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# Overview of quantum potential model implemented into **SiLENSe 5.0**

2011



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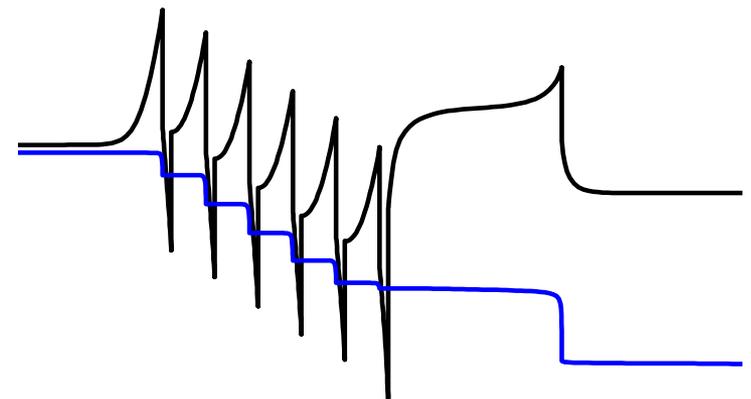
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**Thank you.**

For MQW structures, conventional drift-diffusion model predicts a ladder-like conduction band profile with a considerable decrease of the Fermi level at each barrier. This results in a severe overestimation of the operation voltage. For InGaN/GaN MQWs, the problem becomes more pronounced with increase of Indium content because of both higher band offsets and higher piezoelectric charges at the QW interfaces

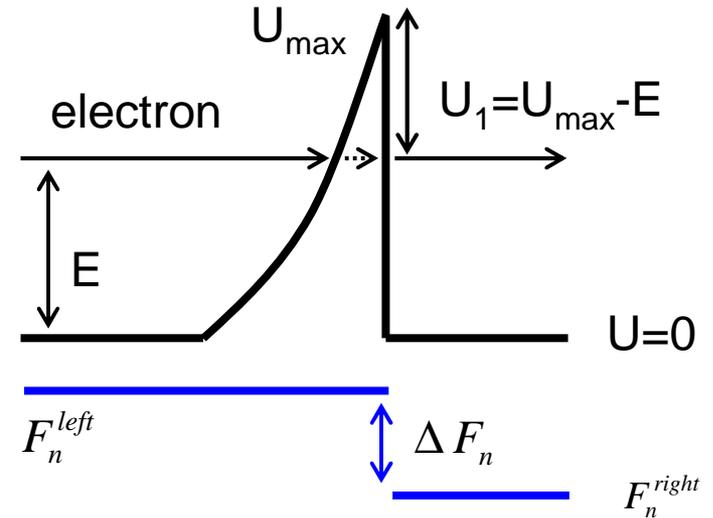
Several transport mechanisms beyond drift-diffusion can contribute to the carrier transport

- ✓ Tunneling through the barriers
- ✓ Ballistic transport
- ✓ Dislocation-mediated conductivity
- ✓ ...



— Conduction band  
— Electron Fermi level

Thermal assisted tunneling seems to be the dominant mechanism of the carrier transport in MQWs with high potential barriers formed by both high band offsets and built-in polarization charges



Transmission coefficient

$$D = \exp\left(-\frac{2}{\hbar} \int |p(z)| dz\right), \quad |p(z)| = \sqrt{2m(U(z) - E)}$$

Electron flux  $\rightarrow$

$$J_{\rightarrow} = \frac{m k T}{2\pi^2 \hbar^3} \cdot \exp\left(\frac{F_n^{\text{left}}}{k T}\right) \cdot \int_0^{\infty} dE \cdot \exp\left(-\frac{E}{k T}\right) \cdot D(E)$$

Electron flux  $\leftarrow$

$$J_{\leftarrow} = \frac{m k T}{2\pi^2 \hbar^3} \cdot \exp\left(\frac{F_n^{\text{right}}}{k T}\right) \cdot \int_0^{\infty} dE \cdot \exp\left(-\frac{E}{k T}\right) \cdot D(E)$$

