**Absorption**

So this is our excitation spectrum so far. And we want to see if we can have photon absorption by phonons, going from a spot on the branch to another spot on the same branch.

Chart, surface chart

Description automatically generated

We’ll presume to have a phonon with momentum ℏq, and energy ℏωq. So we want to know if there is a photon with some momentum ℏk, ℏωk out there that can be absorbed, thereby promoting the phonon to state ℏq´, ℏωq´. We don’t imagine that *any* photon can be absorbed – often only specific ones can be absorbed by a given phonon. So we must at least have conservation of momentum/energy. This requires:



Using ωq = qvs, and ωk = kc, we have:



Let’s presume a 1D collision. Then we have:



And our solutions for k and q´ are:



So basically k = 0, q´ = q is a solution. Basically no photon. Or can verify that we have solution, basically any solution, if vs = c. The requirement that vs = c accords with what we found when studying electrons anyway. Unless the slope of the electron energy spectrum matched that of light, we couldn’t have absorption. But neither electrons nor phonons go that fast. So I’ll conclude that we cannot have such absorption. What about if our phonon changes branch? Then our equations read:



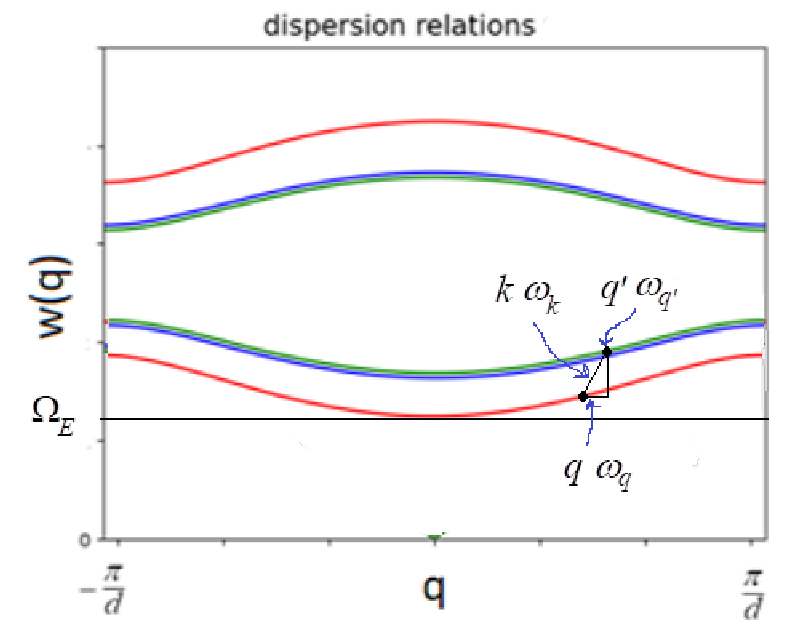
Let’s just presume it’s a 1D collision again so then our equations are:



and our solutions are:



Graphically, the solution would look like this. We start with phonon at momentum, energy q, ωq. Then draw a photon, represented by straightline with slope ωk/k = c (line would be practically vertical on this graph, but making it shallower for clarity). And where the photon line hits the next branch is where we get absorption. Photon absorption by a phonon going from an acoustic branch to another acoustic branch is called ***Brillouin absoption*** I think.



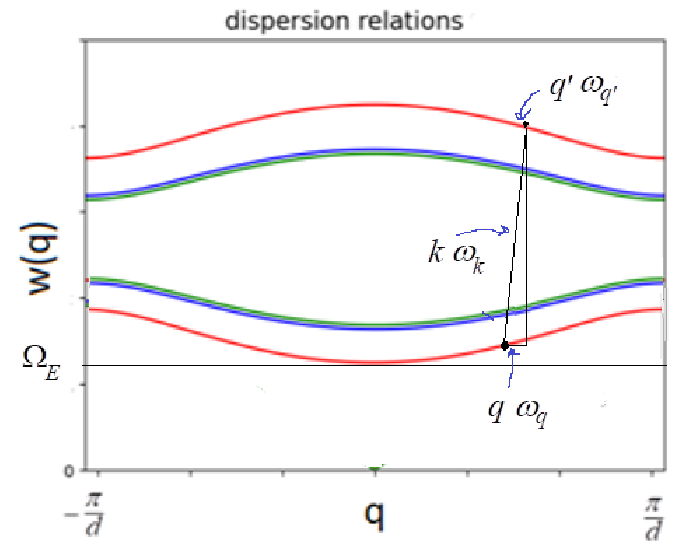
By the same graphical/algebraic procedure we can see that we could have absorption up to an optical phonon line. This is called ***Raman absorption***. In that case momentum, energy conservation would require,



where Ω is the *roughly* constant optical phonon frequency. Then our solution is:



Illustrated here,



In a metal, the basis is typically monatomic, so scattering into the optical branch may not be an option, ‘cause it doesn’t exist. And acoustic -> acoustic may not be as strongly favored as acoustic -> optical, all things being equal. This is because, like with EM rad + atom, the matrix element <acoustic1|photon field |acoustic2> is not that big. Unlike the optical branch, where we often have somewhat oppositely charged atoms within the basis vibrating out of phase, and thereby creating a relatively large oscillating electric dipole moment (and thereby being capable of dramatically responding to electric fields, and creating them), the acoustic branch consists of these same charges basically moving in phase with each other, and thereby w/o any significant dipole moment. What about Umklapp processes?



Well as long as we’re just talking about a single phonon absorbing a photon, we shouldn’t have any such processes, since if q is in the BZ, k’s for optical absorption shouldn’t be large enough to kick into a q´ outside of the BZ. This would only occur if the phonon were reaaaaally close to the edge of the BZ.