Illustrative Examples of Crosslight Simulation Packages

Part IV. Effects of Manybody Gain Enhancement and Inhomogeneous Broadening

CROSSLIGHT Software Inc.

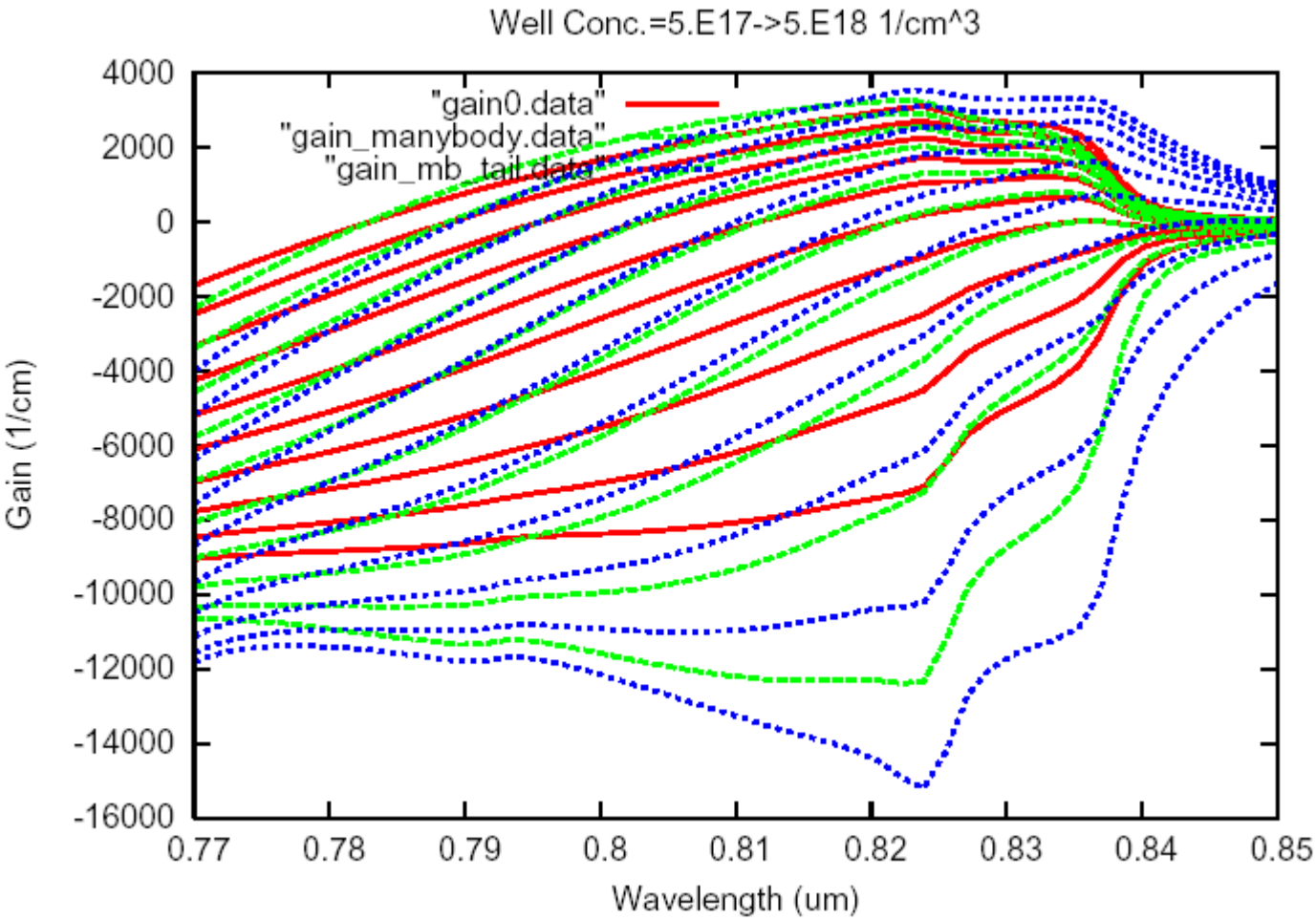
Physical Models

- Coulomb interaction of e-h pair attraction enhances optical transition probability.
- Strong function of carrier screening length.
- Pade approximation in Bloch equation model.
- General effects: magnitude enhancement, change in spectral shape and reduction of effective bandgap.
- Key Reference: Weng W. Chow, Stephean W. Koch, Murray Sargent III, "Semiconductor-Laser Physics", Springer-Verlag, 1994.

Inhomogeneous Broadening (Tail states)

- Fluctuation in quantum well thickness, crystal defects, and impurities all contribute to inhomogeneous broadening of optical gain spectrum.
- Manifests itself in an exponential tail in the bandgap.
- Both density of states (DOS) and joint density of states (JDOS) are modified.
- Results in reduced effective bandgap and modification in gain/spontaneous emission spectrum shape (more symmetrical).

