The Nonlinear Optical Response of the α-T_3 Lattice in the Terahertz Regime

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Abstract — We study the electronic contribution to the nonlinear optical response of the α-T_3 model. This model is an interpolation between a graphene (α=0) and dice or T_3 (α=1) lattice (Fig. 1.). Using a second-quantised formalism we calculate the first and third order responses for a range of α and chemical potential values as well as considering a band gap in the first-order case. Conductivity quantisation is observed in the first order, whilst Higher-order Harmonic Generation (HHG) is observed in the third order response with the chemical potential (μ) determining which applied field frequencies both quantisation and HHG occur at. We observe a range of experimentally accessible critical fields between 10^2-10^6 V/m with dynamics depending on α, μ and applied field frequency. Our results suggest an α-T_3 could be an ideal candidate material for use in tunable terahertz devices.

I. INTRODUCTION

An α-T_3 type structure has recently been fabricated; in the (111) plane of $SrTiO_3/SrIrO_3$ [1], by critically doping $Hg_{1-x}Cd_xTe$ [2] and by confining cold atoms to an optical lattice [3].

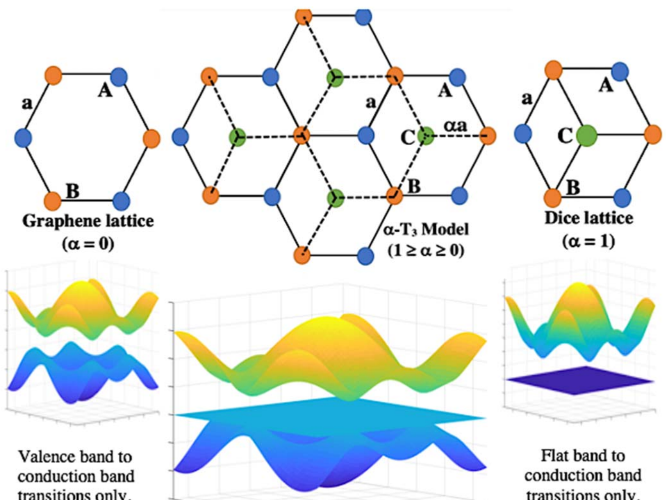

Fig. 1.: Graphical representation of the α-T_3 lattice and associated dispersions with moveable C-atom at extremal points. The band gap is due to the on-site energy of the C-atom.

Like graphene, the α-T_3 lattice provides a setting in which to study Dirac Fermions and the many subsequent exotic transport properties [4]. Although various phenomena have been studied in the low-energy linear regime, the non-linear response is also important for the elucidation of topologically non-trivial systems [5]. Inspired by the quantised linear optical conductivity of the α-T_3 lattice [4] and the well-known Higher-Order Harmonic Generation (HHG) in graphene for THz driving frequencies, we study the electronic contribution to the non-linear response of the α-T_3 lattice in the THz regime.

II. RESULTS

Whilst novel analytical results for the first and third order intra and inter band optical conductivities are possible for charge carriers near the Dirac point, our second quantised formalism handles the non-linear topology of the dispersion to numerically produce results for $\omega > 0.00355$ THz, finite temperature and band gap [6]. Fig 2. shows our most interesting results.

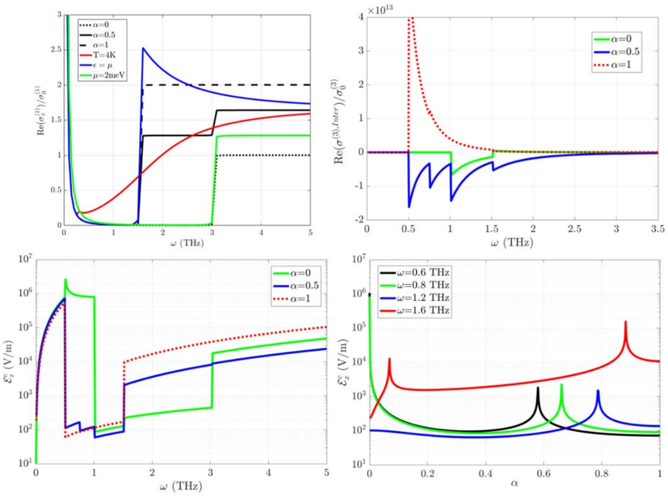

Fig. 2.: From top left to bottom right; First order conductivity (different α, temperature, band gap and μ), third order inter band conductivity for different α and critical field as a function of frequency then α.

In addition to these results we find that the third order intra band response is dependent on the Berry phase. The large and tuneable third order response leads to a highly desirable practically accessible critical field. Through rigorous analysis, each harmonic can be equated to an electron-photon process, some of which are topologically forbidden.

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