Impact of the Purcell and Spontaneous Emission Factors in Nanowire Lasers

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Abstract In this paper, we present a numerical estimation of spontaneous emission factor for nanowire lasers and, investigate the impact of Purcell effect F and spontaneous emission factor β on the threshold and the L-L curves. Theoretical calculations provide more insights into the laser behaviour as they predict spontaneous emission coupling efficiency before fabrication and are helpful to optimise the cavity [1].

Results and discussion The rate equations for nanowire lasers are written as:

$$\frac{dN}{dt} = \frac{\eta P}{hfV} - \frac{(1-\beta_0)N}{t_{sp}} - \frac{F\beta_0 N}{t_{sp}} -, \qquad \frac{dS}{dt} = \Gamma\frac{F\beta_0 N}{t_{sp}} + \Gamma g S - \frac{S}{t_p} \tag{1}$$

$F = \frac{3}{4\pi^2}(\frac{\lambda}{n})^3(\frac{Q}{V})$ is the Purcell factor [2]. β and β_0 are spontaneous emission factors with and without Purcell effect, respectively and, are related as $\beta = \frac{F\beta_0}{(1+(F-1)\beta_0)}$. β is usually treated as a fitting parameter shaping the height of the kink in the L-L curves. However, we propose $\beta \approx \frac{\lambda^3 L_z}{2\pi^2 V \Delta\lambda n^2}$ for multiple quantum disks embedded in nanowire lasers. $\Delta\lambda$ is spontaneous emission linewidth, V is the Volume, and L_z is the thickness of the gain medium. β is calculated with the same approach as [3] using the ratio between spontaneous emission rate into the lasing mode to the total spontaneous emission rate. For the nanowire laser in [4], we calculate the threshold to be around $1.6\frac{\mu J}{cm^2}$, $F \approx 26.17$, and $\beta \approx 0.1$. This agrees with experimental results. Solving (1) for different values of Purcell factors ranging from 26 to 1 shows that lower dimensions of nanowire result in higher F which decreases the threshold non-linearly as shown in Figure 1a. Meanwhile, higher F provides more spontaneous emissions to couple into the lasing mode making less pronounced kinks as β gets closer to unity in Figure 1b.

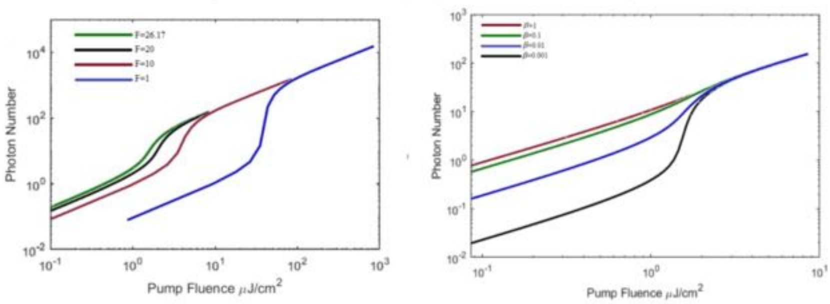

Figure 1. a) Impact of the Purcell factor, b) Impact of spontaneous emission factor

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