THz Intersubband Emitter based on Silicon

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Abstract – We present THz quantum cascade emitters realized on a Si substrate. The emission centered at 3.4 and 4.9 THz originates from L-valley transitions in strain-compensated n-type Ge/SiGe heterostructures. This is an important step towards the realization of Si-based THz quantum cascade lasers.

I. Introduction

The high purity of Si and the advanced CMOS technology enable low optical propagation losses [1]. Additionally, the high thermal conductivity make Si an attractive substrate for optoelectronic devices. But the indirect bandgap of group IV materials hinders the realization of Si-based lasers. An exciting solution is to harness intersubband transitions because such transitions are independent of the nature of the bandgap. However, the quantum cascade laser (QCL) has so far only been demonstrated in polar III-V compound semiconductor materials [2]. At far-infrared wavelengths, the QCL is limited to pulsed operation at 250 K with a large electrical dissipation [3]. This is intrinsically related to the polar nature of the gain material. Developing group IV heterostructures with weaker electron-phonon interaction is therefore an interesting approach to realize a room-temperature THz QCL [4].

II. Results

We report electroluminescence measurements from n-type Ge/ $Si_{0.15}Ge_{0.85}$ quantum cascade structures [5]. The employed single quantum well active region was designed with a non-equilibrium Green's function (NEGF) model [4] to unambiguously demonstrate intersubband electroluminescence [5]. The layers are strain-compensated and grown by ultra-high vacuum chemical vapour deposition. The nominally 4.2 µm thick layers consisting of 51 quantum cascade periods were processed into deeply etched diffraction gratings, see Fig. 1 (a) [5]. The surface emitting devices are characterized at 5 K with an under-vacuum Fourier transform infrared spectrometer. The spectra observed from two different samples are shown Fig. 1 (b)-(c) [5]. The spectra exhibit two distinct emission peaks which are well described by NEGF calculations. The emission efficiency is compared to a GaAs/AlGaAs emitter with identical device geometry [5]. The results pave the way towards laser action from Ge/SiGe heterostructures.

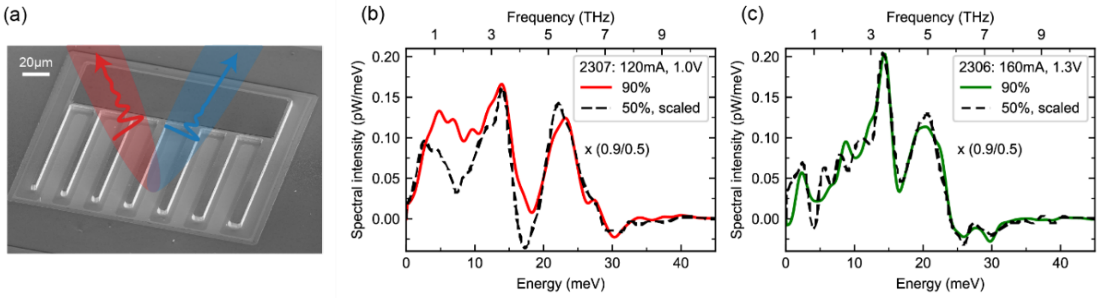

Fig. 1. (a) SEM image of the fabricated Ge/SiGe quantum cascade emitter. The colored arrows indicate the two emission peaks centered at different frequencies. The electroluminescence spectra with different duty cycles are shown in (b) and (c). The colored lines show the spectra acquired with 90% duty-cycle and the dashed lines show the spectra acquired with 50% duty-cycle scaled to 90%. Sample 2307 and sample 2306 are shown in (b) and (c) respectively. The figure is adapted from [5].

III. References

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