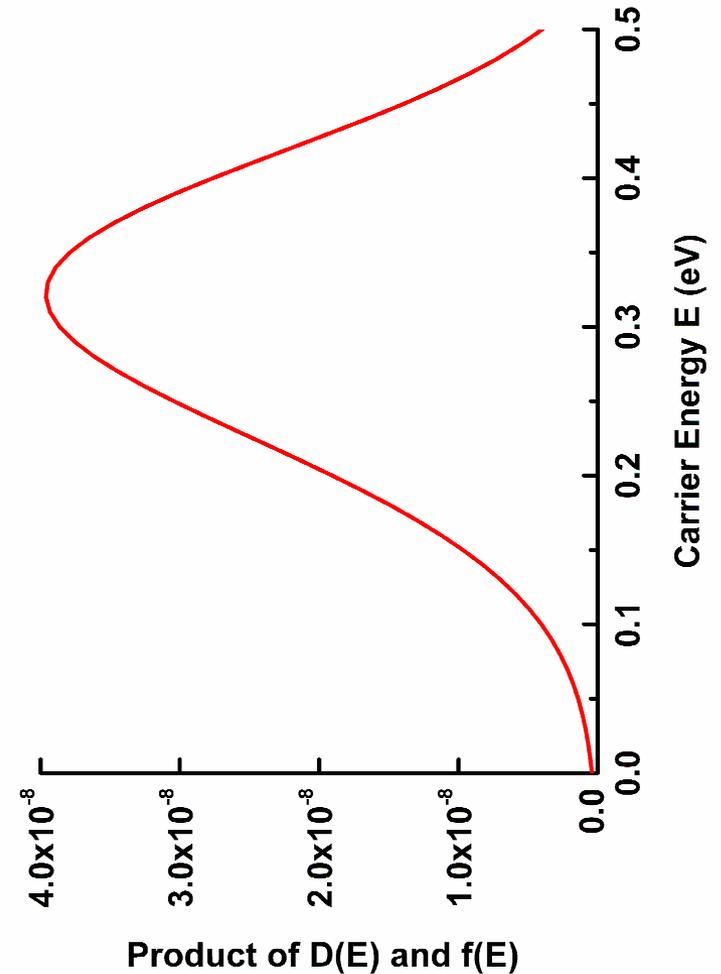
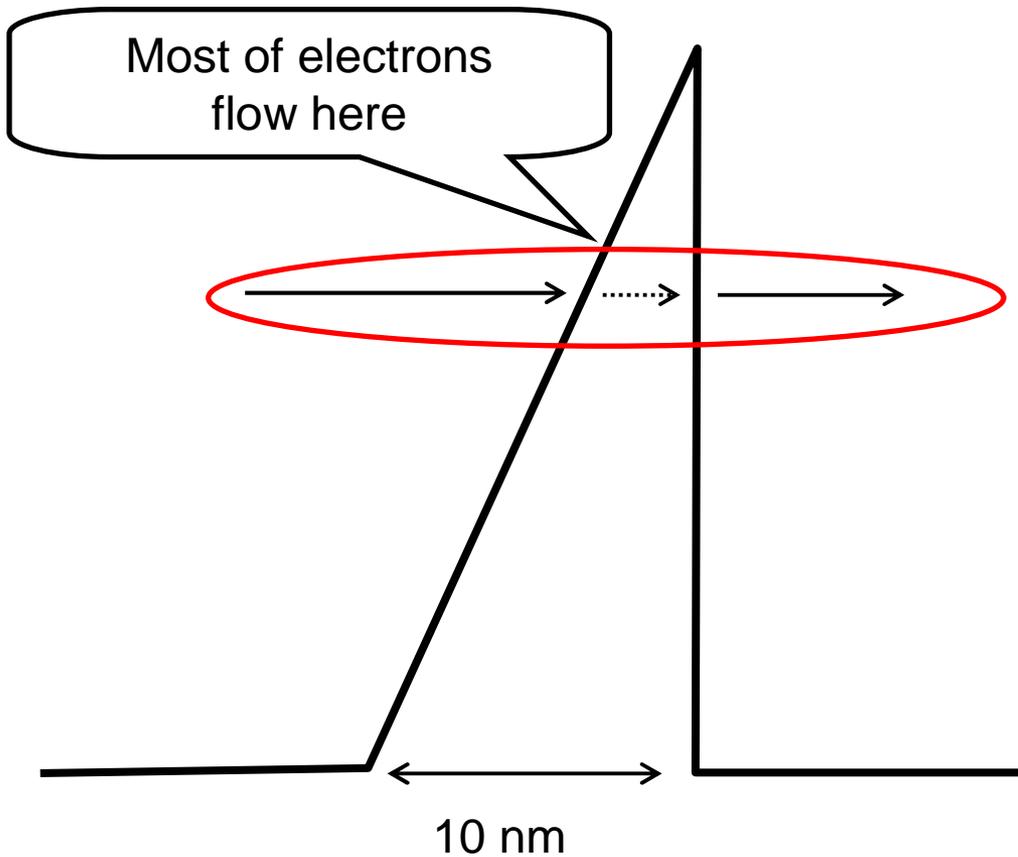
Total electron flux

$$J = J_{\rightarrow} - J_{\leftarrow} = J_{\rightarrow} \left(1 - \exp\left(\frac{\Delta F_n}{k T}\right)\right)$$



