0.1 Electric Field Limits

Dirac

In the literature quoted in the original FLL draft McIver et al. 10.1038/s41567-019-0698-y they use electric field strengths from $10^7 - 10^8 V/m$ with $\hbar\omega = 191 meV$. They also make a band dispersion graph for a dirac point illuminated by normally incident CPL. I noticed they are not using the high-frequency (HF) expansion. Instead, one can build the quasi-energy matrix in momentum space and make a cutoff for the mode then run the eigenvalue solver to get the energy spectrum. So, I wanted to compare that to the effective Hamiltonian for CPL incident on Dirac cone. For the HF expansion we require $\hbar\omega \gg \frac{v_F eE}{2\omega}$ or we can state

$$E \ll \frac{2\hbar\omega^2}{ev_F} \tag{1}$$

$$E_{\text{max}} \approx \frac{1}{20}\frac{2\hbar\omega^2}{ev_F} \tag{2}$$

$$E_{\text{max}} \approx 3.53 \cdot 10^6 V/m \tag{3}$$

where I'm assuming a factor of 1/20 still lets the HF expansion be comparable, $\hbar\omega = 191 meV$ and $v_F = 1.57 \cdot 10^6 m/s$. I've plotted the effective energy versus the quasienergy spectrum and they agree fairly well for the given E_{max}. When using the literature electric field values we get non-matching results

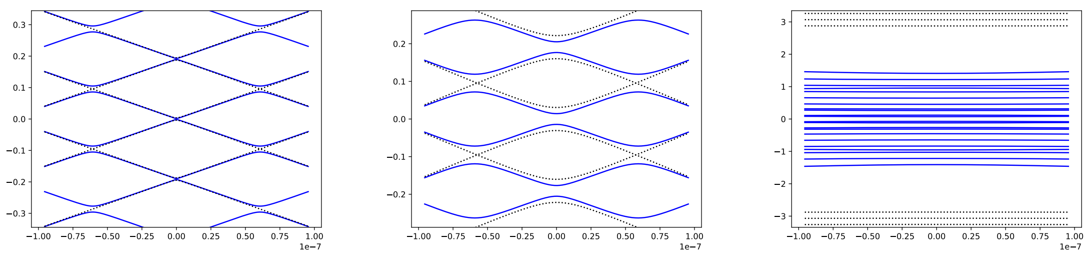

Figure 1: From left to right, $E = 3.53 \cdot 10^6 V/m$, $E = 10^7 V/m$, $E = 10^8 V/m$

For the given E_{max} the effective magnetic field is $B^D_{\text{max}} = 1.91 mT$, for $K = 2\pi/d$ with $d = 100 nm$. So we see that E has an upper limit for a given $\hbar\omega$ and K becomes our last tunable parameter, which is also limited by the wavelength with the angle as the last adjustable piece.

2DEG

We want to use similar laser parameters for 2DEG, since we know these are easily available in lab. If we look at the HF expansion fro 2DEG we have a slight alteration, $\hbar\omega \gg |H_{\pm 1}|, |H_{\pm 2}|$, more explicitly

$$\begin{aligned}\hbar\omega &\gg \frac{eE}{2m^*\omega}\left|\pm ip_x + p_y\cos(Kx)\right|, \frac{e^2E^2}{8m^*\omega^2}\sin^2(Kx),\\ \hbar\omega &\gg \frac{\hbar eE}{2m^*\omega}k_x, \frac{e^2E^2}{8m^*\omega^2}\sin^2(Kx).\end{aligned} \tag{4}$$

Here I set $k_y = 0$, notice that k_x and x are in the expression. So, I am not sure how to go about this. Does this mean for smaller values of k_x and x we can make E much larger to allow for the HF expansion?

Let me know what you think about both systems and which values to consider. Also, the original draft used $\hbar\omega = 220meV$ but I could not find that in any of the references cited in that section of the discussion, maybe it is a typo and supposed to be $120meV$?