Numerical modelling of mode-locking at low repetition rate in Quantum Dot lasers

Presented by: Mohammad Heydari

M. Heydari[1], P. Bardella[1], L. L. Columbo[1], **M. Gioannini[1]**

[1]Department of Electronics and Telecommunication, Politecnico di Torino, Italy

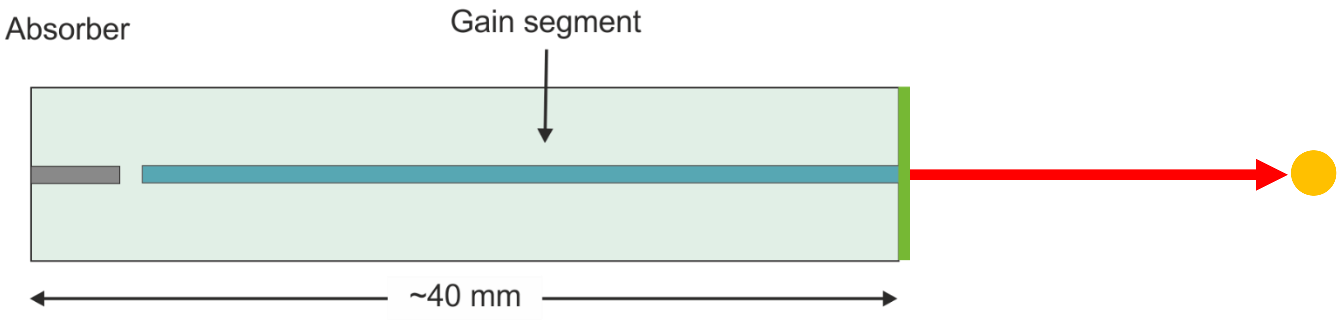
mariangela.gioannini@polito.it

Politecnico di Torino
1859
Department of Electronics and Telecommunications
DET

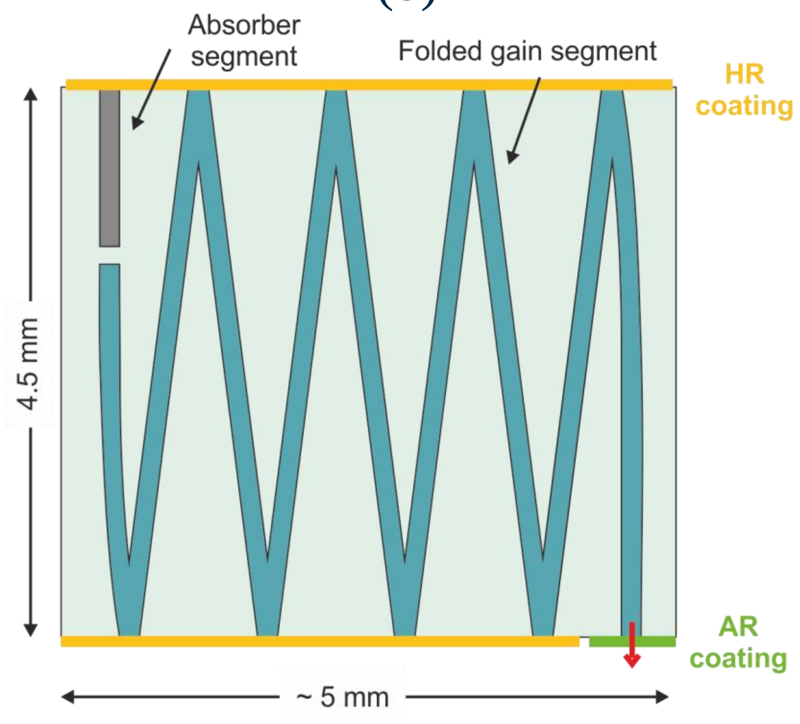
What is our project?

- Initially, we intend to simulate the figure (a), which is a quantum dot mode-locked laser with a long cavity.
- The second step will be to simulate the quantum dot laser as shown in figure (b) in order to reduce the length of the laser.