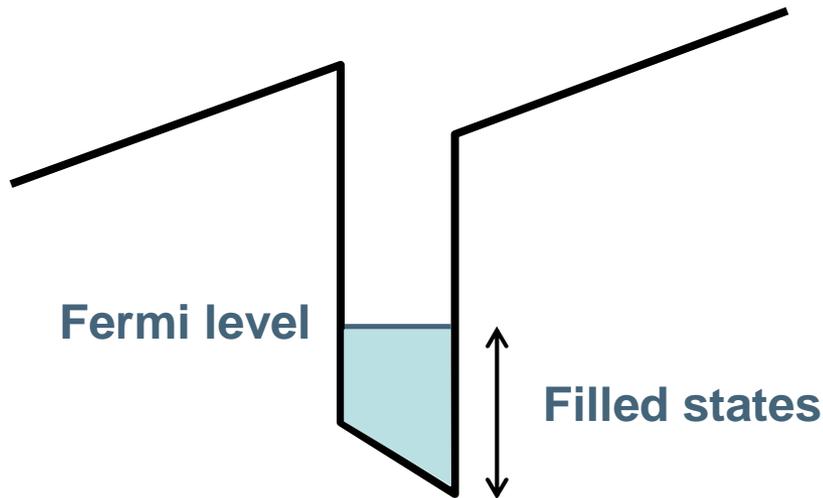
# Quantum Effect 1: Thermal assisted tunneling

