Physics 360/460 Intermediate Laboratory

Experiment #23

One Dimensional Lattice Dynamics

Introduction:

A row of sliders on an air track connected by springs can be thought of as a one-dimensional chain of atoms with the connecting springs corresponding to a nearest neighbour bond between the adjacent 'atoms'. By exciting different wavelengths, k, which have a corresponding frequency, ω, a plot of $\omega(k)$, called a dispersion relationship, can be generated for the quasi l-D slider lattice.

If all the 'atoms' and 'bonds' are equivalent, the dispersion relation will only have an ACOUSTIC branch. By alternating heavier and lighter carts (or equivalently, loser/stiffer springs) it is possible for $\omega(k)$ to be double valued and the additional, different relationship which exists between wavelength and frequency is labeled as the OPTIC branch.

Experiment:

You can use either the motor supplied or your hand to generate different wavelengths on the air-track. If you use the supplied eccentric cam motor, there is a voltage readout which can be converted to frequency by dividing by Hz = mV/183. (**note**: Always set the multimeter to the highest range to consistently cope with the large voltage spikes that are supplied to the stepping motor.)

The lab report should answer and include the following:

1. Investigate both a l-D 'monatomic' and 'diatomic' lattices and plot their dispersion relation, $\omega(k)$, using 6 or 3+3 slider respectively.
2. Explain the terms 'Acoustic' and 'Optical' branches of $\omega(k)$ and give examples of how one or the other might be excited.
3. What is the maximum cut-off or 'Debye' frequency, ω_D, and wave vector, k_m, for the model lattice? Explain the maximum.
4. What is the speed of sound in the lattices as the wave vector $k \rightarrow 0$?
5. What is the magnitude of the forbidden energy zone or 'band gap' characteristic of your 'diatomic' lattice?
6. Compare the experimentally obtained 'band gap' to the theoretical 'gap' which you can calculate after measuring the cart mass and the spring constant 'k' of the springs connecting the carts. Comment on the agreement.

References:

Ch. 4 of 'Introduction to Solid State Physics' by Kittel.