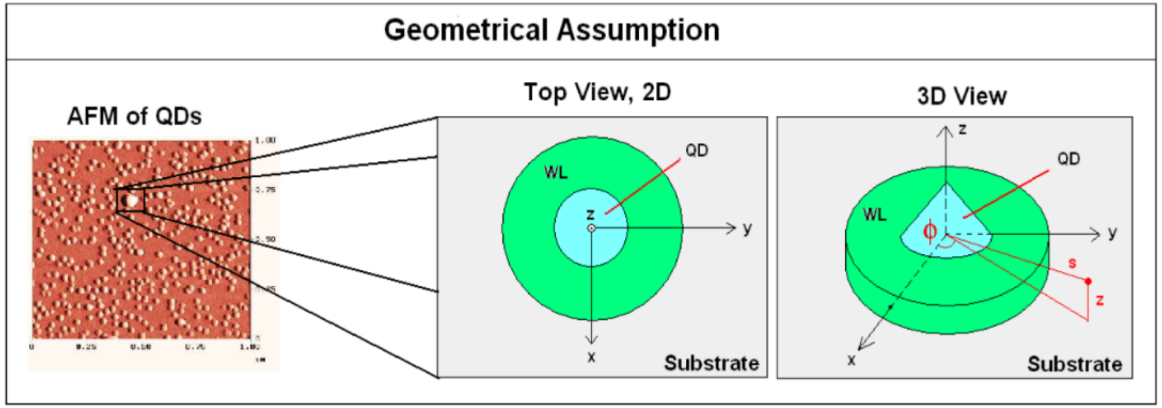
(a)