## Analytical result for a triangular barrier

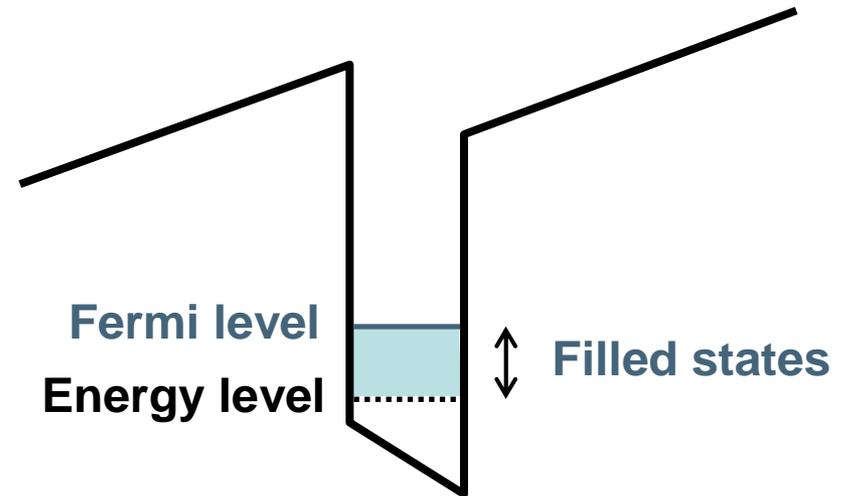




**Classical** description  
of the carrier concentration



**Quantum** description  
of the carrier concentration

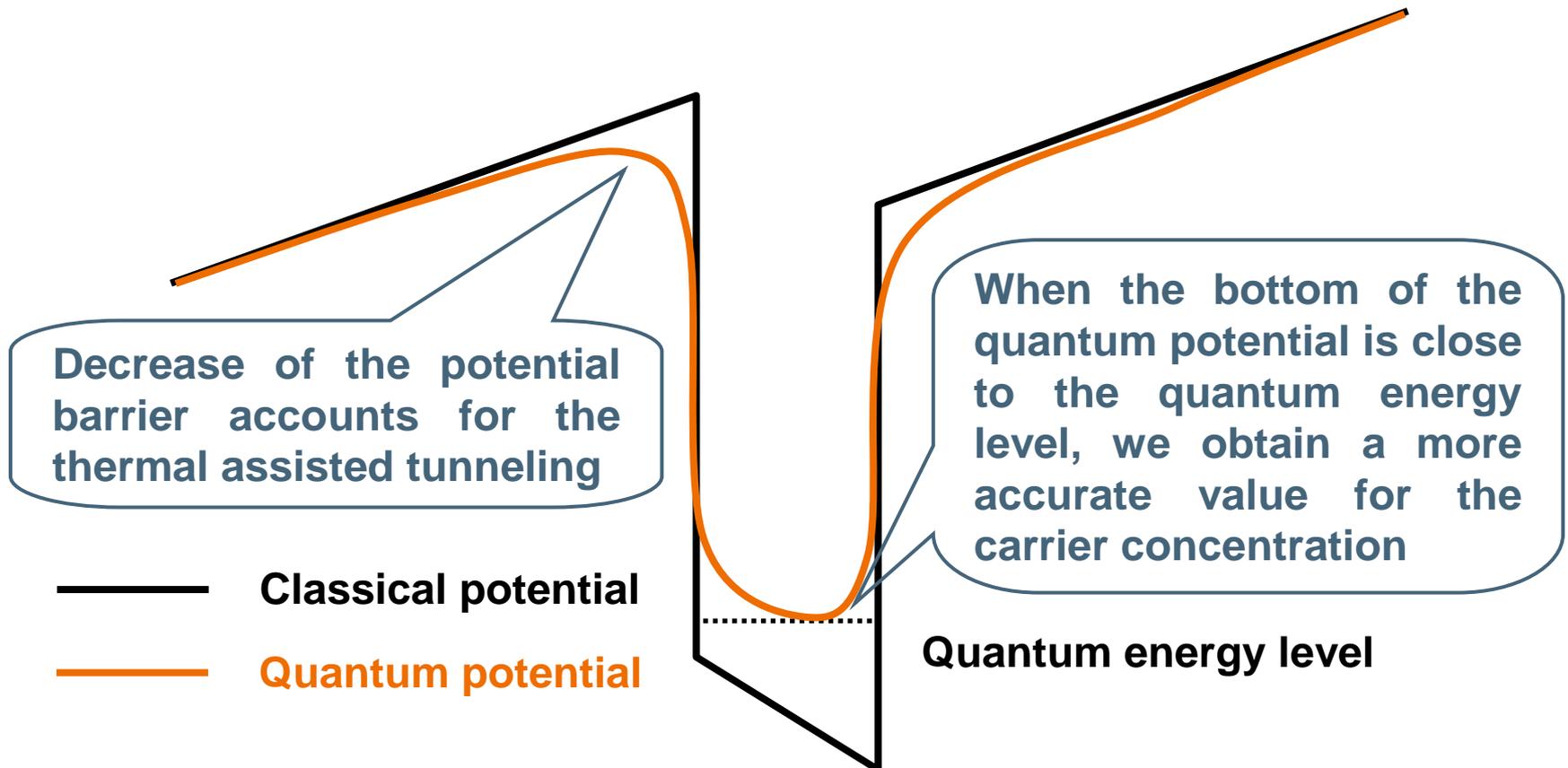


The same two-dimensional carrier concentration in a QW refers to a different Fermi level position for classical and quantum carrier description.