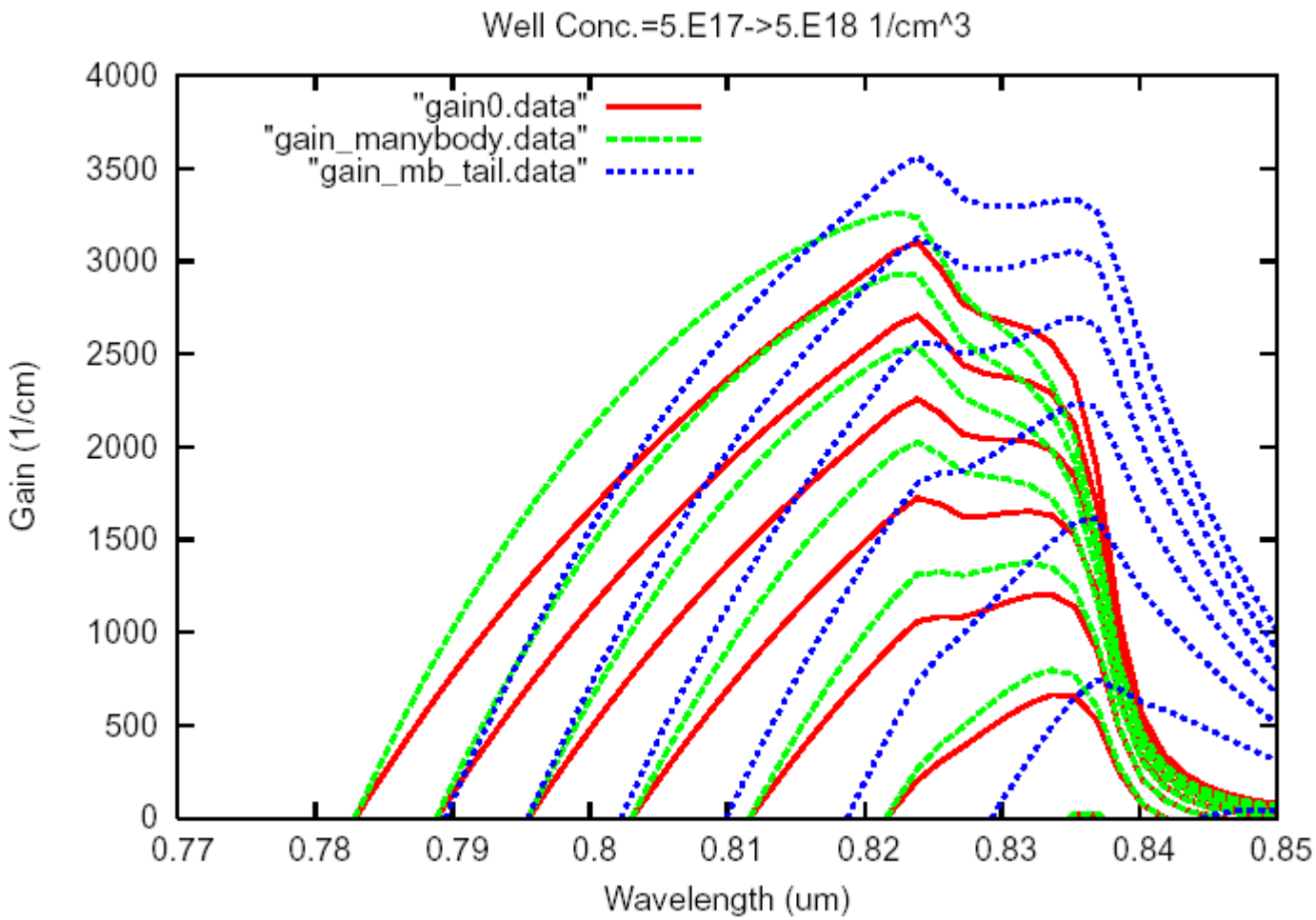
Optical gain in GaAs/AlGaAs QW



mb=manybody, Well width=76A, Barrier Al=33%

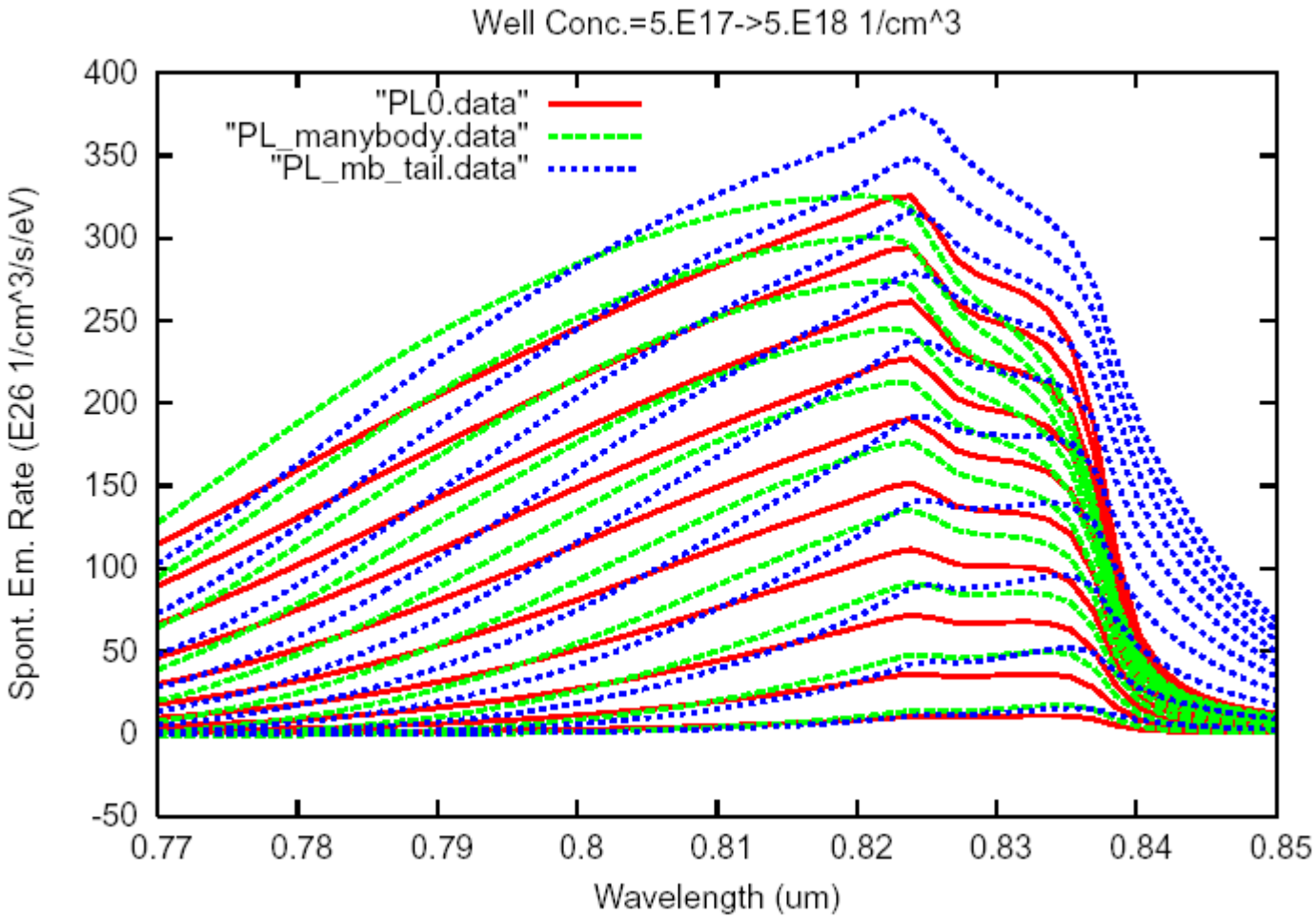
