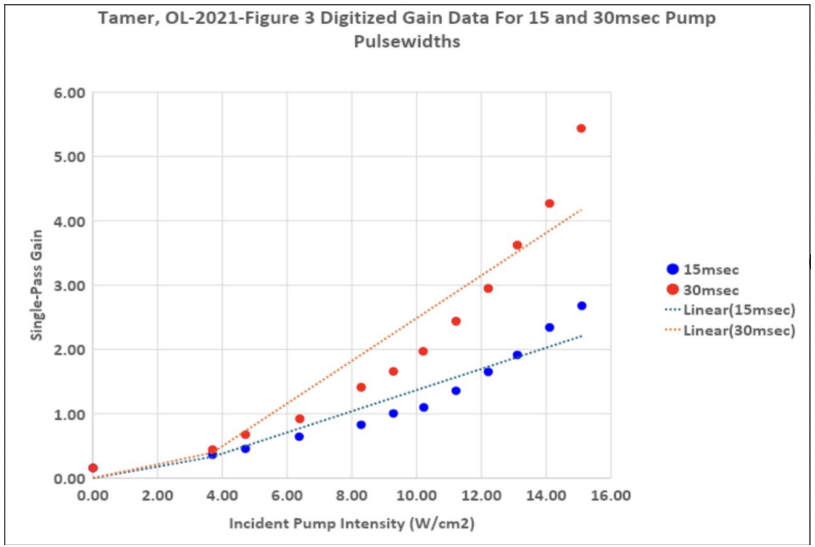
Optimization and Validation of Thulium Laser Gain Models through Numerical Simulation and Experimental Data



Energy Level Diagram For Rate Equations Derivation

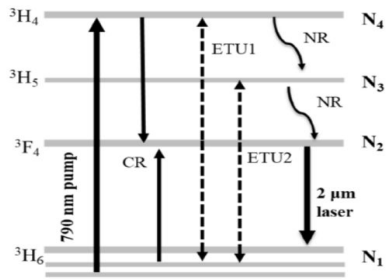


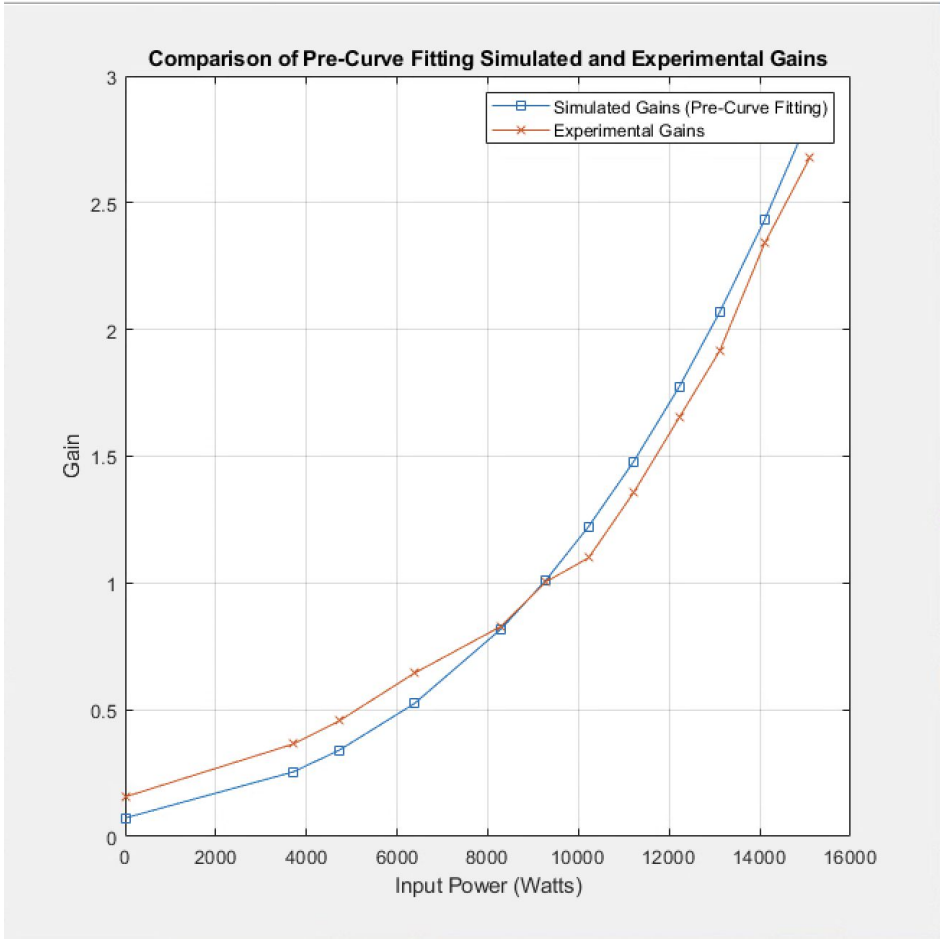
Figure 5. Energy-level transition diagram of Tm^{3+} ion.

