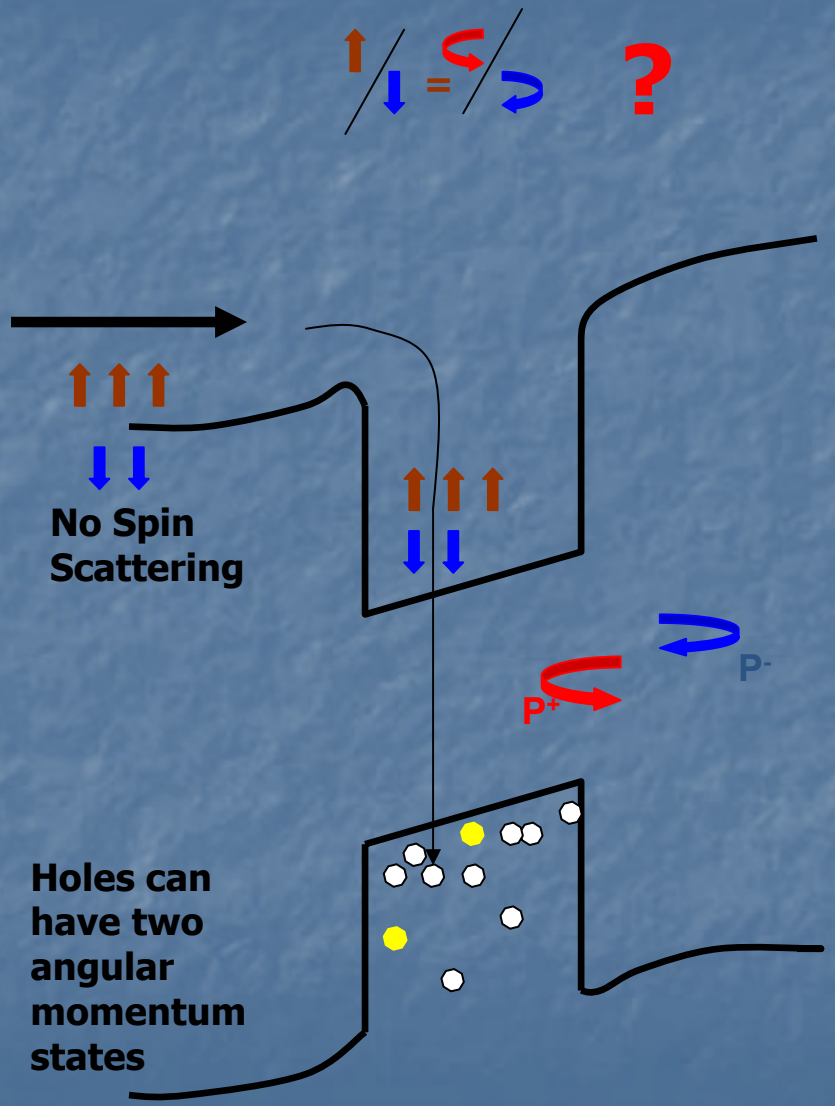
Semiconductor Band Structure Effects on the Emission Polarization from a Spin Polarized Electron Reservoir

Mukul Agrawal and G. S. Solomon

Solid State Photonics Laboratory, Stanford University,
Stanford, CA 94305

Motivation

- Optical polarization as a spin diagnostic tool
- Radiation from zone center recombination in QWs can give the estimate of injected spin polarization of carriers
- Angular momentum states of holes are also equally important
- Emitted optical polarization can be controlled through electrical bias
- Conversely spin polarized carriers can be generated by optical excitation by circularly polarized light and generation can be controlled through electrical bias



Outline

- Bands of quasi confined states calculated
- 8 band k.p theory used
- Effects of band mixing away from zone center, electric bias, strain, quantum confined stark effect and spin orbit coupling included
- Carrier distribution among k-states simulated
- Emitted optical polarization through inter-band recombination studied

k.p Band Calculations

In k.p theory we use the knowledge of the symmetries of all the zone center unit cell functions in order to explain the k variation of any one of them.

$$-\frac{\hbar^2}{2m_0}\nabla^2\psi_{n,k}(r)+V_{crystal}(r)+V_{so}(r)+V_{ext}(z)=E_{n,k}\psi_{n,k}$$