Inhomogeneous broadening=15 meV

Optical gain>0 in GaAs/AlGaAs



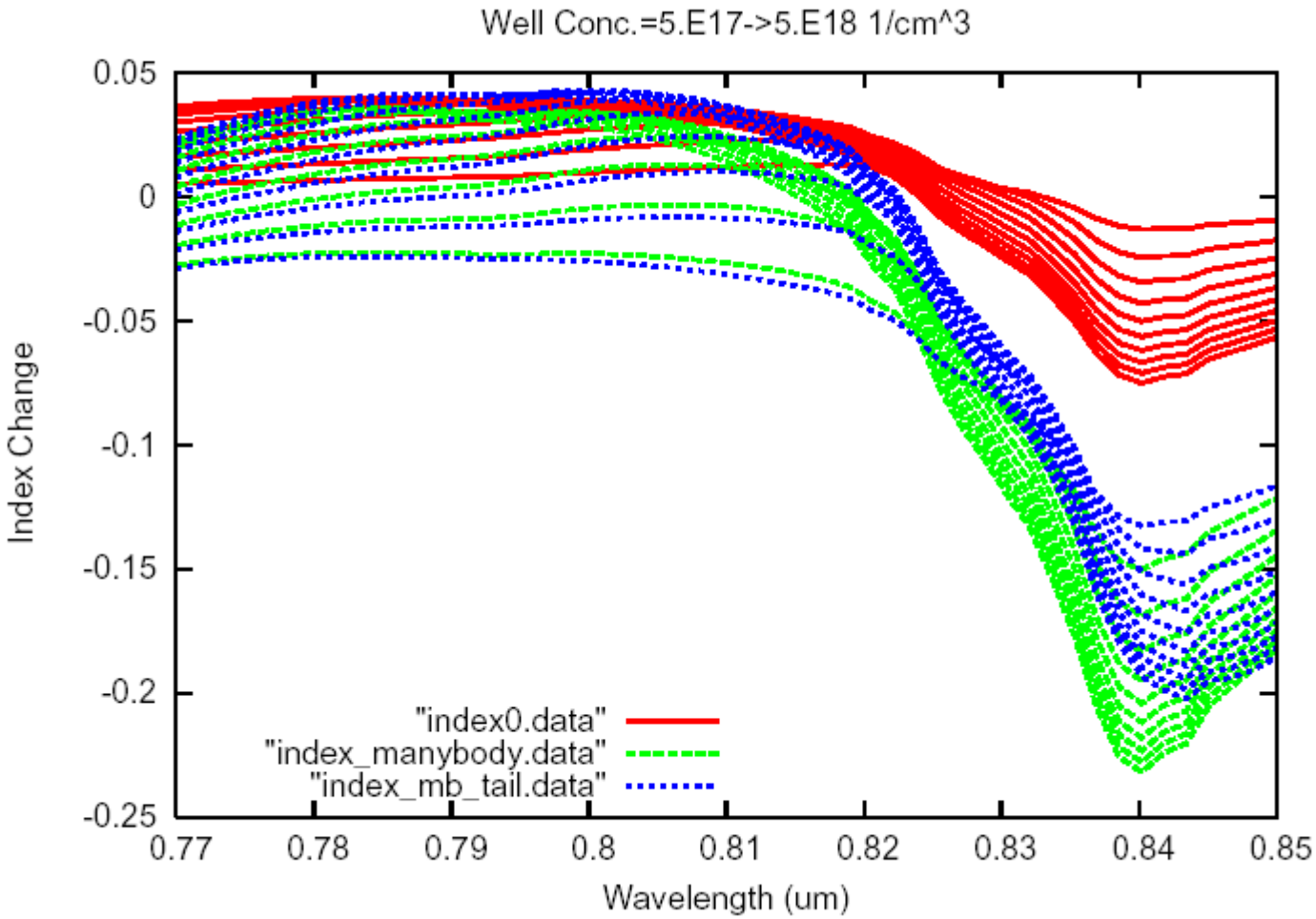
mb=manybody, Well width=76A, Barrier Al=33%
Inhomogeneous broadening=15 meV