Then, the coupled rate equation model of an actively Q-switched laser, considering the cross-relaxation phenomenon, upconversion losses and ground-state depletion, is introduced to simulate the characteristics of the emitted pulses as follows Equations (1)–(8):

Guo, Molecules, Fig. 5 (2021) (Reference [2])

This graph shows the experimental data derived from the initial Thulium laser experiment.

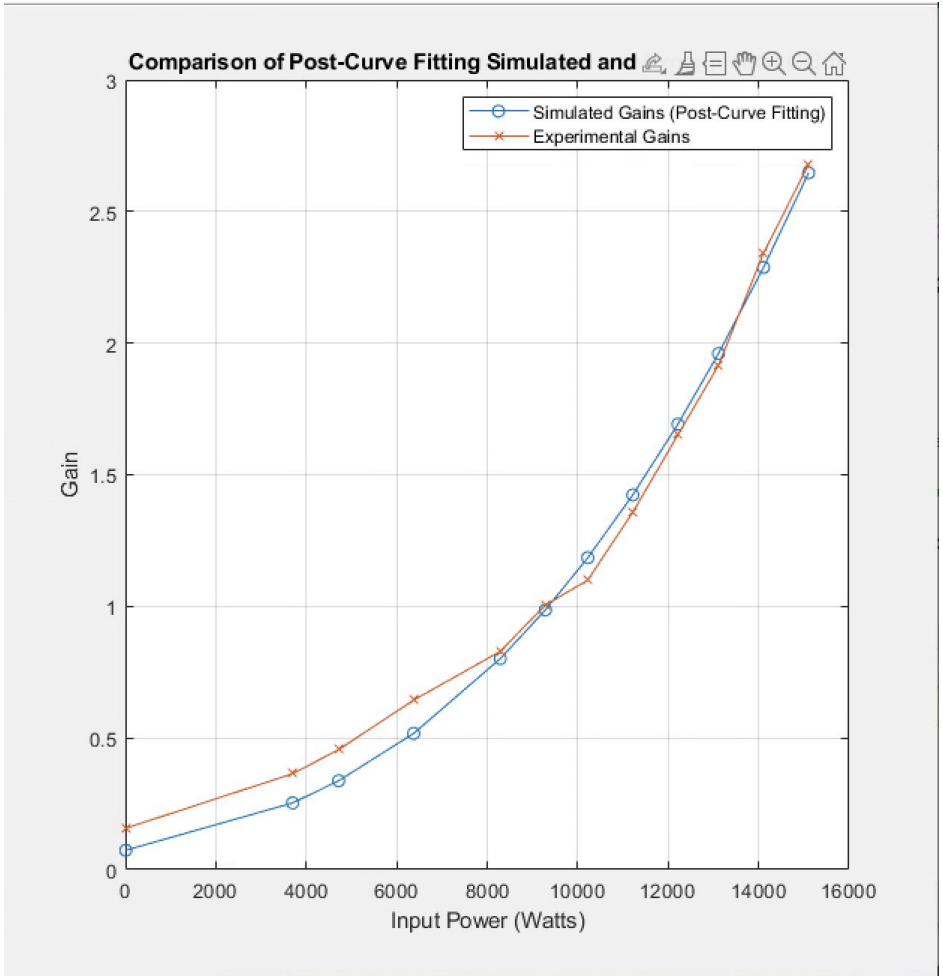
This data is critical as it demonstrates how varying the pulse width of the pump laser affects the gain achieved, informing the optimization of laser settings for specific applications.



