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Title

Fundamental frequency noise and linewidth broadening caused by intrinsic temperature fluctuations in quantum cascade lasers

Source

Physical Review B (Condensed Matter and Materials Physics), vol.84, no.12, 15 Sept. 2011, 125322 (14 pp.). Publisher: American Physical Society, USA.

Abstract

We theoretically investigate fundamental thermal frequency noise and linewidth broadening caused by intrinsic temperature fluctuations in both terahertz (THz) and mid-infrared (IR) quantum cascade lasers (QCLs) for the first time. The analytical derivation is based on the Green function analysis and the <i>Van Vliet-Fassett</i> theory. The results show that the fundamental frequency noise caused by temperature fluctuations is prominent in the low frequency range (below a few kHz) and is sensitive to the temperature, heat conductivity, and the thickness of the active region/substrate. It also shows that this fundamental frequency noise does not show a 1/f trend in the whole frequency spectra for both THz and mid-IR QCLs. For THz QCLs, considering only the refractive-index variation caused by the current-induced device self-heating, we calculate the linewidth broadening to be only around 1 Hz, which is comparable to the value of 3 Hz caused by spontaneous emission, stimulated emission, and blackbody radiation in high power THz QCLs. For mid-IR QCLs this frequency noise leads to the linewidth broadening from 14.74 Hz to 62.02 Hz as the temperature increases from 200 K to 400 K. When the microscopic features of the refractive-index variations associated with the intersub-band gain transition, the self-heating-induced thermal expansion and energy-level broadening in mid-IR QCLs are considered, an estimation shows that the linewidth broadening increases greatly by a factor of at least four times. (64 References).