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### Abstract

- Optoelectronic devices based on self-assembled Quantum Dots (QDs) have strong potential in many applications including quantum technologies, visible light communications, and optical sensing.
- We report spectral bi-modality in double-layer quantum dot (QD) laser based on InP/AlGaInP material system attributed to smaller and larger QD groups.
- The InP/AlGaInP self-assembled quantum dots are fabricated by metal-organic vapor-phase epitaxy.

### Structure and Experimental Setup

- The laser structure contains a 100 nm-thick GaAs:Si buffer layer, followed by a 50 nm-thick GaInP:Si layer and a 1 μm-thick AlInP:Si optical confinement layer. The p-side layers are similar to the n-side, but the dopant was changed to Zn as shown in Fig.1a.
- The InP quantum dot active region was grown and placed in the center of a 2x10 nm thick Al\(_{0.46}\)Ga\(_{0.54}\)InP barrier, surrounded by 2x150 nm Al\(_{0.46}\)Ga\(_{0.54}\)InP waveguide.
- The two QD layers are separated by 6 nm spacer layer.

### Sub-threshold Characteristics

- The spectrum can be divided into three regions as shown in Fig. 2.
  - The first and 2\(^{nd}\) regions are shown in Fig. 2a, from 0.462 kA/cm\(^2\) till 0.833 kA/cm\(^2\) where the emission from the large QDs dominates the spectrum around 710.72 nm at full width half maximum (FWHM) of 92.48 nm at 0.416 kA/cm\(^2\).
  - The 2\(^{nd}\) second region from 0.740 kA/cm\(^2\) till 0.833 kA/cm\(^2\), the emission from the small and large quantum dot groups exist simultaneously with the second peak centered at \(\lambda = 671.7\) nm at 0.740 kA/cm\(^2\).
  - In the third region from 0.925 kA/cm\(^2\) the lasing from the small quantum dot group dominates as shown in Fig.2b. The peak of the spectrum is then shifted to 665.6 nm and a drop in FWHM is observed to 3.84 nm for 0.925 kA/cm\(^2\).

### Gaussian Fitting

- For further illustration, fitting of two Gaussian curves has been used as shown in Fig. 2a,b. The power density of the two emission peaks versus pumping current is shown in Fig. 3a indicating lasing of the small QD group only. Power percentage contribution of each QD group is shown in Fig.3b indicating comparable contribution at high pump current.
- The fitting equation is indicated below where \(a_{Small, Large}\) represent amplitude, \(b_{Small, Large}\) is the center wavelength, \(c_{Small, Large}\) is the spectral width.
- \[ PSD = a_{Small} e^{-\frac{(b_{Small} - \lambda)^2}{2c_{Small}^2}} + a_{Large} e^{-\frac{(b_{Large} - \lambda)^2}{2c_{Large}^2}} \] \[ Power\ contribution = \frac{a_{Small} + a_{Large}}{a_{Small} + a_{Large} + a_{Small} + a_{Large}} \] \[ \text{Current (kA/cm}^2\text{)} \]

### References