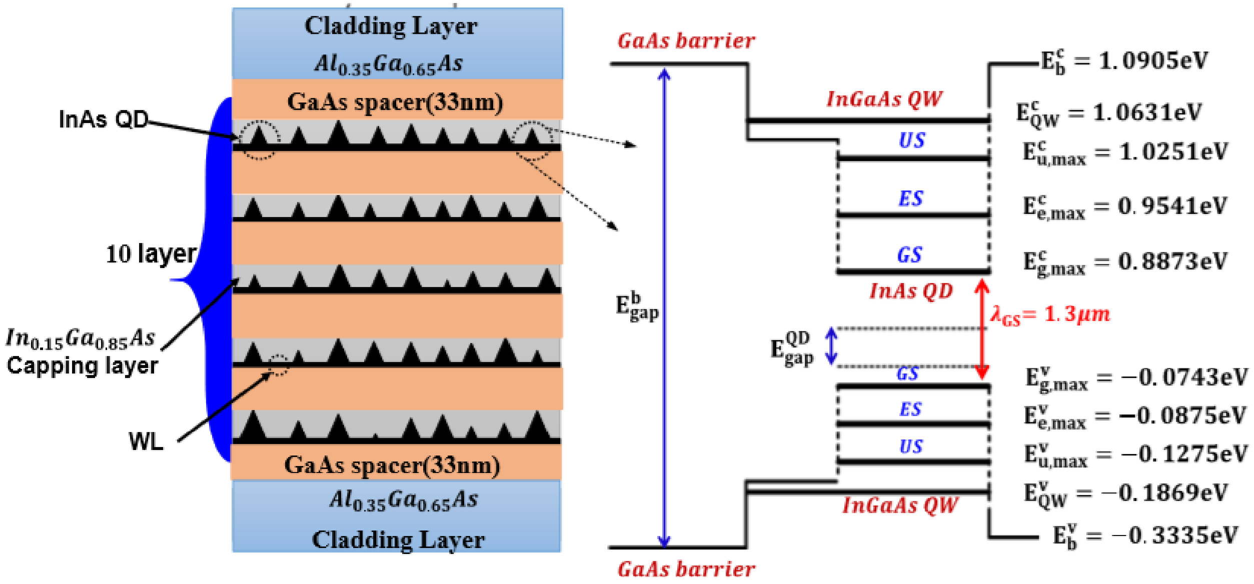


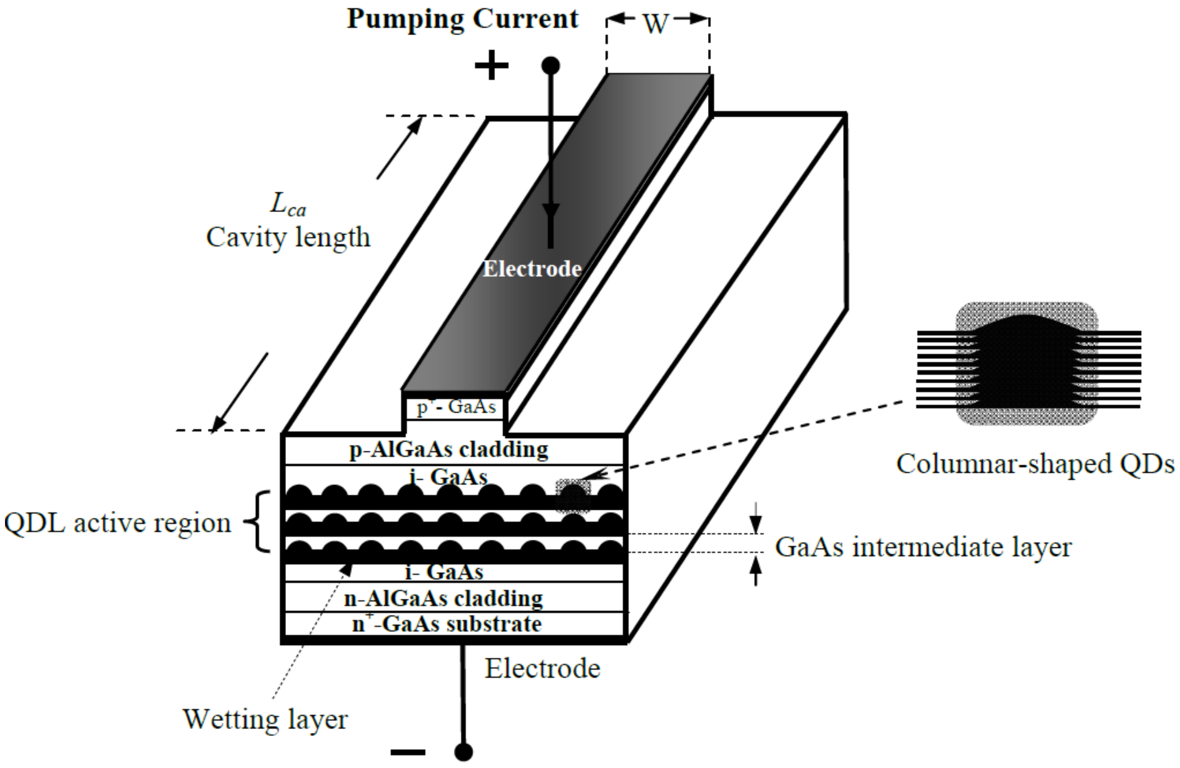
(b)