Initially, we started with a mathematical model to simulate the laser based on various initial guesses for parameters.

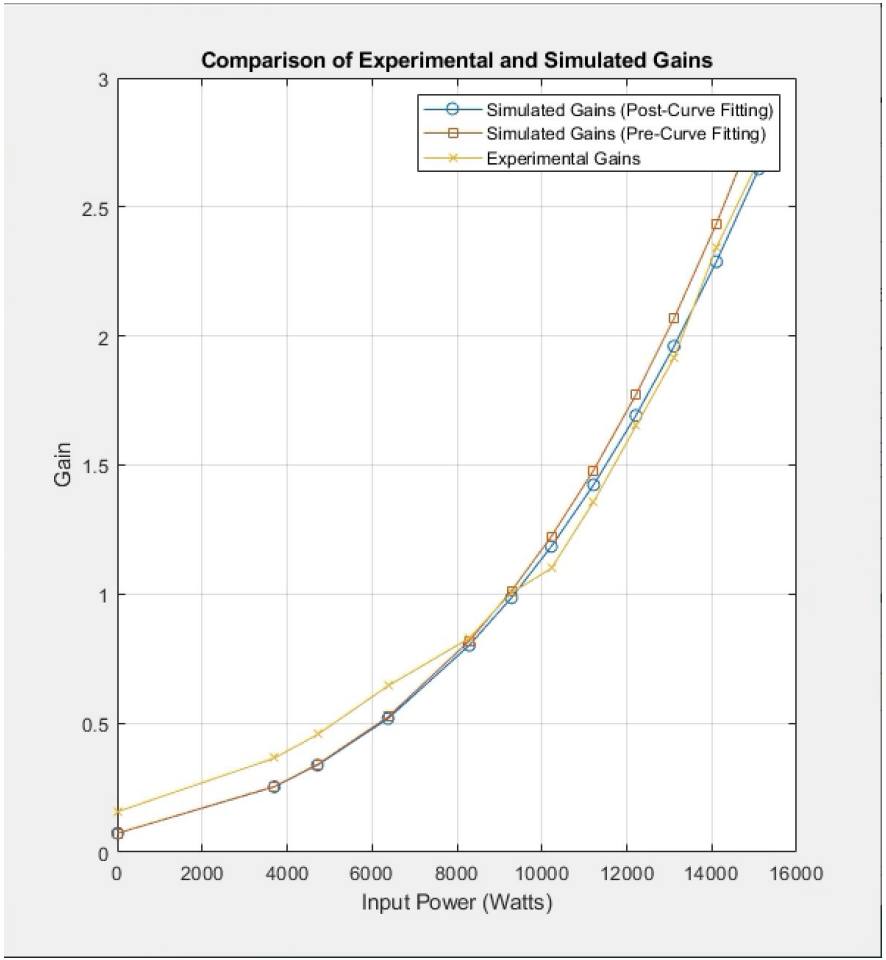
This program utilizes a runge-kutta ODE model in order to discern the population of electrons within a thulium laser over a duration of 15 ms.

The graph on the left shows how well the initial model was able to fit to the curve of the experimental data.



Throughout the semester, we refined the constants in our program using a genetic algorithm, aiming to align the simulated data curve more closely with the experimental data.

This optimization helped us achieve parameter values that better matched the observed results.



The graph on the left illustrates a comparison between the simulated gains before and after optimization, juxtaposed against experimental gains.

It is evident that the curve, post-optimization, aligns more closely with the experimental data at higher input powers. However, further refinement of the parameters is necessary to enhance the model's accuracy at lower power levels.

Summary of Model Development and Optimization

Model Development:

Developed a Runge-Kutta ODE model to simulate electron population dynamics in a Thulium laser, focusing on accurate initial parameter estimations.

Parameter Optimization:

Systematically refined model parameters using experimental data, enhancing accuracy across various input powers.

Applied merit functions to evaluate and guide model adjustments.

Validation:

Validated the model by comparing simulated gains, both pre- and post-optimization, with experimental gains, noting marked improvements at higher power settings.