# SSE Project Report

SIMULATION OF A RESONANT TUNNELLING DIODE USING THE MATRIX APPROACH

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**Objective**

The objective of this project was to simulate the quantum mechanical transmission properties of a resonant tunneling diode (RTD) using the matrix approach. The simulation investigates:

- Transmission through a double barrier structure
- The impact of external voltage on transmission
- Calculation of current using the Tsu-Esaki formula

All simulations were performed in **MATLAB** using and modifying the file **injector.m**.

**1. Transmission through a Double Barrier**

**Setup:**

- Barrier height: $V0 = 0.5$ eV
- Barrier width = 1 nm
- Well width = 1 nm
- Electron energy range: $E=0$(exclusive)$\rightarrow 0.8$eV
- Effective mass of electrons: assumed to be $m{*}= 1$

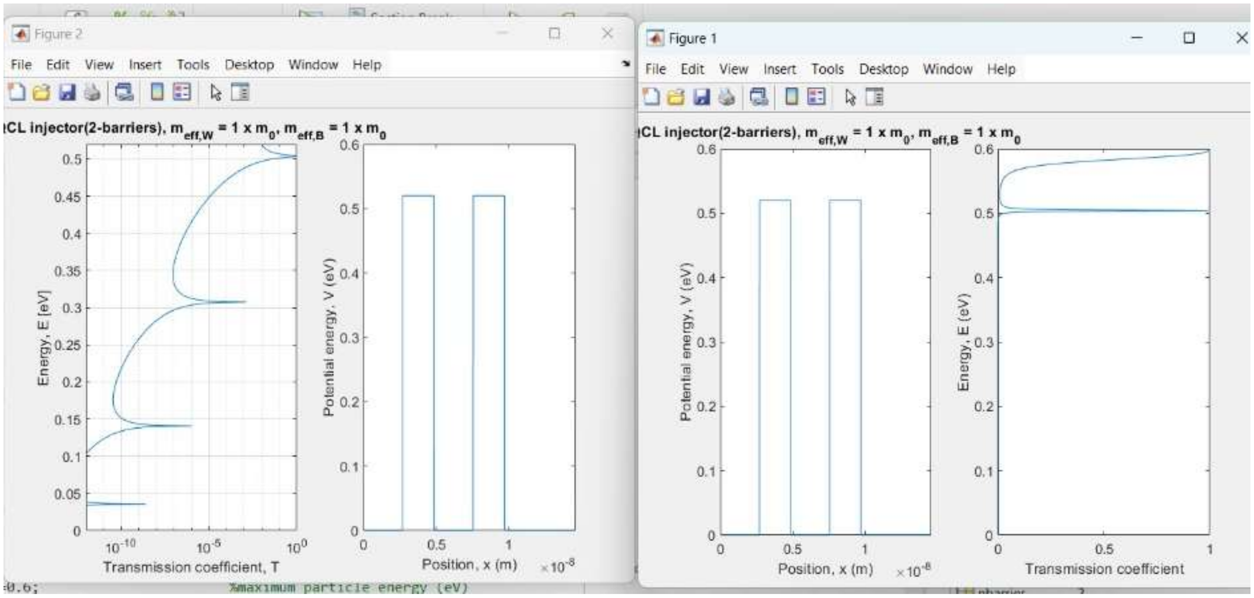
We modeled the double barrier potential using step functions and calculated the transmission coefficient using the **Transfer Matrix Method (TMM)**. The simulation was built on the existing **injector.m** script.

**Results:**

The transmission shows resonance peaks where quantum tunneling is most probable. These peaks correspond to the bound states in the potential well between the barriers. A logarithmic plot of the transmission revealed sharp peaks near specific energies, characteristic of resonant tunneling.

**Figure Reference:**

An example plot showed multiple sharp resonance peaks, confirming expected tunneling behavior.




## 2. Transmission under External Voltage

The code was extended to simulate an **external voltage** applied across the entire double-barrier structure. The potential was made to decrease linearly from the left to the right end to simulate an electric field.

**Modifications:**

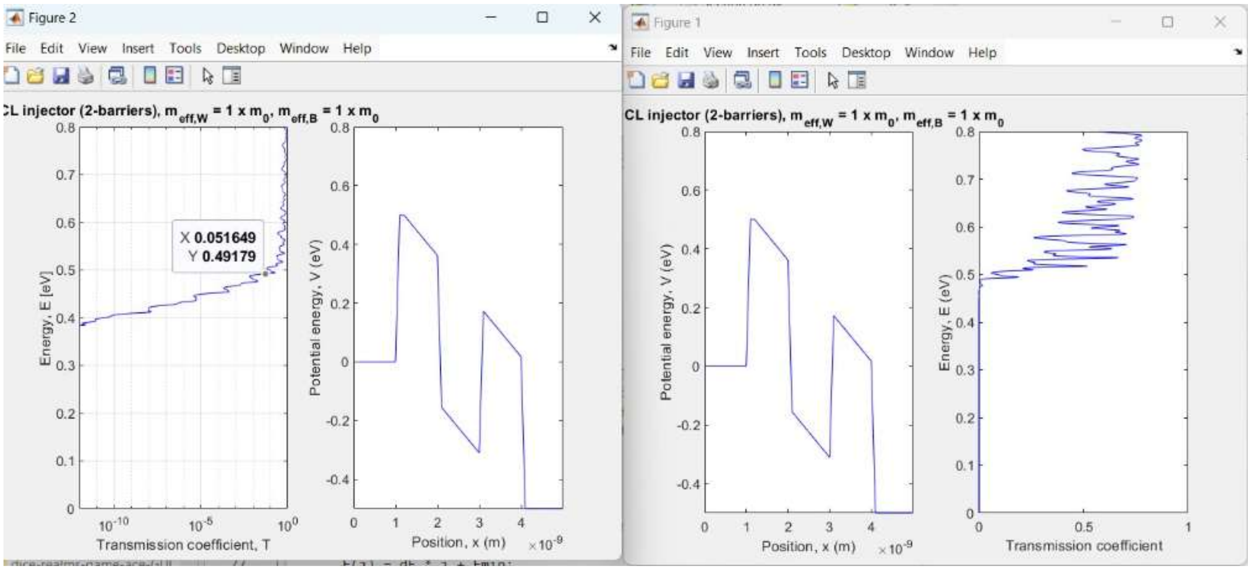
- The potential profile was modified to incorporate voltage drop (e.g., 0.5 V over 5 nm)
- The step-wise potential was recomputed in 0.1 nm intervals
- Electron energies were adjusted: E→E+qVE \rightarrow E + qVE→E+qV