Spont. Emission in GaAs/AlGaAs



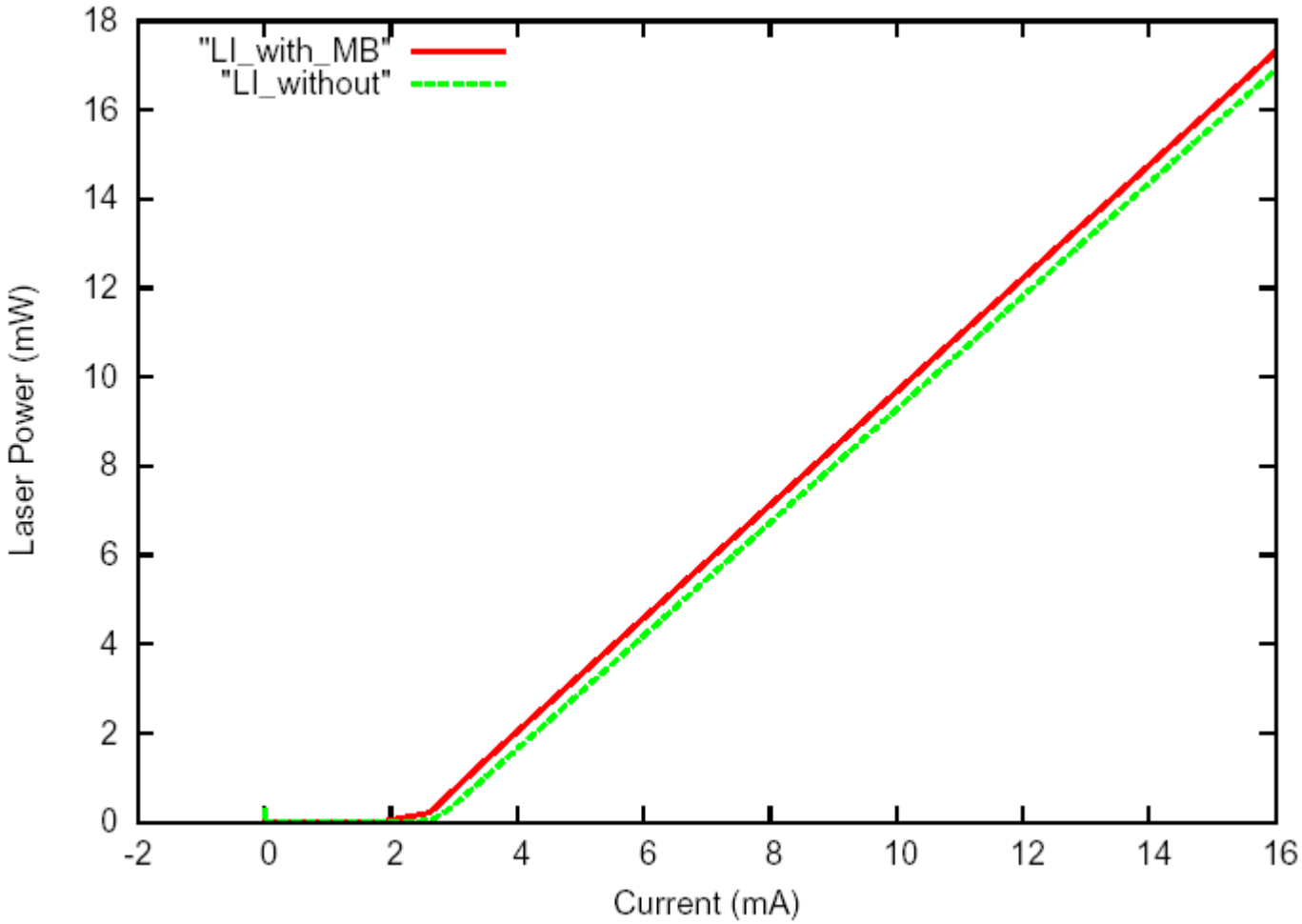
mb=manybody, Well width=76A, Barrier Al=33%
Inhomogeneous broadening=15 meV

