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Direct Current Modulation Response of Metal-Clad Semiconductor Nano-lasers

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Abstract Calculations of both the small signal and large signal direct modulation response of nanolasers indicate opportunities to access modulation bandwidth up to 60 GHz with peak responses at resonant frequencies of order 40 GHz.

Introduction

Semiconductor nano-lasers have attracted considerable attention due to their potential applications in photonic integrated circuits, optical information processing and system-on-a-chip technologies. Such nano-lasers are anticipated to exhibit enhanced dynamical performance which may arise from a combination of physical factors including Purcell spontaneous emission enhancement factor *F*, and spontaneous emission coupling factor, *β*. In recent work, the impact of Purcell enhanced spontaneous emission on the modulation performance of nano-LEDS and nano-lasers[1] have been examined.Enhancement of nano-laser dynamics have been studied based on the Purcell effect leading to a proposal of modulation bandwidths in excess of 100 GHz[2-5]. However, in complementary work[6] on the dynamical performance of metal-clad nano-lasers it was shown by means of a simple analysis that the direct-current modulation bandwidth of such lasers may suffer deleterious effects due to increased Purcell spontaneous emission enhancement factor *F*, and spontaneous emission coupling factor, *β*.

The aim of the present paper is to explore the dynamical performance of the nano-laser studied in previous work[7]. The focus of this work is to determine the influence of Purcell spontaneous emission enhancement factor *F*, and the spontaneous emission coupling factor, *β* for direct current modulation in both the small signal and large signal regimes.

Small and Large Signal Analysis

Sinusoidal modulation of the nano-laser is considered, at a modulation frequency f_m. The depth of modulation,m,. is prescribed via a modulation current I_m defined relative to the laser dc bias current, For small signal modulation m=0.1 is taken whereas for large signal modulation m=0.8 is used. Other device parameters are defined for a cylindrical GaN nano-laser having a cavity length of 2 μm and a cavity radius of about 200 nm.

Results

Firstly attention is given to the influence of the Purcell spontaneous emission enhancement factor F. Using fixed parameters β = 0.004 and bias current $I_{dc} = 5I_{th}$, variation in F in the range 10-40 is taken into account as shown in Figure 1.

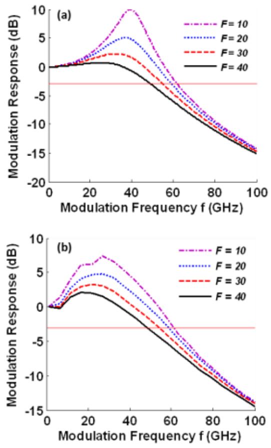

Fig. 1 : Modulation Response of Nano-laser at β = 0.004 and $I_{dc} = 5I_{th}$ for (a) Small Signal (b) Large Signal Modulation. The solid red line indicates the 3dB level.

Secondly attention has been given to the impact of the spontaneous emission factor β. It is observed that when β increases in this range the 3dB bandwidth decreases from 62GHz to 36GHz. Finally a comparison has been made of the magnitude of the modulation response for small and large signal modulation. It was found that in both small and large signals regimes the peak modulation response occurs at resonant frequencies 40GHz and 30GHz respectively.

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