Quantum Dot and QD Laser

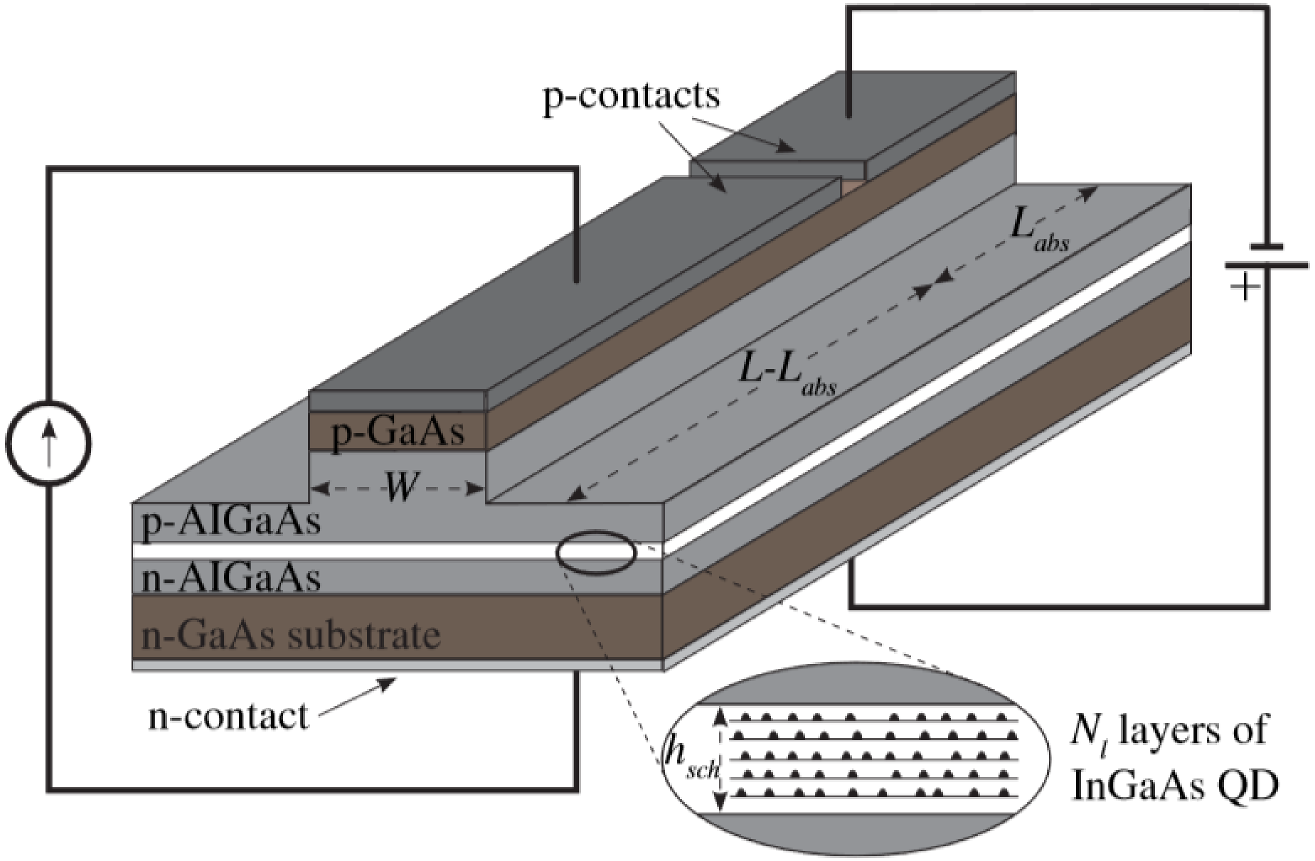


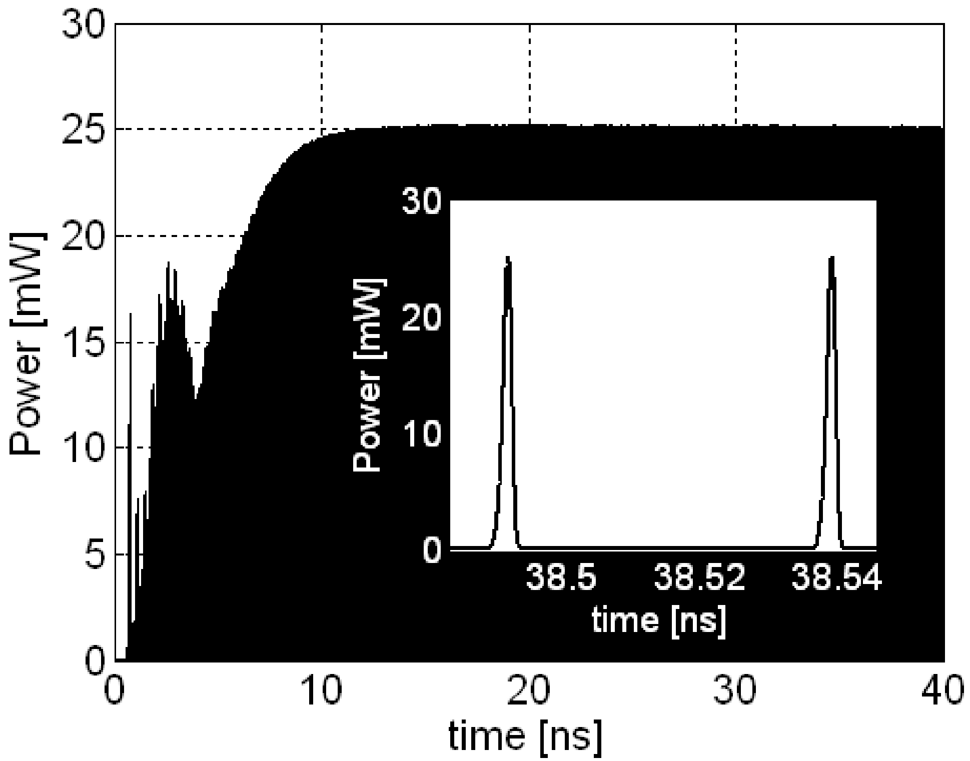




K. L. Jensen, J. T. Kristensen, and J. R. de Lasson, "Semiconductor Quantum Dots."

Laser structure for passive mode-locking





M. Rossetti, P. Bardella and I. Montrosset, "Modeling Passive Mode-Locking in Quantum Dot Lasers: A Comparison Between a Finite-Difference Traveling-Wave Model and a Delayed Differential Equation Approach," in *IEEE Journal of Quantum Electronics*, vol. 47, no. 5, pp. 569-576, May 2011, doi: 10.1109/JQE.2010.2104135.
M. Rossetti, P. Bardella, M. Gioannini and I. Montrosset, "Time domain travelling wave model for simulation of passive mode locking in semiconductor quantum dot lasers," CLEO/Europe - EQEC 2009 - European Conference on Lasers and Electro-Optics and the European Quantum Electronics Conference, Munich, Germany, 2009, pp. 1-1, doi: 10.1109/CLEOE-EQEC.2009.5196365.