Index Change in GaAs/AlGaAs



mb=manybody, Well width=76A, Barrier Al=33%
Inhomogeneous broadening=15 meV

GRIN-SCH-SQW Laser Simulation



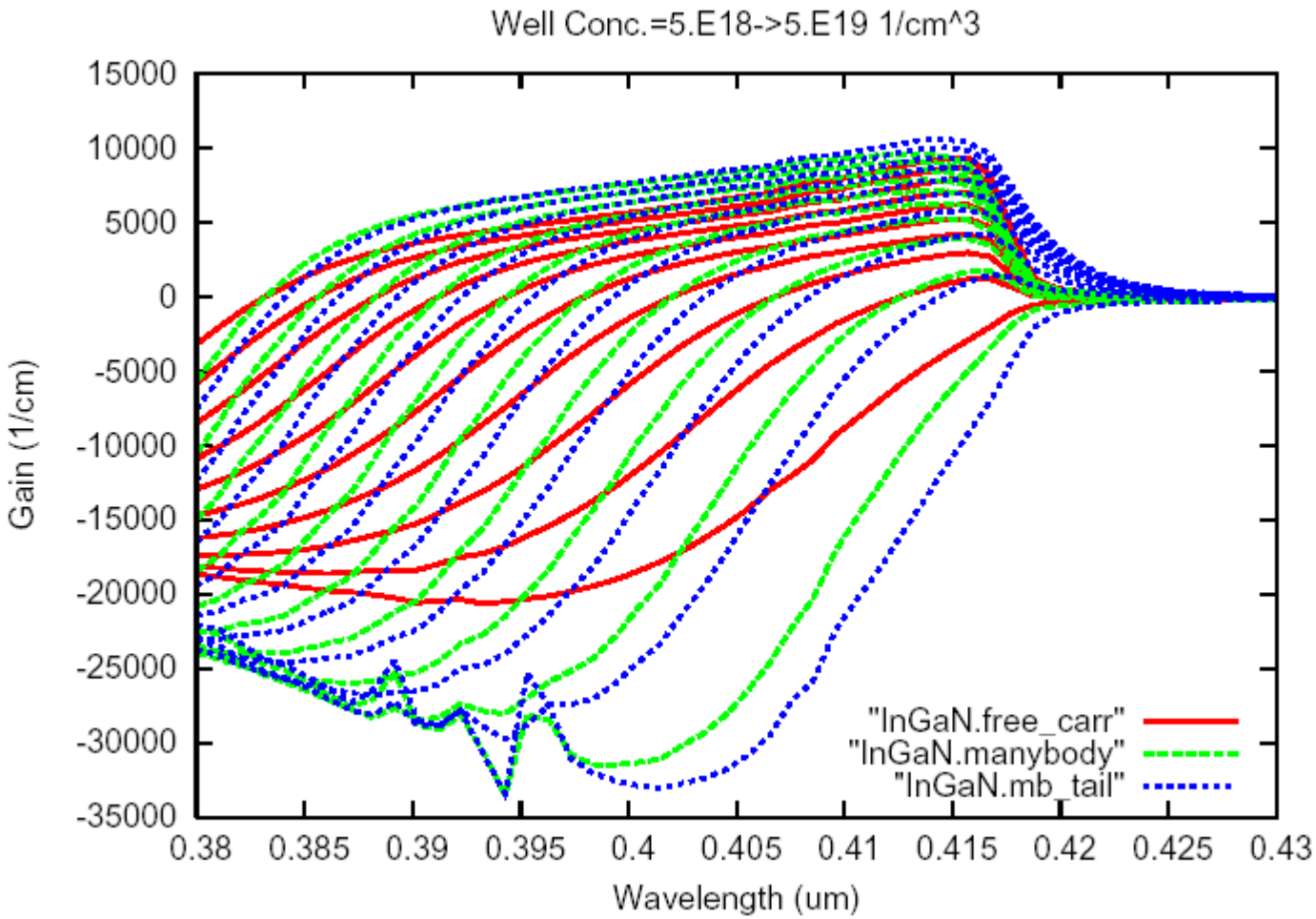
Conclusion Re Zincblende QW

- Manybody enhancement effects are generally small in zincblende material system and may be neglected in many cases.
- Inhomogeneous broadening of optical gain and PL spectrum may have stronger effects on the shape and magnitude of the spectrum.
- Some form of inhomogeneous broadening, such as Landsberg gain broadening, or tail states in JDOS, should be used when fitting experimental gain spectrum.