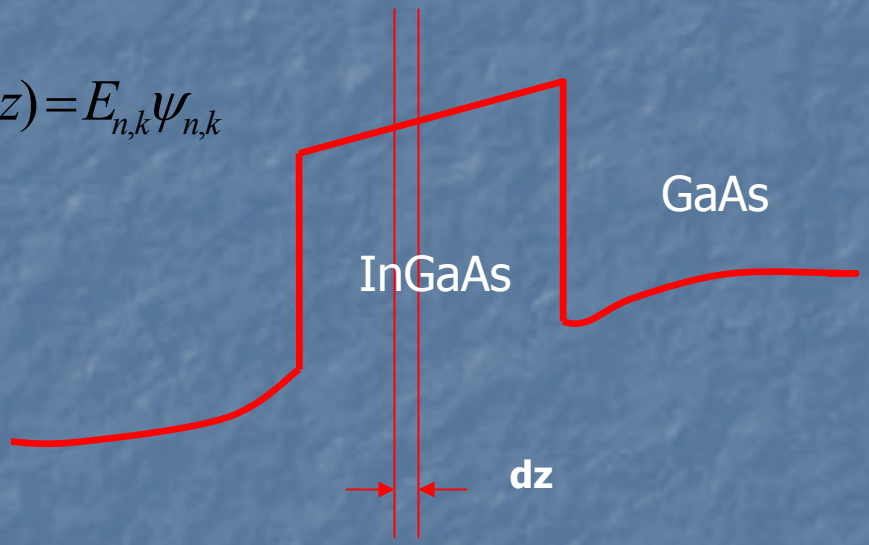
$$u_n(r,k)=\sum_n u_n(r,k=0)$$

$$\psi_{n,k}=u_n(r,k)\exp(ik.r)$$

For the slowly varying potentials

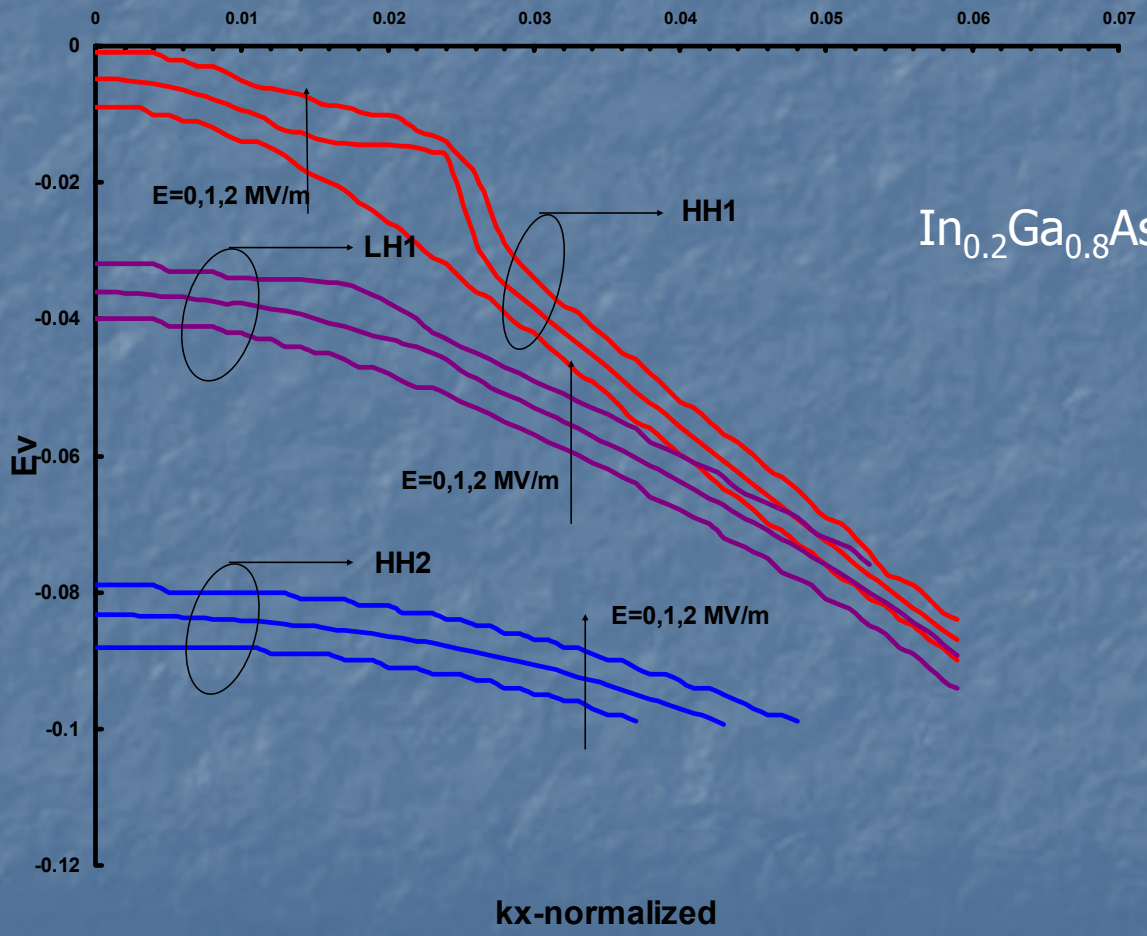
$$\psi_{n,k}(r)=\sum_{n'} u(r,k=0)F_{n'}(r)$$

