Controlling Nonlinearities in Semiconductor Superlattice Multipliers

M.F. Pereira[1,2] and A. Apostolakis[2]

[1]Department of Physics, Khalifa University of Science and Technology, Abu Dhabi 127788, UAE
[2]Institute of Physics, Czech Academy of Sciences, 18221 Prague, Czech Republic

***Abstract*— A hybrid approach combining Nonequilibrium Green's Fuctions with solutions of the Boltzman equation, delivers voltage and intrinsic asymmetry control of nonlinearities in semiconductor superlattices. Unexpected nonlinear behavior is predicted for high harmonics as a result of voltage control.**

I. Introduction

Semiconductor superlattices (SSLs) are very important materials to study quantum transport and optics under controlled conditions [1, 2]. Of particular interest is the possibility to study optical nonlinearities, which are well understood in general in the visible and near to mid infrared, but difficult to exploit in the Gigahertz-Terahertz (GHz-THz) range at room temperature and using low excitation power [3-7]. Nonlinear susceptibilities are successful in most materials, but cannot be used in the case studied here. In this paper, We extend previous studies [10-15] and apply our theory to demonstrate the combined effect of intrinsic current flow asymmetry and applied voltages in the nonlinear generation of high order harmonics in superlattice multipliers excited by commercially frequencies and input powers generated by IMPATT diodes [16].

II. Numerical Method and Results

The average power emitted by l^{th} Harmonic is calculated from the Poynting vector

$$P_l(\nu) = T(\nu)\ \{< I(t)\cos(2\pi\nu t) >^2 + < I(t)\sin(2\pi\nu t) >^2\}, \qquad (1)$$

Where $I(t)$ is the nonlinear current in equation induced in the SSL by the total field $E(t) = E_{dc} + E_{ac}\cos(2\pi\nu t)$ and the <…> averaging is performed over the period $T = 1/\nu$. $T(\nu)$ is the transmission of the waveguide containing the SSL. Details of the equations and their derivations are given in Refs. [10-15].

Figure 1 shows output powers for the second, fourth and sixth harmonics of SSLMs excited by well -defined IMPATT diode input powers and frequencies [16].

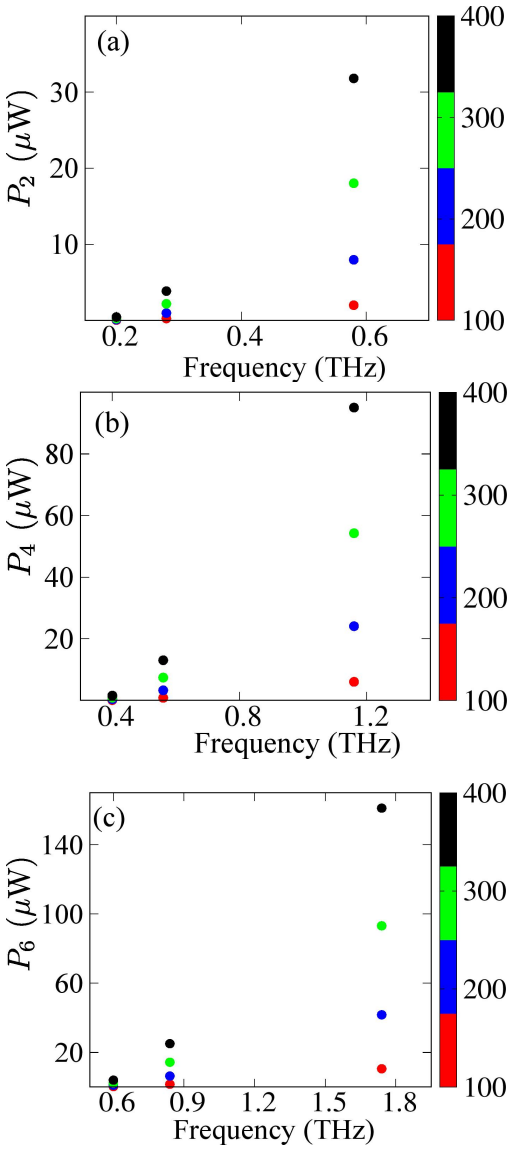

Fig. 1. (a) Second, (b) Fourth and (c) Sixth harmonics output powers for SSL multipliers under the influence of a biased oscillating field for different input IMPATT diode devices over frequency ranges 250-1500 GHz for a perfectly symmetric current-voltage curve. The input frequencies and powers are given respectively by 100, 140, 290 GHz and 80, 30, 10 mW.

One can notice that the higher-order harmonics (e. g. 6th harmonics in Fig. 1(c) for ν=290 GHz) have significantly larger output in comparison to the second or fourth harmonic. This unexpected behavior of the harmonic response further confirms the relevance of our studies regaridng the extraordinary nonlinear processes taking place during harmonic generation in SSLs [10-15].

A thorough study of the combined effect of current-voltage asymmetry and applied voltages control will be shown at the conference.

These results are useful as guidelines for the simulation of realistic combinations of GHz input sources with superlattice multipliers that can reach the THz range with useful power for spectroscopic applications at low cost and operating at room temperatures.

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