Manybody Effect in Wurtzite QW

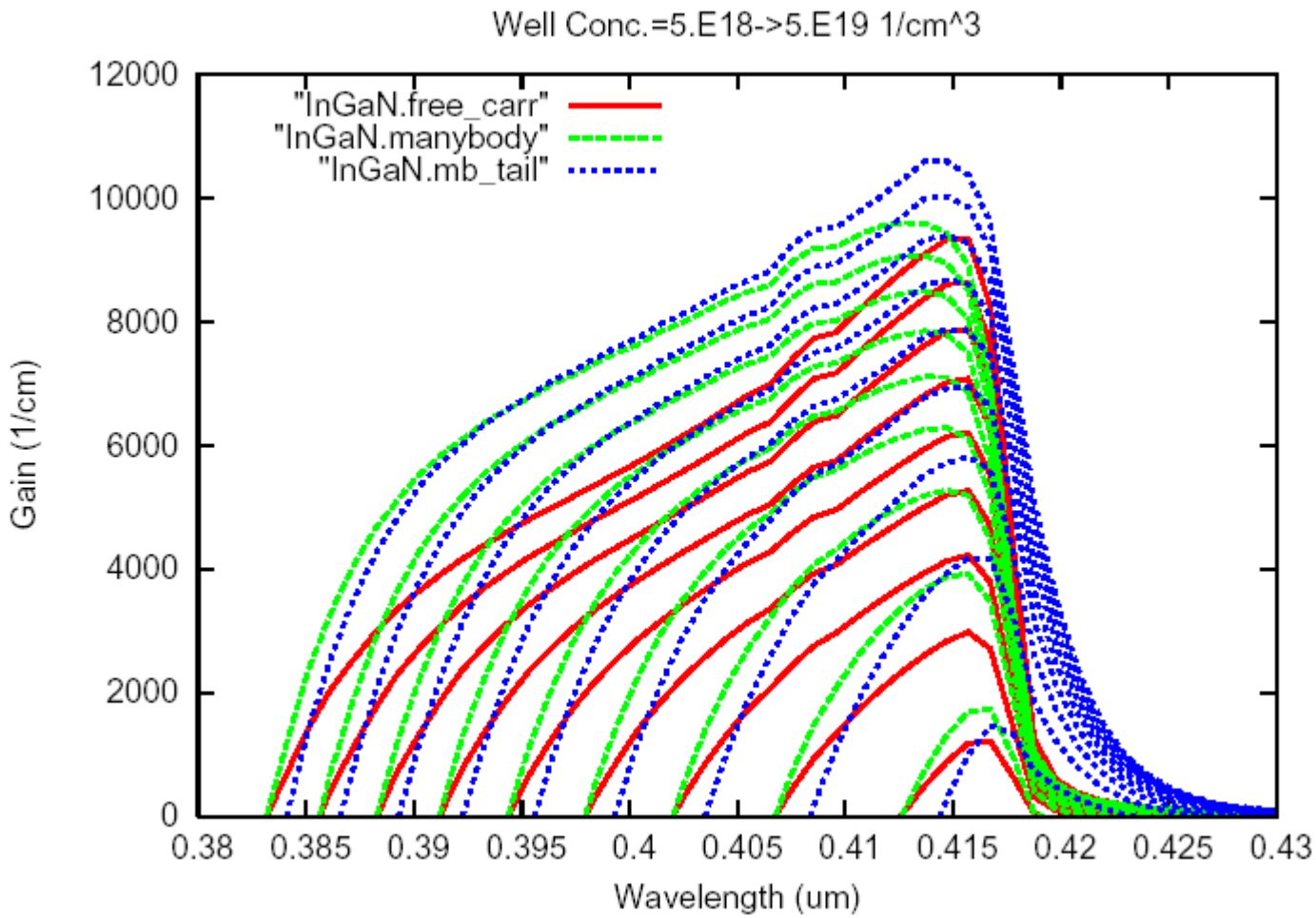
- Due to piezo charge-> self-consistent quantum mechanical model must be used.
- Effective piezo electrical field may be applied in preprocessing stage (.gain simulation) to generate gain spectrum with self-consistent model.
- The above spectrum maybe imported into a full 2D/3D device simulation to improve computation speed.

Gain in InGaN/GaN QW



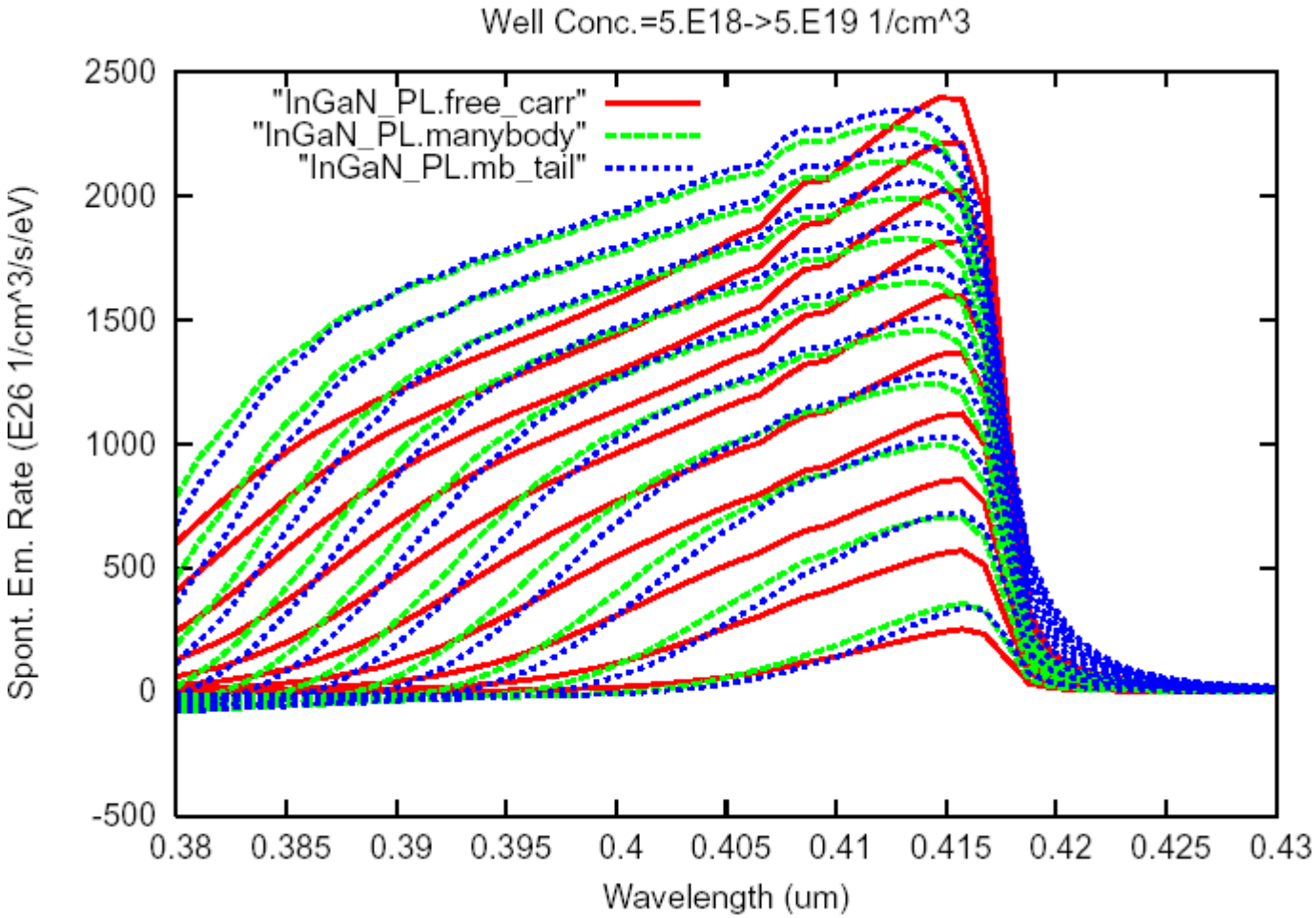
mb=manybody, Well width=35A, Well In=15%
Inhomogeneous broadening=15 meV