Simulation method

- **Simplified Time Domain Travelling Wave Model:** it does non consider inhomogeneous gain broadening
- **Time Domain Travelling Wave (TDTW) Model:** inclusion of inhomogeneous gain broadening to account for inhomogeneous QDs (multi-population rate equation model)

$$\frac{dN_{SCH}}{dt} = \eta_i \frac{J}{e} \Delta z W - \frac{N_{SCH}}{\tau_r^{SCH}} - \frac{N_{SCH}}{\tau_c^{W}} + \frac{N_W}{\tau_e^{W}}$$

total number of carriers in the 3-D SCH states

$$\frac{dN_W}{dt} = \frac{N_{SCH}}{\tau_c^{W}} - \frac{N_W}{\tau_e^{W}} - \frac{N_W}{\tau_r^{W}} - \sum_{i=1}^{N} \frac{G_i}{\tau_c^{ES_2}} N_W \left(1 - \rho_{i\,ES_2}\right) + \sum_{i=1}^{N} \frac{N_{i\,ES_2}}{\tau_e^{ES_2}}$$

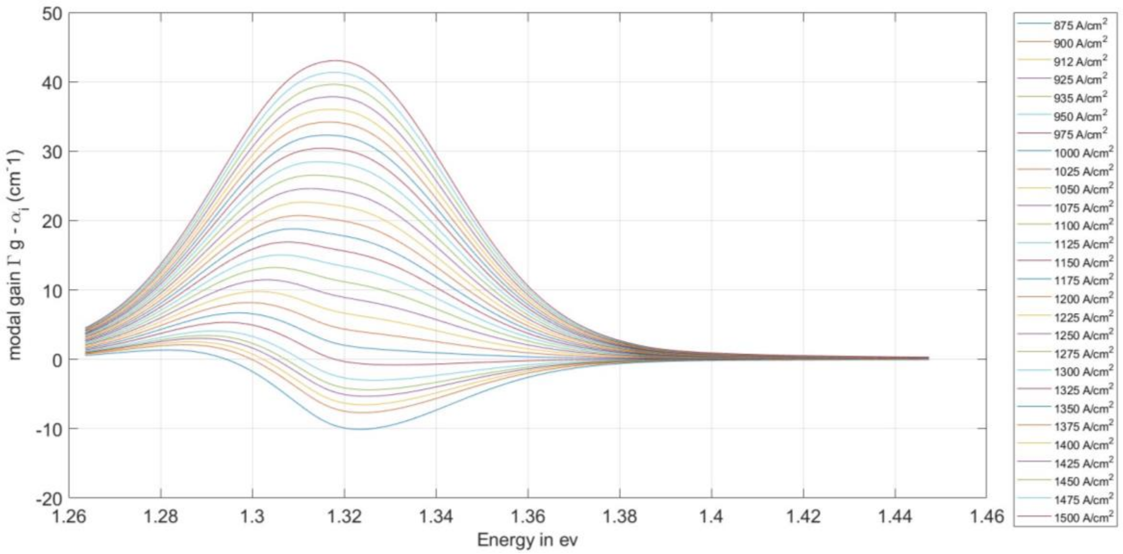
total number of carriers in the 2-D QW states