$$\sum_{n'}[E_n\delta_{n,n'}+\sum_{\substack{p=x,y,z\\q=x,y,z}} D_{n,n'}^{p,q}(-\frac{\partial^2}{\partial p\partial q})+V_{ext}(z)]F_{n'}=EF_n$$



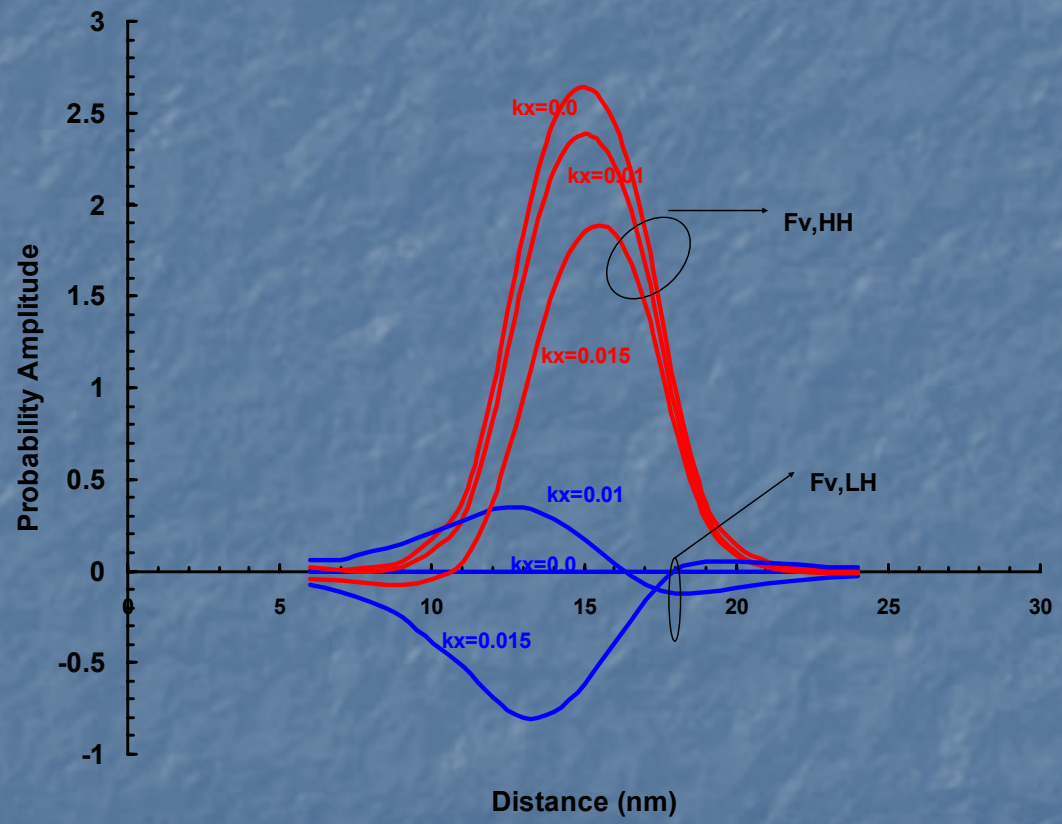
This set of coupled differential equations can be solved by dividing the structure into infinitesimally small sections and forcing boundary conditions among all sections. Transfer matrix approach used.