# Solution For Both Quantum Effects: Use of Quantum Potential

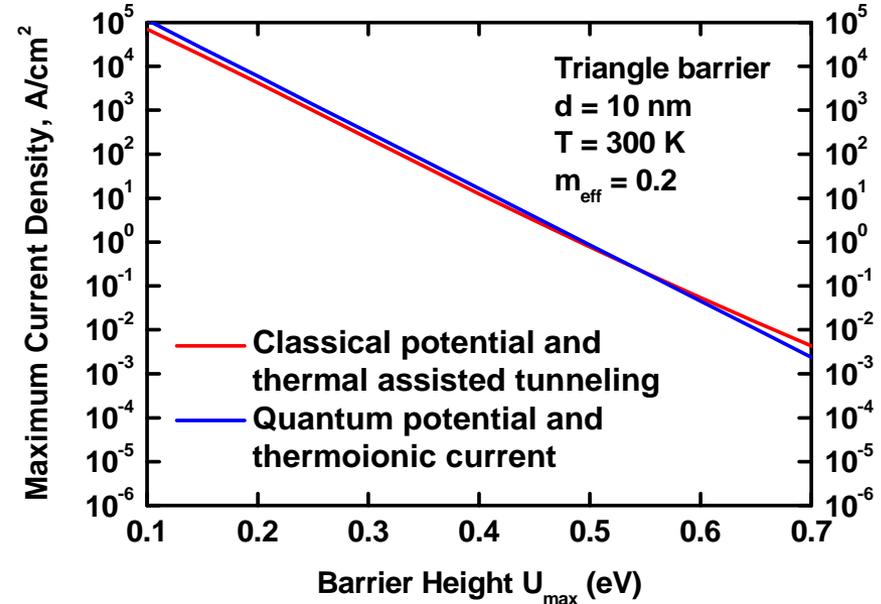
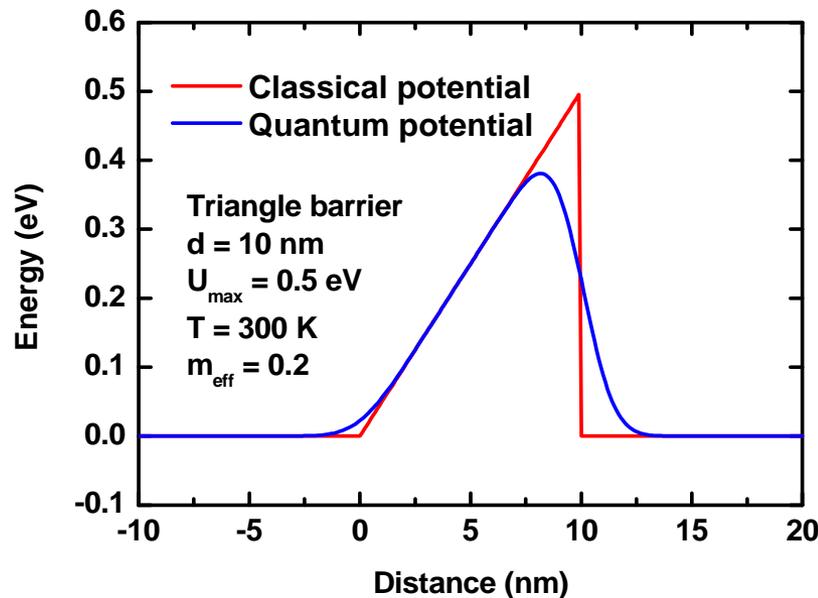


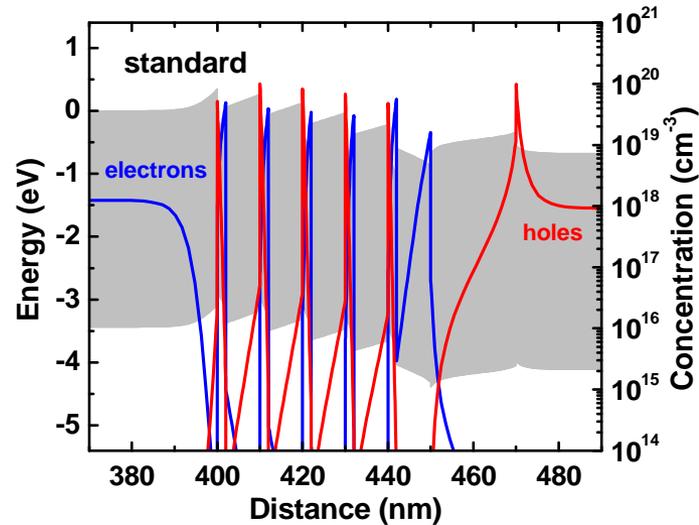
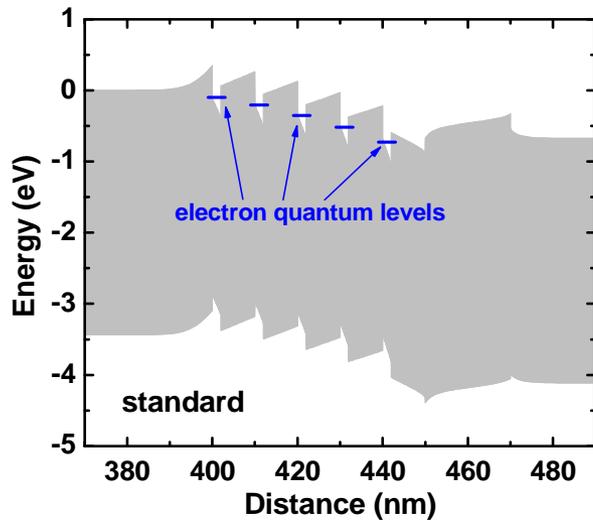
Quantum potential accounts for the quantum delocalization of the electrons/holes in a heterostructure with thin QWs and barriers, producing an effective band alignment used in the transport equations