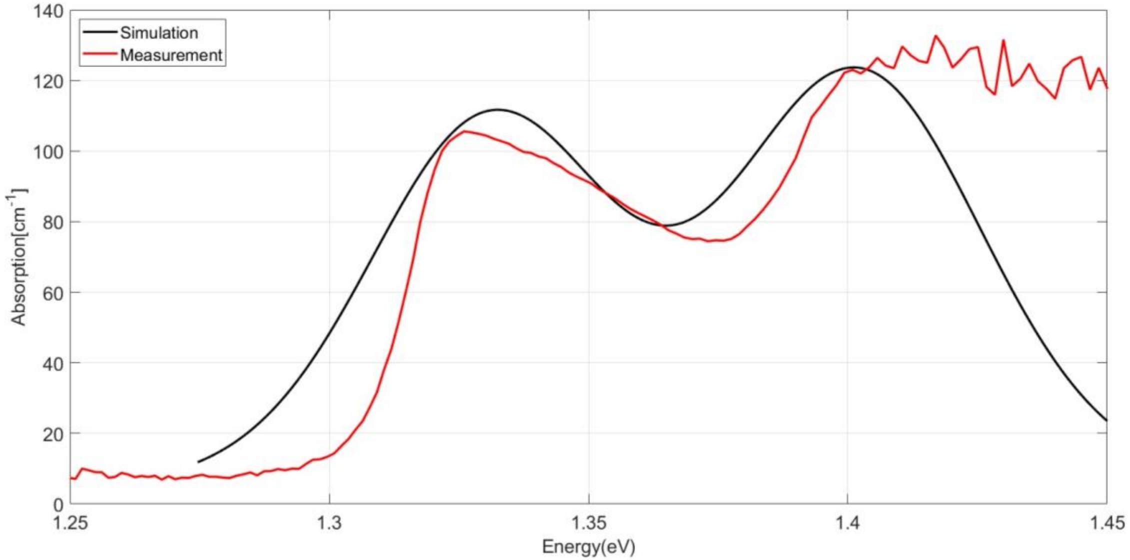
$$\frac{dN_{i\,ES_2}}{dt} = \frac{G_i}{\tau_c^{ES_2}} N_W \left(1 - \rho_{i\,ES_2}\right) - \frac{N_{i\,ES_2}}{\tau_e^{i\,ES_2}} - \frac{N_{i\,ES_2}}{\tau_s^{ES_2}} - \frac{N_{i\,ES_2}\rho_{i\,ES_2}}{\tau_{Au}^{ES_2}} - \frac{N_{i\,ES_2}}{\tau_c^{ES_1}} \left(1 - \rho_{i\,ES_1}\right) + \frac{N_{i\,ES_1}}{\tau_e^{i\,ES_1}} \left(1 - \rho_{i\,ES_2}\right)$$

