Frequency comb generation in a time-dependent graphene ribbon lattice

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Abstract— Recently, frequency comb generation using modulated planar graphene sheets was introduced [1]. Here we show that this process is more efficient in a graphene ribbon lattice than in a planar structure. To do so we exploit the plasmonic resonances of the lattice, which are very sensitive to the graphene doping level. By dynamically changing this doping the transmission becomes time-dependent and allows for effective frequency comb generation in the infrared range.

1. INTRODUCTION

Graphene is a 2D hexagonal lattice of carbon atoms with remarkable optical properties. At infrared frequencies, graphene sheets support plasmonic modes that have already been observed [2]. A recent paper [1] reported that if the conductivity of a graphene sheet is modulated in time, a monochromatic incident plane wave can generate a frequency comb in transmission. The frequency separation between the peaks of this frequency comb is given by the modulation frequency applied to the graphene sheet. In this work we investigate 2D graphene ribbon lattices to enhance this process. These lattices support plasmonic resonances that are widely tunable [3] and of high quality for sufficiently large relaxation times (Figure 1).

2. RESULTS

The graphene lattice resonances are very sensitive to the doping level, thus by slightly changing this doping one can significantly change the transmission of the lattice (Figure 2). Therefore, to instigate frequency comb generation in lattices we can employ a time-dependant doping that is small, compared to the conductivity change required for planar sheets in [1].

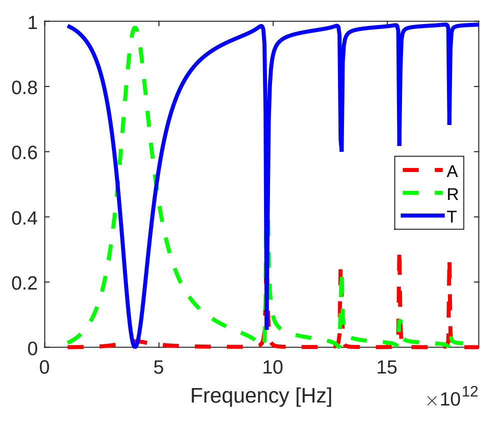

Figure 1: Transmission T, absorption A and reflexion R of a typical graphene ribbon lattice used for frequency comb generation.

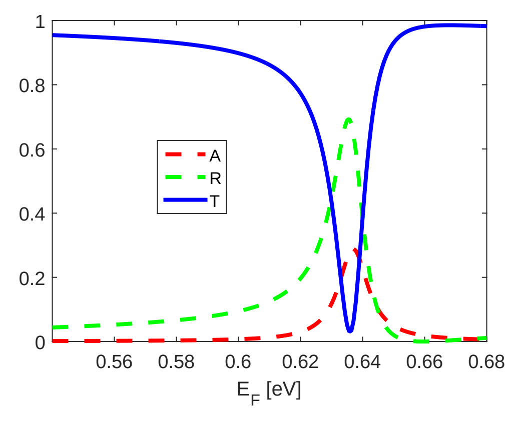

Figure 2: Transmission T, absorption A and reflexion R as a function of graphene doping for a given frequency (10 THz).

With this alternative technique the comb generation process is more efficient than for a planar graphene sheet, even if the lattice covers a smaller area (Figures 3 and 4). These results are obtained with rigorous finite-element simulations. A theoretical model is currently under development.

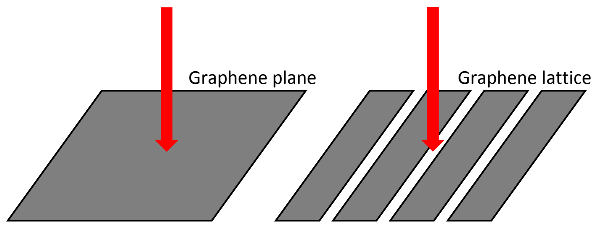

Figure 3: Geometries used for the frequency comb generation with a graphene plane and a graphene lattice.

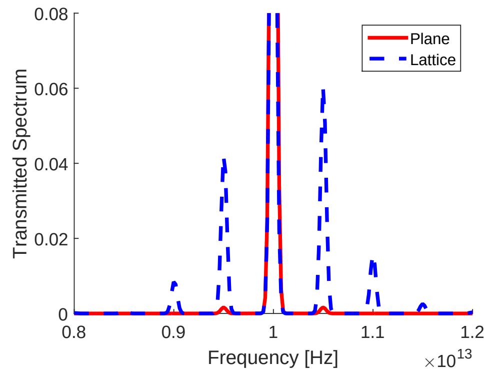

Figure 4: Comparison between a frequency comb generated by a plane and a lattice. All the parameters used in the simulations are the same, except for the geometry.

3. CONCLUSION

We show that frequency comb generation using time-dependent graphene ribbon lattices is possible and more efficient than in a planar structure. Furthermore, this effect is widely tunable as the resonance frequency of plasmonic modes in graphene lattices scales with the ribbon width. This generation process can then be used for a very wide range of frequencies in the THz range.

ACKNOWLEDGMENT

This work was supported by the Belgian Science Policy Office under the project “Photonics@be” (P7-35) and by the Fonds pour la Formation à la Recherche dans l’Industrie et dans l’Agriculture (FRIA) in Belgium.

REFERENCES

1. V. Ginis, P. Tassin, T. Koschny, and C. M. Soukoulis. Tunable Terahertz frequency comb generation using time-dependent graphene sheets. *Phys. Rev. B*, 91:161403, 2015.
2. J. Chen, M. Badioli, P. Alonso-Gonzalez, S. Thongrattanasiri, F. Huth, J. Osmond, M. Spasenovic, A. Centeno, A. Pesquera, P. Godignon, A. Zurutuza Elorza, N. Camara, F. J. Garcia de Abajo, R. Hillenbrand, and F. H. L. Koppens. Optical nano-imaging of gate-tunable graphene plasmons. *Nature*, 487(7405):77–81, 2012.
3. A. Yu. Nikitin, F. Guinea, F. J. Garcia-Vidal, and L. Martin-Moreno. Surface plasmon enhanced absorption and suppressed transmission in periodic arrays of graphene ribbons. *Phys. Rev. B*, 85:081405, 2012.