We investigate high harmonic generation in a solid, modeled as a multilevel system dressed by a strong infrared laser field [1]. We show that the cutoff energies and the relative strengths of the multiple plateaus that emerge in the harmonic spectrum can be understood both qualitatively and quantitatively by considering the dynamics of the laser-dressed system. In particular, we show that HHG proceeds through a combination of strong-field driven adiabatic and diabatic processes. Such a model was recently used to interpret the multiple plateaus exhibited in harmonic spectra generated by solid argon and krypton [2].

Fig. 1 shows an example of a harmonic spectrum generated by a four-level system that originates in the band structure of ZnO, at k = 0, driven by an intense mid-infrared laser field. The beginning and end of the two plateaus in the resulting harmonic spectrum can be recognized as the minimum and maximum of the dressed states of the system in the presence of the field.

![Figure 1](image1.png)

Figure 1: Bottom panel: harmonic spectrum from a model ZnO crystal, generated by a 3.2 μm, 6 x 10^{14} W/cm^2 laser pulse. The beginning and end of the two plateaus can be recognized as the minimum and maximum of the dressed state energies of the system in the strong field as shown in the top panel. The dressed states, which originate in the k=0 band structure of ZnO, map out the band structure as the field increases.

We show that when the multilevel system originates from the Bloch states at the Γ-point of the band structure, the laser-dressed states (which are equivalent to the so-called Houston states [3]) map out the band structure away from the Γ-point as the laser field increases. This means that the cutoff energy of a given plateau can never exceed the maximum band gap between the valence band (VB) and the conduction band (CB) responsible for that plateau, thereby extending the cutoff limitation proposed in [4] to a multiband system.

![Figure 2](image2.png)

Figure 2: Schematic of the momentum-space three-step picture for HHG in solids. In the first step, the valence electron tunnels through the band gap. In the second step, the electron wave function evolves adiabatically in the valence and conduction bands. In the final step, the coherence between the valence and the conduction band states leads to the emission of radiation with energies corresponding to the instantaneous energy difference between the dressed valence and conduction bands.

Finally, we discuss how this understanding leads to a semiclassical three-step picture in momentum space that describes the HHG process in a solid, see Fig. 2. In this picture, the delocalized electron first tunnels from the VB to the CB at the zero of the vector potential and then is accelerated on the CB as the vector potential increases and decreases through an optical half-cycle. The coherence between the VB and the CB populations leads to the emission of XUV radiation, with photon energies corresponding to the instantaneous energy difference between the VB and the CB. This means that each energy below the cutoff energy is emitted twice in each laser half-cycle.

References