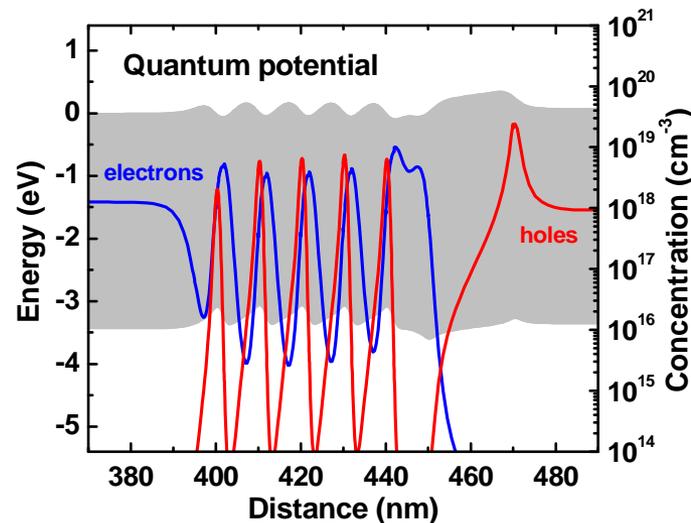
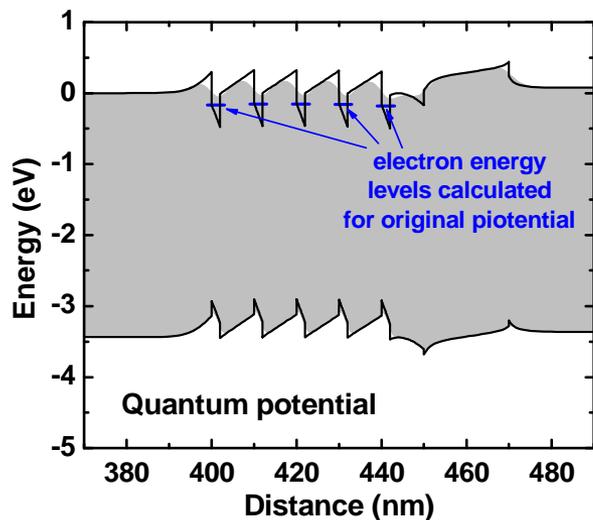


Thermo-ionic current density calculated with the quantum potential is in very good agreement with the tunnel current obtained from the original potential. This fact indicates that the quantum potential model provides reasonable estimation for the tunnel current density





Drift-Diffusion



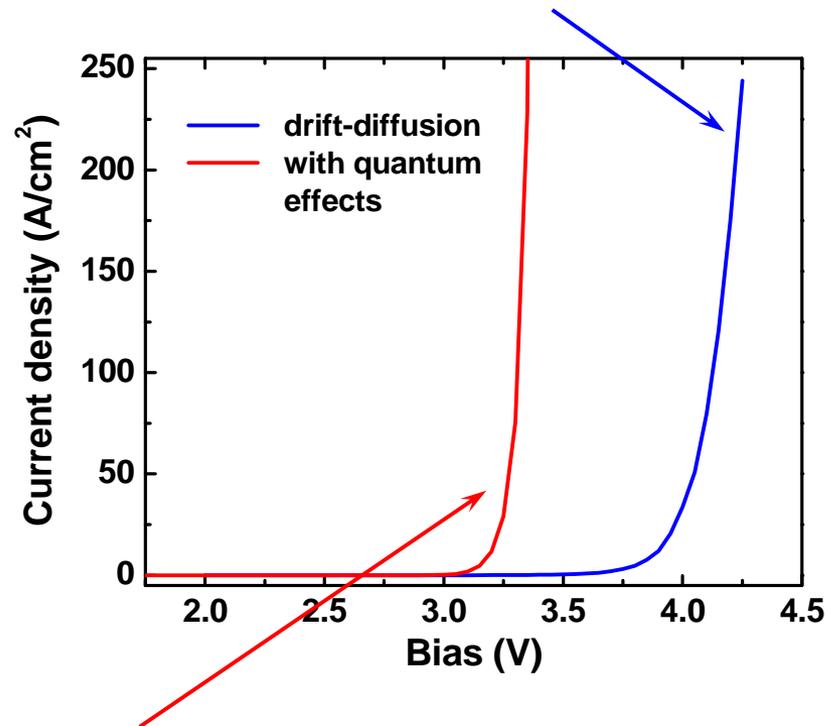
Quantum potential



# Model Verification

## Improvement of I-V characteristics

Conventional drift-diffusion model overestimates the turn-on and operation voltage of MQW blue LEDs



Use of quantum potential improves predictability of the current-voltage characteristics for MQW blue LEDs