**Targets:**

* **what exactly is the momentum matrix element?**

The absorption coefficient is calculated by:

 (2.2.16)

Without current injection or optical pumping,,



With enough active pumping, the semiconductor can overcome the transparent condition and have gain:



The physical principle of gain and absorption spectrum should be the same, because they both require the incidence of the photons.

Before a specific calculation, several constants are defined to simplify the expression.



In Kane’s model, the electron wave vector is original assumed to be in the z direction. For a general direction in the spherical coordinates,

 (6.5-1a)

Using coordinate transformation, the heavy-hole wavefunctions are changed to





The momentum matrix element is



Substituting the wavefunction, we get *Mc-hh+*









*Mc-hh+*：

*Mc-hh* −： 

*Mc-lh++*： 

*Mc-lh-−*：

*Mc-lh-+*：

*Mc-lh+−*：

*Mc-so*： (6.5-1*zl*)

 (6.5-1*zm*)

(6.5-1*zn*)

 (6.5-1*zo*)

## In bulk material

The band-edge momentum matrix elements will be averaged over the solid angle for the bulk semiconductors.

### c ->hh

For TE wave,  ,the spin up conduction electron to heavy hole transition will be



in unit of [eV2s2cm-2]

For TE wave , the spin up conduction electron to heavy hole transition will be



For TM wave , the spin up conduction electron to heavy hole transition will be



### c->lh

For TE wave,  ,the spin up conduction electron to light hole transition will be



## If no coordinate transform, wrong!

### c ->hh

For TE wave,  ,the spin up conduction electron to heavy hole transition will be



For TE wave , the spin up conduction electron to heavy hole transition will be 

For TM wave , the spin up conduction electron to heavy hole transition will be 0

For spin down electron, the result is the same. Both cases included in density of states.

### c ->lh





For TE wave,  ,the spin up conduction electron to light hole transition will be



For TE wave, ,the spin up conduction electron to light hole transition will be



For TM wave , the spin up conduction electron to light hole transition will be



For spin down electron, the result is the same. **Both cases included in density of states**.

### summary

For TE wave, for c-hh ;  for c-lh

For TM wave, for c-hh ;  for c-lh

