

Thermal Management of QCL Devices & Packaging

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Objectives

Quantum cascade lasers (QCLs) have found applications in spectroscopy, infrared detection and countermeasures, optical communications [8] and gas and remote sensors [1-6]. Uncooled continuous wave QCLs are highly desirable for various applications; however, their performance is limited by the elevated gain media temperature due to the very high heat load. For the pulsed QCLs, the rapid temperature rise during the pulse causes laser frequency chirping and/or mode hopping. Moreover, this problem is exasperated by continued increase in output power by orders of magnitude over the past decade [1, 7-9].

Summary of the methods, and results & discussion

In this work, we aim to minimize the hierarchy of thermal resistances to spread heat over larger areas and transmit heat to cooling solutions. The thermal resistance of the QCLs has three main components: (1) QCLs multilayer thermal resistance, which is largely affected by the geometry and thermal conductivity of the QCL; (2) the bonding material (e.g., electroplated Au and In solder) contact thermal resistance that can be degraded due to thermal cycling; (3) heat spreader (*i.e.* copper, diamond, thermal ground plate) in combination with the appropriate convective air or liquid cooling solutions. In addition, if proper thermal ground scheme is applied, the spreading of the heat within the InP substrate could also contribute to the total thermal resistance of the QCLs. This paper will report a parametric study of the total thermal resistance of the QCL devices by developing solid conduction models. This parametric study allows us to investigate the impact of geometry and thermal conductivity of the QCL multilayers on device temperature rise. The effect of bonding materials between the QCLs and potential heat spreader on thermal performance will be also investigated. Finally, we will assess the impact of heat spreader (copper, diamond, thermal ground plate,) in combination with the appropriate convective air or liquid cooling solutions. This will include detailed simulations of the QCL chip, package and cooling solutions. Therefore, we make comprehensive assessment of various components and propose novel thermal management solutions to minimize the total thermal resistance.

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Figures

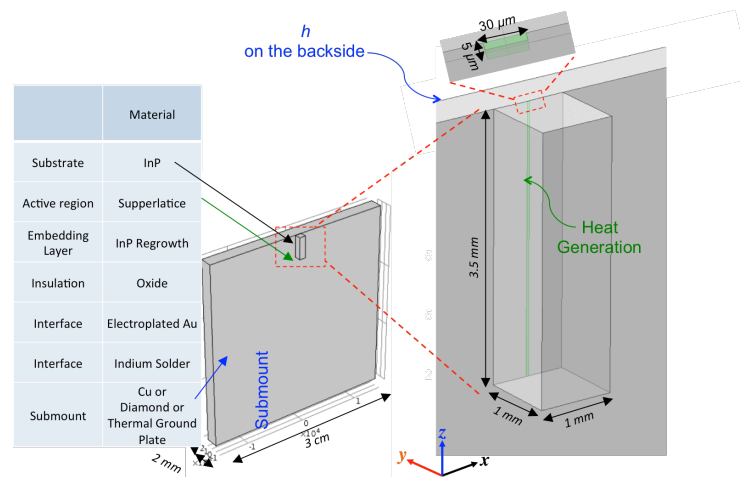


Figure 1. A solid conduction simulation is developed by using COMSOL *multiphysics* to account for the overall thermal resistance from the heat generation to the convecting area. A heat transfer coefficient of 700W/m²K on the backside.

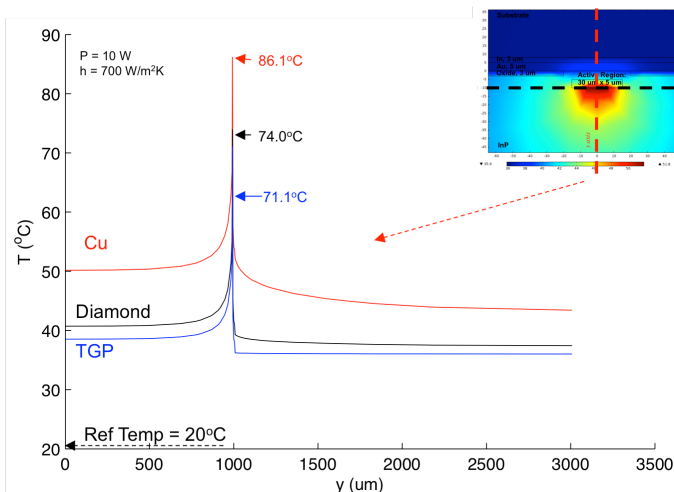


Figure 2. Temperature profiles along the y-axis are plotted to indicate the maximum temperature. The materials of Cu, diamond, and thermal ground plate are selected for the heat spreader. The different materials with a range of thermal conductivity change the temperature profile as well as the maximum temperature.