the indirect L-valley and the direct Γ-valley is required to achieve room temperature lasing. Recently lasing was reported at 180K in GeSn alloys with Sn concentrations as high as 22,3% [3]. Alternatively ΔE can be increased by adding tensile strain to the GeSn layers. Here we will discuss that an appropriate combination of Sn concentration and strain will be advantageous to tailor gain and temperature stability of the structures.

Here, we will present a comprehensive characterization of direct bandgap heterostructures multiple quantum well (MQW) structures, formed from active GeSn layers and SiGeSn ternary claddings. Fig. 1 shows spectra of an optically pumped μ-disc MQW laser taken at various optical pump power. The data reveal a lasing threshold at 20 K from light in/light out curves of 39 kW/cm2, which is an order of magnitude smaller than the threshold observed for devices fabricated from bulk GeSn layers, clearly evidencing the superiority of MQW structures over bulk layers. The performance of the optically pumped laser were investigated in dependence of temperature, pump power and excitation wavelength. The gained insight reveals that carrier dynamics are crucial and that the “directness” of the bandgap ΔE=E$_Γ$-E$_L$ is a decisive parameter on the path towards an electrically pumped laser operating at room temperature. Fig. 2 compares the modeled carrier distribution in MQW and heterostructures. The population in the Γ-valley reflects the maximum operation temperature of the laser. The impact of design, composition and strain of the SiGeSn/GeSn MQW structures on ΔE will be discussed.

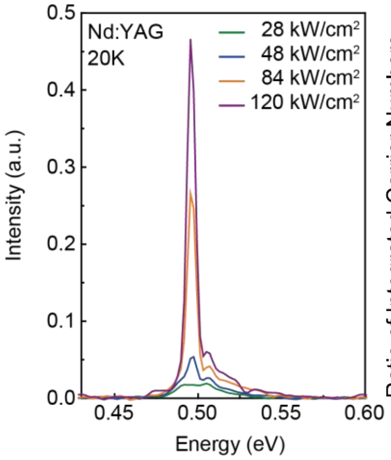

Fig 1: Power dependence of lasing spectra taken at 20K of a optically pumped GeSn/SiGeSn μ-disc laser. Threshold at 20 K from LL: 39 kW/cm^2

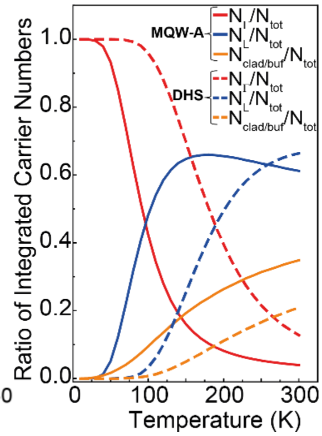

Fig 2: Modeled electron numbers in the Γ- (red) and, L-valleys (blue) and in the barriers layer (orange) as a fraction of total electron concentration, MQW (solid line) and DHS (dashed line).

[1] Wirths, S. et al. Nat. Photonics 9, 88–92 (2015),
[2] von den Driesch, N. et al.. Small 1603321 (2017).
[3] Dou, W. et.al. Optics 43, 4558 (2018)