Bands of Quasi Bound States



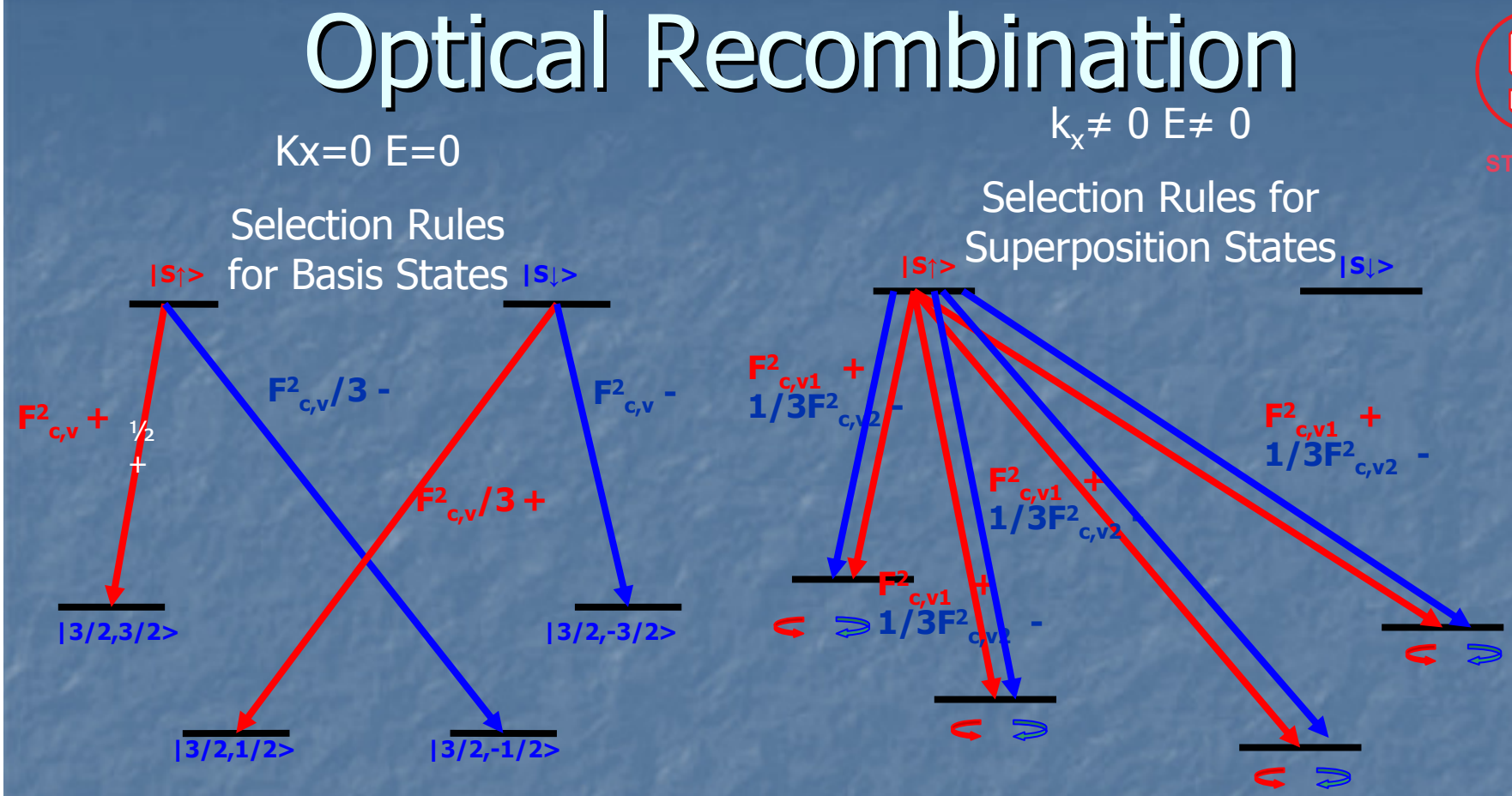
$In_{0.2}Ga_{0.8}As$

Band Mixing



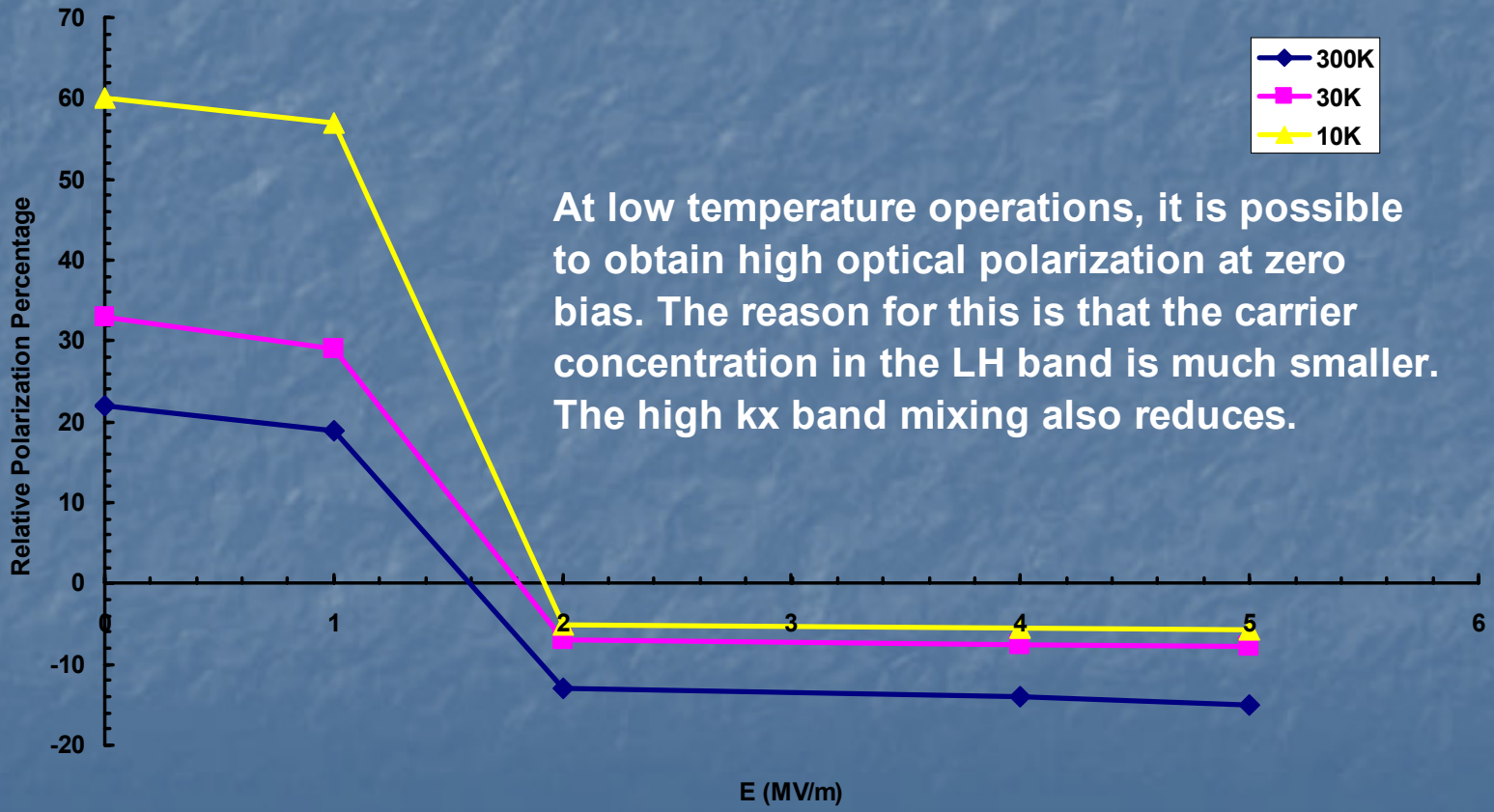
As we start moving away from the zone center the amplitude of the envelop function corresponding to LH zone center unit cell function continues to grow. Similar results were obtained when we observed a constant kx state at different Electric biases. One may also be able to control the shape of these envelop function by intelligent material system selection to control the optical polarization.