Gain>0 in InGaN/GaN QW



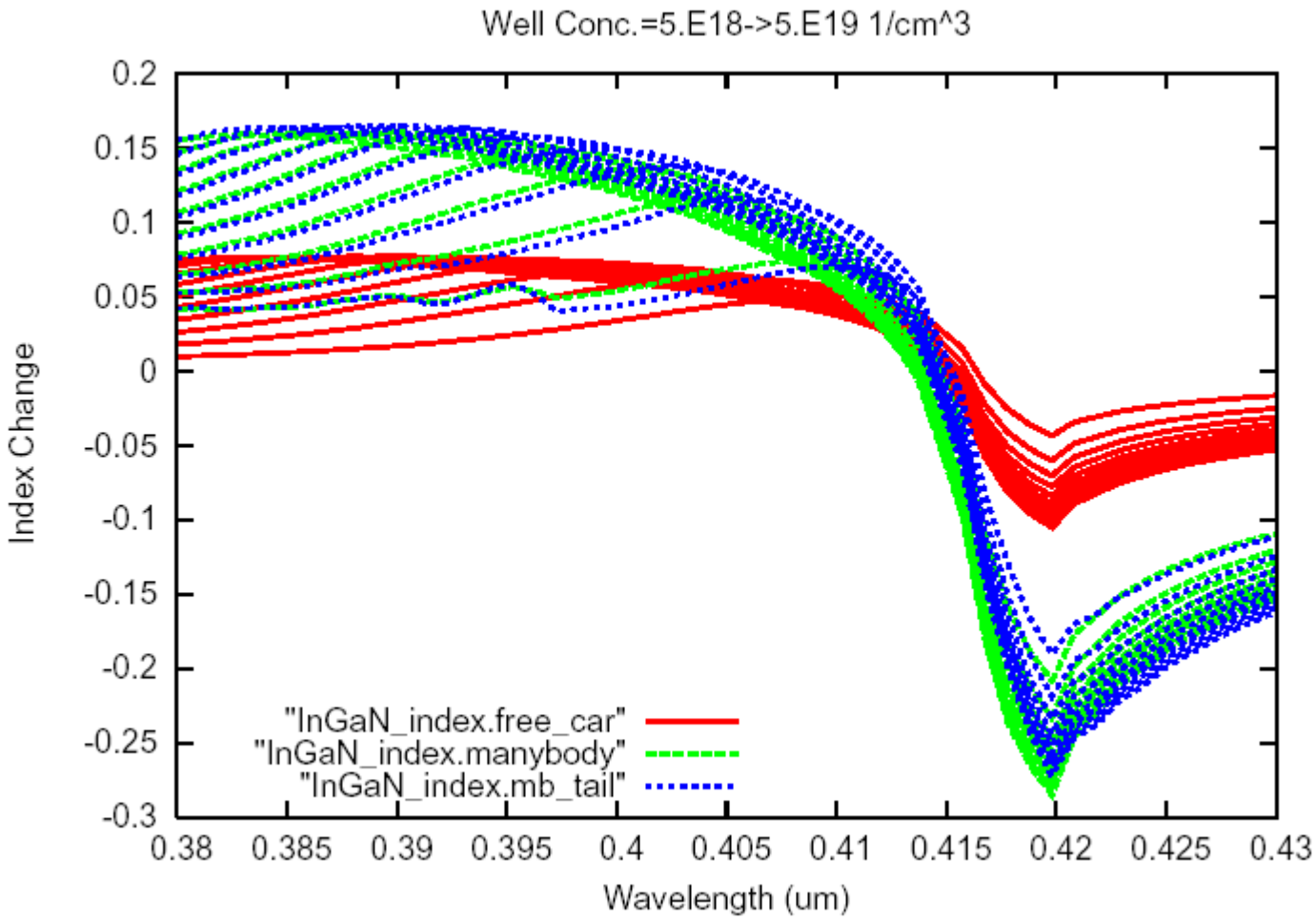
mb=manybody, Well width=35A, Well In=15%
Inhomogeneous broadening=15 meV

