Terahertz quantum cascade lasers with quasi-periodic resonators

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***Abstract*—We report simulations and experimental results of THz QCLs with quasi-periodic resonators based on a Fibonacci sequence.**

Terahertz quantum cascade lasers were first demonstrated in 2002 [1] and have since undergone rapid development. One of the most active areas of reasearch into these devices has been the development of devices emitting in a single longitudinal mode through the use of distributed feedback (DFB) resonators. Because the optical mode in these devices arises through a surface plasmon, it is possible to implement them with periodically arranged slits in the top metallisation. These have been demonstrated for both single- and double-metal waveguides [2],[3],[4].

Since the patterns are easily defined with optical contact lithography, this system is well suited to study novel resonator concepts like quasi-periodic or random structures. As a first step, a Fibonacci structure was chosen. It is usually generated by two different layers of dielectric A and B stacked according to the following rule: $S_{j+1} = \{S_{j-1}, S_j\}$ for $j > 1$, with $S_0 = \{B\}$ and $S_1 = \{A\}$. A sequence of this type shows interesting transport properties for light [5]. Like in a DFB, a range of forbidden energy occurs, a so-called pseudouse of Distributed feed band gap, where light transport is prohibited and the wavefunctions decay exponentially. The existence of a pseudo-gap and the related peak in the density of states make this configuration interesting for alternative DFB resonators. The degeneracy between the two band-edges is removed, and improved stability against variations in the periodicity is found. In order to fabricate such a resonator as a THz-DFB, a slit was introduced each time the material would change from A to B. Thus the reflection at a dielectric interface is replaced by the reflection at the narrow barrier for the surface plasmon (Fig. 1(c)). Fig. 1(a) shows a measured spectrum of a 2.5 THz QCL with a quasi-period of 6.4 μm; in devices with 6.2 and 6.6 μm gratings no lasing occurred, most likely due to the band-edge of the pseudo-gap being detuned from the gain. Improved results should be achievable in double-metal waveguides; in fact the numerical simulations shown in Fig. 1(b) indicate a much clearer resonance at the band-edge in this case.

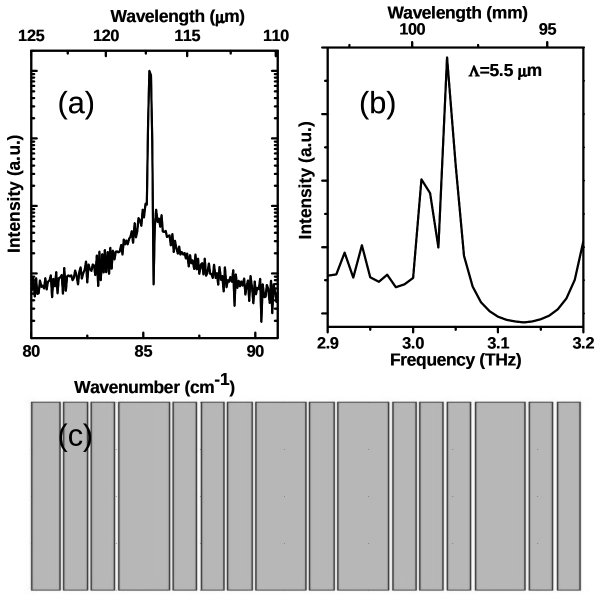

Fig. 1. (a) Laser emission spectrum measured from a single plasmon THz QCL with a Fibonacci resonator. (b) Calculated maximum intensity for a similar device with a double metal waveguide, excited with a point source. (c) Schematic diagram of the structure used.

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