Optical Recombination



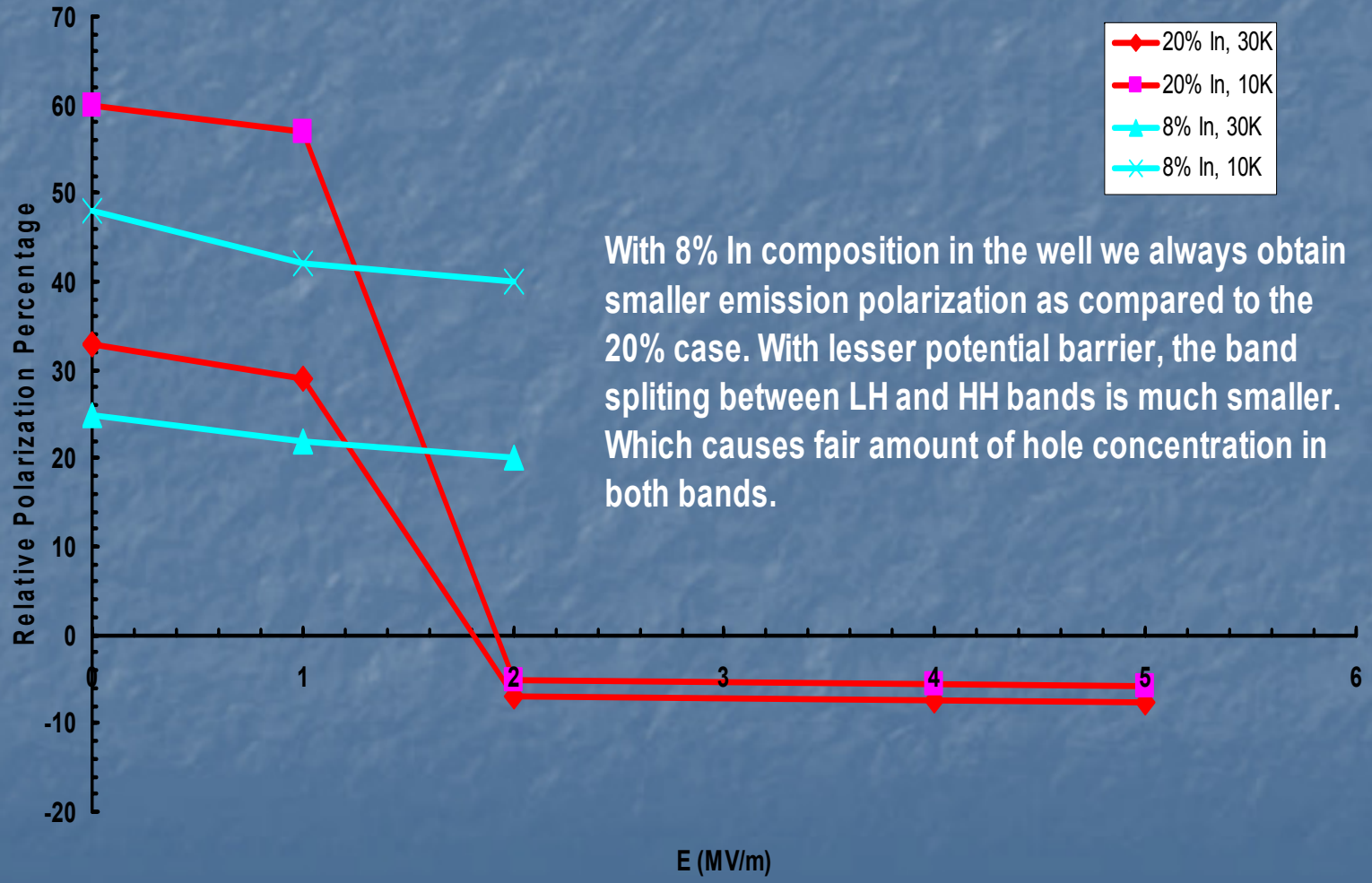
With no applied bias, the zone center hole states have definite z angular momentum. But the higher k hole states are linear combination of definite z angular momentum states. This linear combination is also affected by applied bias. This is commonly known as band mixing and it completely changes the optical selection rules as shown above

Relative Polarization vs Temperature



At low temperature operations, it is possible to obtain high optical polarization at zero bias. The reason for this is that the carrier concentration in the LH band is much smaller. The high kx band mixing also reduces.

Relative Polarization vs Composition



With 8% In composition in the well we always obtain smaller emission polarization as compared to the 20% case. With lesser potential barrier, the band spliting between LH and HH bands is much smaller. Which causes fair amount of hole concentration in both bands.