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Optical gain by simultaneous photon and phonon confinement in indirect bandgap semiconductor acousto-optical cavities

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Abstract Optical gain that could ultimately lead to light emission from silicon is a goal that has been pursued for a long time by the scientific community. The reason is that a silicon laser would allow for the development of low-cost, high-volume monolithic photonic integrated circuits created using conventional CMOS technologies. However, the silicon indirect bandgap—requiring the participation of a proper phonon in the process of light emission—is a roadblock that has not been overcome so far. A high-Q optical cavity allowing a very high density of states at the desired frequencies has been proposed as a possible way to get optical gain. However, recent theoretical studies have shown that the free-carrier absorption is much higher than the optical gain at ambient temperature in an indirect bandgap semiconductor, even if a high-Q optical cavity is formed. In this work, we consider a particular case in which the semiconductor material is engineered to form an acousto-optical cavity where the photon and phonon modes involved in the emission process are simultaneously confined. The acousto-optical cavity confinement effect on the light emission properties is characterized by a compound Purcell factor which includes both the optical as well as the acoustic Purcell factor (APF). A theoretical expression for the APF is also introduced. Our theoretical results suggest that creating an acousto-optical cavity the optical gain can overcome the photon loss due to free carriers as a consequence of the localization of phonons even at room temperature, paving the way towards the pursued silicon laser.

Keywords Optical gain · Indirect bandgap semiconductor · Optical cavity · Purcell factor · Silicon laser

1 Introduction

A key advantage of using silicon as a photonic material is that it can be easily processed in microelectronics foundries using mature CMOS technology with high yield and low cost

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