Spont. Em. in InGaN/GaN



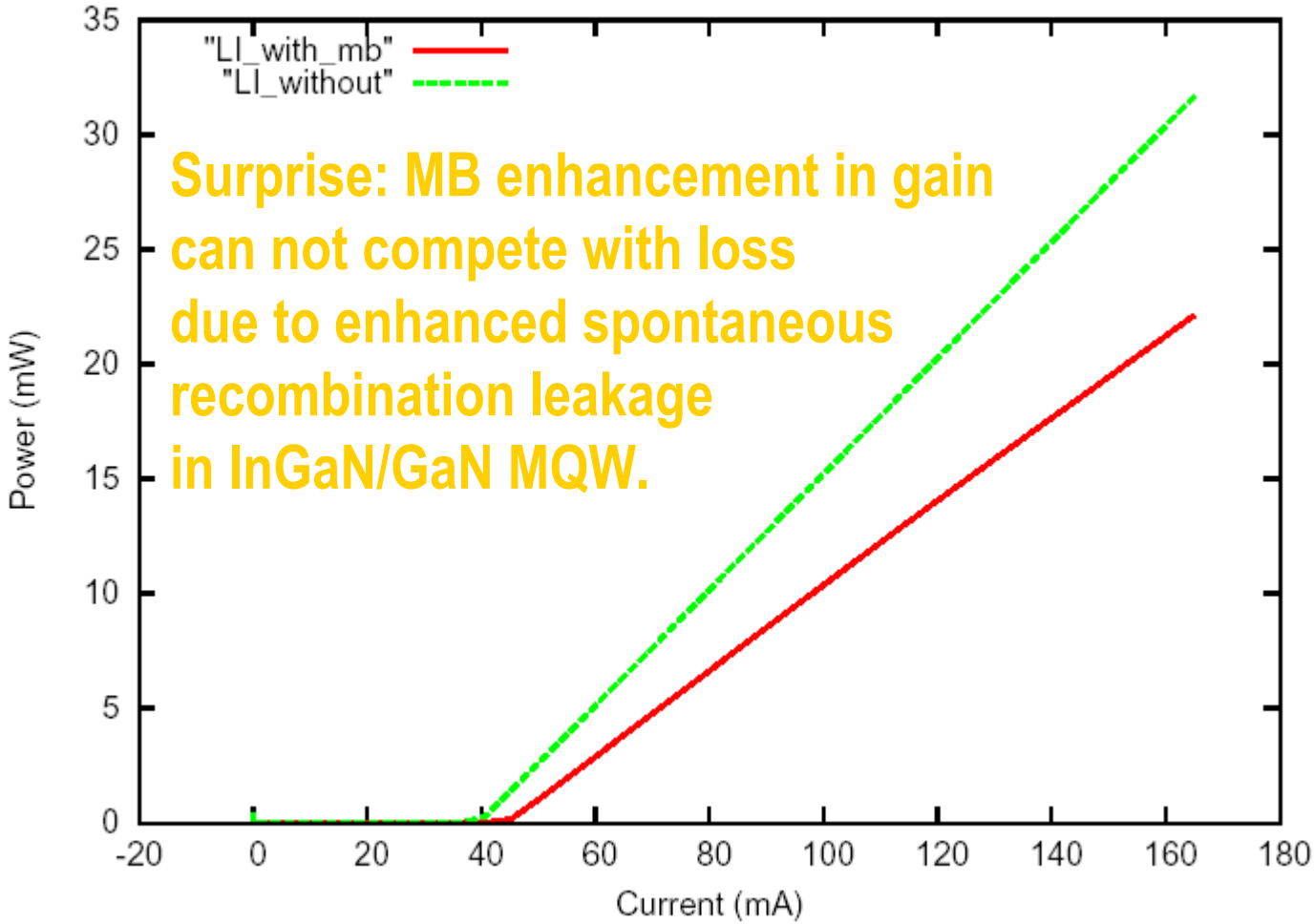
mb=manybody, Well width=35A, Well In=15%
Inhomogeneous broadening=15 meV

Index Change in InGaN/GaN



mb=manybody, Well width=35A, Well In=15%
Inhomogeneous broadening=15 meV

Simulation for a 3 Well Device



Surprise: MB enhancement in gain can not compete with loss due to enhanced spontaneous recombination leakage in InGaN/GaN MQW.

MB=manybody, Well width=35A, Well In=15%
Inhomogeneous broadening=15 meV

Conclusions Re: Wurtzite QW

- Manybody effects are more pronounced in wurtzite material systems due to imbalance of conduction/valence band DOS and occupancies.
- Inclusion of manybody effects for gain/PL/index spectrum calculation is generally recommended for better accuracy.
- Flexible spectrum and k.p data import/export capabilities may enhance simulation speed substantially for such systems.