**Results:**

With external voltage applied, the resonance peaks in the transmission curve shifted. The tunneling probability changed as the potential profile no longer remained symmetric.

**Figures:**

Potential profile graphs showed sloped barriers due to applied voltage, and corresponding transmission plots revealed voltage-induced energy shifts.




### 3. Transmission Current via Tsu-Esaki Formula

The current was computed using the **simplified Tsu-Esaki formula**:

$$J \sim \int_{E\min}^{E\max} TC(E)\sqrt{E} \cdot dE$$

Where:

- T(E) is the transmission coefficient
- Emin=0eV
- Emax=0.005eV
- Integration was done numerically using MATLAB (with > 50 steps)

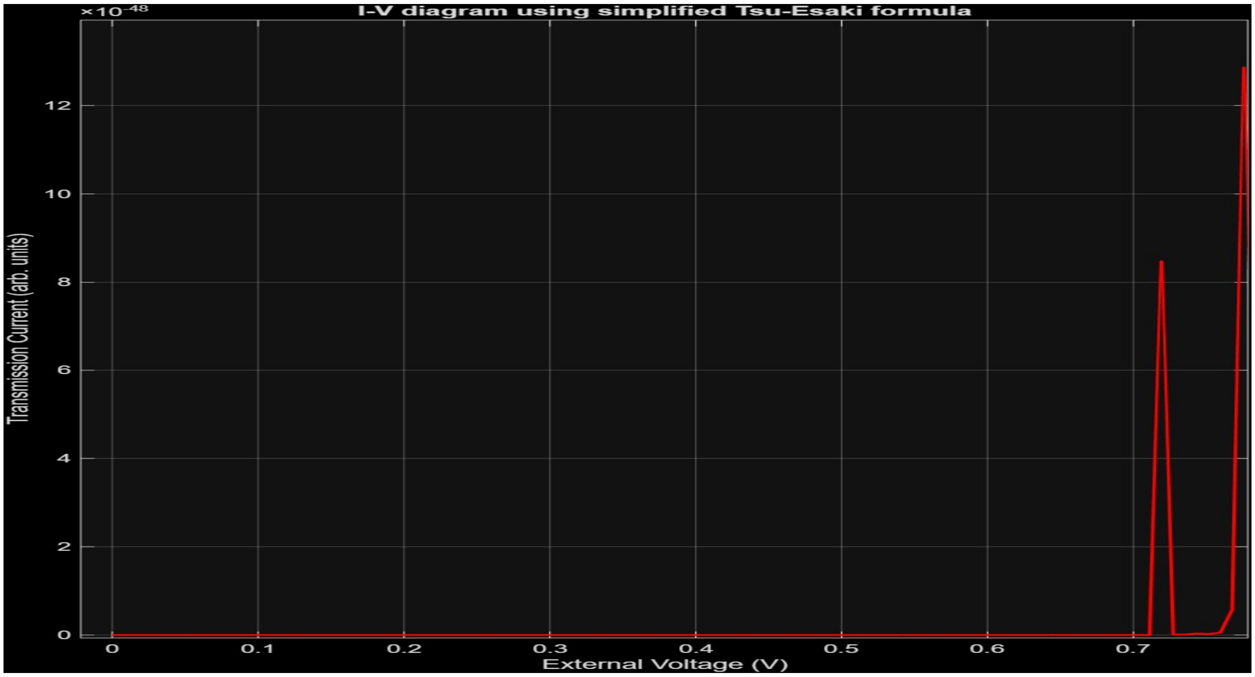
**Results:**

The I–V curve showed **non-monotonic behavior**, which is typical of resonant tunneling diodes. Regions of **negative differential resistance (NDR)** were observed—where increasing voltage leads to a drop in current.

This behavior arises from the misalignment of the Fermi level with the quantized energy levels in the well as voltage increases.

**Figures:**

I–V plots showed a clear current peak followed by a valley, indicating NDR and validating the functionality of the resonant tunneling diode.




## Conclusion

This project successfully simulated the quantum mechanical behavior of a resonant tunneling diode using MATLAB. The key findings include:

- **Resonant peaks** in transmission for double barrier structures
- **Voltage-induced shifts** in tunneling resonances
- **Nonlinear I–V behavior** and **negative differential resistance**, matching expected RTD characteristics

The simulation verified the theoretical predictions of quantum tunneling and its control through structural and voltage parameters. It also demonstrated the usefulness of the matrix method in handling such quantum transport problems.