S3-O1

Plasmonic Eigenmodes of a Semiconductor Superlattice in Conditions of Bloch Gain

Lukas Stakėla[1], Kirill N. Alekseev[2]

[1]Center for Physical Sciences and Technology, Department of Optoelectronics
Saulėtekio av. 3, LT-10257 Vilnius,
Email: lukas.stakela@ftmc.lt

DC-biased semiconductor superlattices (SLs) can operate in the regime of negative differential conductivity due to excitation of the electron Bloch oscillations [1]. This potentially could lead to a high-frequency Bloch gain resulting in an amplification of GHz-THz signals [2]. The SL devices can work at room temperature which is inherently different from the available THz quantum cascade lasers that still require low temperatures. The ac signal amplified in the SL can be either a transverse electromagnetic wave (optical gain) or a longitudinal space-charge wave (plasmonic gain). The physical mechanisms of the plasmonic gain effects in SLs are still poorly understood, and this encompasses the main area of our interest.

Here, following the seminal work [3], we calculate and analyze the complex eigenfrequencies ($\omega = \omega + i\omega$) of the transverse plasma modes (~$exp(-i\omega t)$) in dc-biased SL. The behaviour of the modes is mainly governed by two parameters: $\omega\,\tau$ and $\omega\,\tau$ (Bloch and plasma frequencies and the scattering time - τ). When $\omega\,\tau > 1$ and $\omega\,\tau > 1$, the Bloch and plasma oscillations are excited and hybridized into a high-frequency "hybrid Bloch-plasma mode". Simultaneously, the low- frequency "relaxation mode" becomes unstable. Our computations show good correspondence with the approximate analytic solutions found in [2] in the limit $\omega\,\tau \leq 1$. Moreover, we consider the interesting limit of $\omega\,\tau \gg 1$ corresponding to the heavily doped SL devices [4], and find a very large increment of the unstable mode which appearance coincides with a significant increase of the hybrid mode decay rate [see Fig. 1]. Our findings provide useful insights into the understanding and development of novel active plasmonic devices.

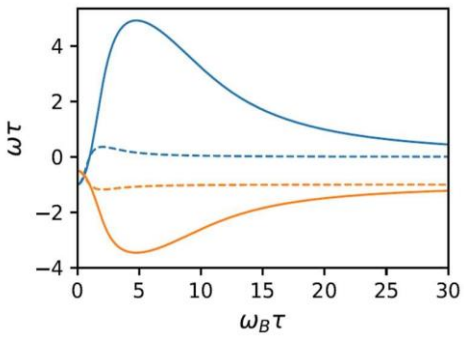

Fig. 1 Increment (ω >0) of the unstable relaxation mode (blue) and decrement of the stable hybrid mode (orange) for two values of the plasma parameter: $\omega\,\tau$=2 (dashed) and $\omega\,\tau$=20 (solid).

REFERENCES

[1] Esaki, L. and Tsu, R., IBM J. Res. Dev. 14, 61–65 (1970).
[2] Ktitorov, S. A., Simin, G. S. and Sindalovskii, V. Y., Fiz. Tverd. Tela 13, 2230–2233 (1971).
[3] Ignatov, A. A. and Shashkin, V. I., Sov. Phys. JETP 66, 526 (1987).
[4] Renk, K. F. et al., Phys. Rev. Lett. 95, 126801 (2005).