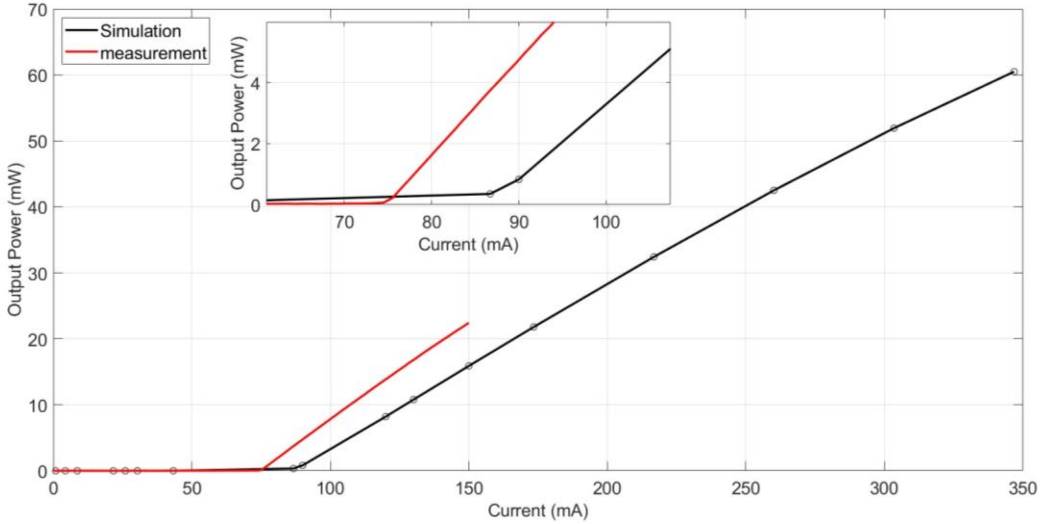
$$\frac{dN_{i\,ES_1}}{dt} = \frac{N_{i\,ES_2}}{\tau_c^{ES_1}} \left(1 - \rho_{i\,ES_1}\right) - \frac{N_{i\,ES_1}}{\tau_e^{i\,ES_1}} \left(1 - \rho_{i\,ES_2}\right) - \frac{N_{i\,ES_1}\rho_{i\,ES_1}}{\tau_{Au}^{ES_1}} - \frac{N_{i\,ES_1}}{\tau_c^{GS}} \left(1 - \rho_{i\,GS}\right) + \frac{N_{i\,GS}}{\tau_e^{i\,GS}} \left(1 - \rho_{i\,ES_1}\right) - \frac{N_{i\,ES_1}}{\tau_s^{ES_1}}$$
$$- \frac{j\Delta z}{\hbar\bar{\omega}_{i\,ES_1}} \left[\left(E^{+} {p_{i\,ES_1}^{+}}^{*} - E^{+*} p_{i\,ES_1}^{+}\right) + \left(E^{-} {p_{i\,ES_1}^{-}}^{*} - E^{-*} p_{i\,ES_1}^{-}\right)\right]$$

$$\frac{dN_{i\,GS}}{dt} = \frac{N_{i\,ES_1}}{\tau_c^{GS}} \left(1 - \rho_{i\,GS}\right) - \frac{N_{i\,GS}}{\tau_e^{i\,GS}} \left(1 - \rho_{i\,ES_1}\right) - \frac{N_{i\,GS}}{\tau_s^{GS}} - \frac{N_{i\,GS}\rho_{i\,GS}}{\tau_{Au}^{GS}} - \frac{j\Delta z}{\hbar\bar{\omega}_{i\,GS}} \left[\left(E^{+} {p_{i\,GS}^{+}}^{*} - E^{+*} p_{i\,GS}^{+}\right) + \left(E^{-} {p_{i\,GS}^{-}}^{*} - E^{-*} p_{i\,GS}^{-}\right)\right]$$

Results


modal gain Γ g - α_i (cm^-1)
Energy in ev
875 A/cm2
900 A/cm2
912 A/cm2
925 A/cm2
935 A/cm2
950 A/cm2
975 A/cm2
1000 A/cm2
1025 A/cm2
1050 A/cm2
1075 A/cm2
1100 A/cm2
1125 A/cm2
1150 A/cm2
1175 A/cm2
1200 A/cm2
1225 A/cm2
1250 A/cm2
1275 A/cm2
1300 A/cm2
1325 A/cm2
1350 A/cm2
1375 A/cm2
1400 A/cm2
1425 A/cm2
1450 A/cm2
1475 A/cm2
1500 A/cm2


Simulation
Measurement
Absorption[cm-1]
Energy(eV)


Simulation
measurement
Output Power (mW)
Current (mA)
Output Power (mW)
Current (mA)

Thank you very much for your attention