Notes 5

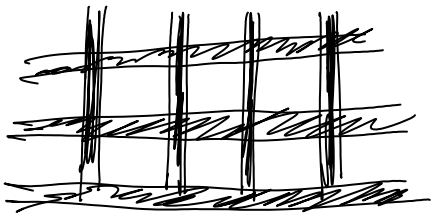
Monday, September 27, 2010
11:13 AM

2D crystal structures

we have crystals that are periodic in 2D but infinite/homogeneous in the 3rd

some typical configurations

rods 

"woodpiles" 

holes 

we can arrange the rods/holes in any arrangement & by introducing defects we can play some games

Examine the symmetries

$\hat{z}$ homogeneous, continuous translation

x, y periodic $\Rightarrow$ discrete translation

break $\vec{k}$ into k_z $k_{\parallel}$

we know k_z will be plane slip by

& know $k_{\parallel}$ has Bloch periodicity

$\parallel$, $e^{ik_{\parallel}P}$ $e^{ik_z z}$

$H(\nu, k_z, k_{||})(\vec{r}) = e^{j k_{||} \cdot \rho} \, e^{j k_z z} \, u(\nu, k_z, k_{||})(\rho)$

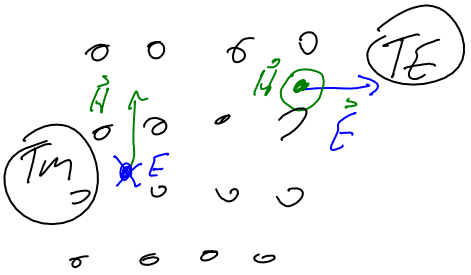
ρ ; projection of $\vec{r}$ into x, y plane

due to mirror symmetry we can break this

in TE & TM modes

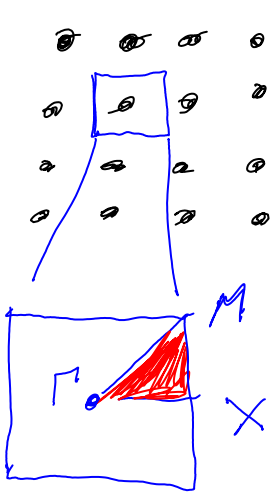
TE : $\vec{N}$ is normal to xy plane
$\vec{E}$ is in the plane (transvers)

TM : $\vec{E}$ is normal
$\vec{N}$ is transverse



Lets look at an example

rods in air



$r = .2a$

$\epsilon_r = 8.9$

$k_{||} = 0$

Γ: center of Brillouin Zone

$k_{||} = \frac{\pi}{a}\hat{x}$ X : center of a face

M: corner $k_{11} = \frac{\pi}{a}\hat{x} + \frac{\pi}{a}\hat{y}$

why? tradition

show pic from book

look @ TE & TM modes separately

TM: complete gap from

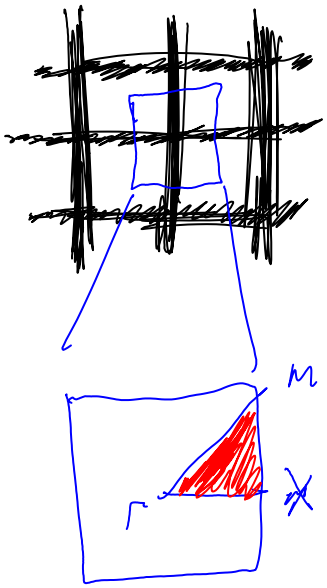
$\omega \sim .3 \Rightarrow .45$

no other gaps

TE: no gaps

get very different behavior for TE & TM.

look @ another example



slow band structure

now we have a TE gap

~.35 ⇒ .42

no TM gap

why do each of these configurations lead to bandgaps for TM or TE but not both?

Look @ field distribution

TM

Rods: E_z is highly concentrated in rods @ lowest band.

we want to concentrate energy in dielectric in general but higher modes must still be orthogonal

To stay orthogonal the upper bands must have a node in the dielectric this forces a significant amount of energy into the air, this has a much higher freq.

TE

magnetic field is much more homogeneous across the crystal.

because $\vec{E}$ is in plane it must

penetrate the rods to reach diffuse parts of the crystal

this leads to less contrast in freq between modes

Now look @ "woodpile"

the E field can stay concentrated in the dielectric as it's propagated the plane. This means there is a discrimination between modes for the magnetic field though doesn't have this

In general.

Localized regions of dielectric w/ gaps in between tend to have TM bandgaps but not TE whereas

holes in connected regions of dielectric tend to have TE gaps but not TM!

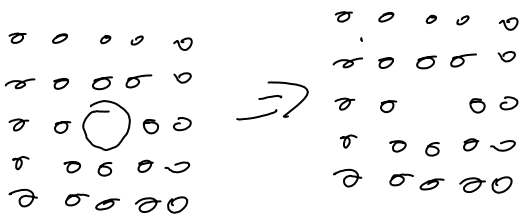
Defects in our structure

Point defect

modify a single point to break periodicity

change some dimension or index

or index



states now are allowed at the source of the defect but can not exist in the rest of the crystal

localized the location can be used as a cavity or a coupler

Line Defects

modify a row/column of the crystal