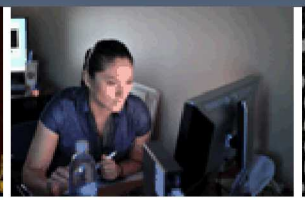
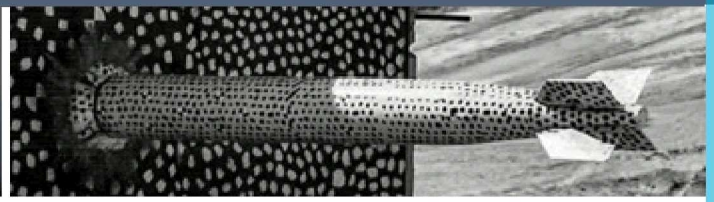
This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.

SAND2019-6457C

Cases 3-5





Thomas Gomez

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Motivation

- There is interest in the H-beta line as a diagnostic and what it can tell us about plasmas
- The interaction between charged particles is given by the Coulomb interaction (hydrogen-like atom is shown)

$$V = \sum_p \frac{1}{r_p(t)} - \frac{1}{|r_r - r_p(t)|}$$

- This is often evaluated using a multipole expansion (in spherical coordinates)

$$V = \sum_k \frac{r_<^k}{r_>^{k+1}} P_k(\cos\gamma)$$

Motivation (2)

- The numerator is often assumed to be atomic part and the denominator the plasma coordinate
- In addition, the expansion usually stops at first (with the zeroth order cancelling with the nuclear part

$$V \approx r_r \frac{1}{r_p^2} \cos\gamma$$

- For many plasma conditions, this is a good approximation
- But for high density plasmas, the higher-order corrections become important

$$V \approx r_r \frac{1}{r_p^2} \cos\gamma + r_r^2 \frac{1}{r_p^3} \frac{1}{2}(3\cos^2\gamma - 1)$$

Motivation (2b)—a tangent

- There is also a discrepancy between how screening is evaluated within the trivial simulations which includes
  - Xenomorph
  - SimU
  - Simulation

- Discussion of Carlos' manuscript?

Motivation(3)

- Historically, only the ion quadrupole contribution has been included
- Gomez et al. (2016) published a simulation with quadrupole and higher-order multipole corrections for both ion and electron species
- This resulted in a slight narrowing of the line at 10^{18} e/cc and a broadening at 10^{19} e/cc

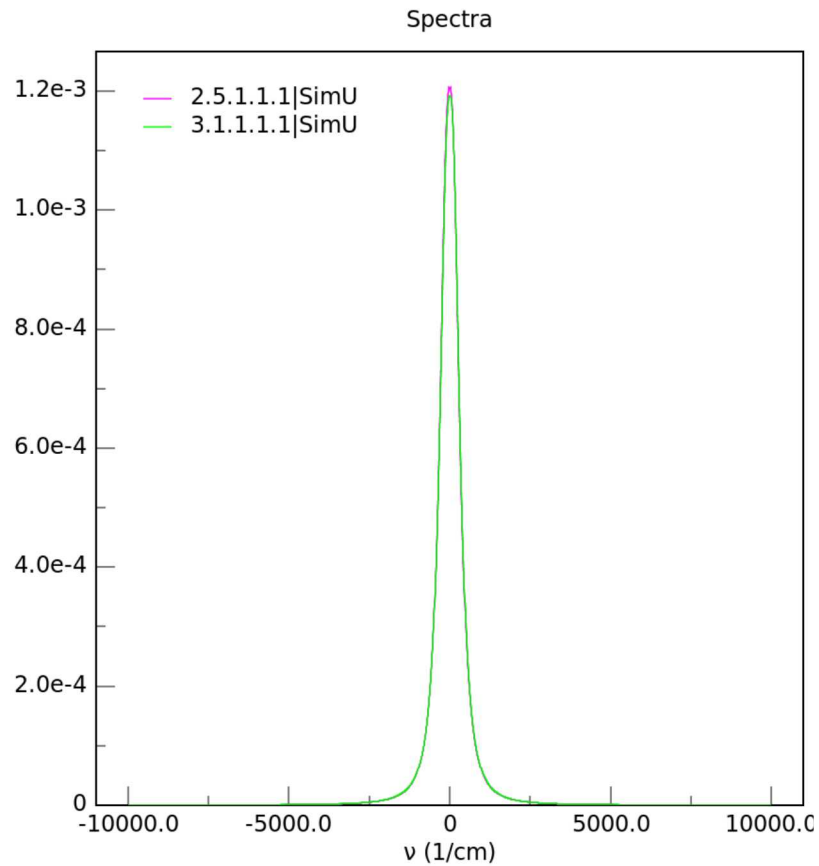
- This result has not yet been verified by other codes, so we are trying to dig deeper into the codes to find out how each code works

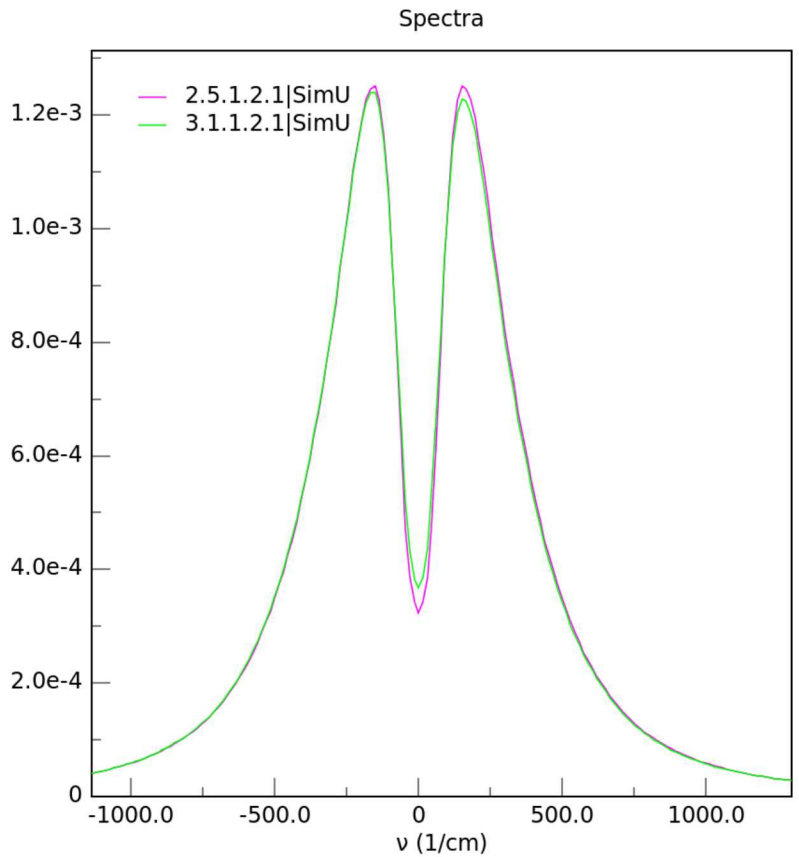
How Matrix elements are calculated

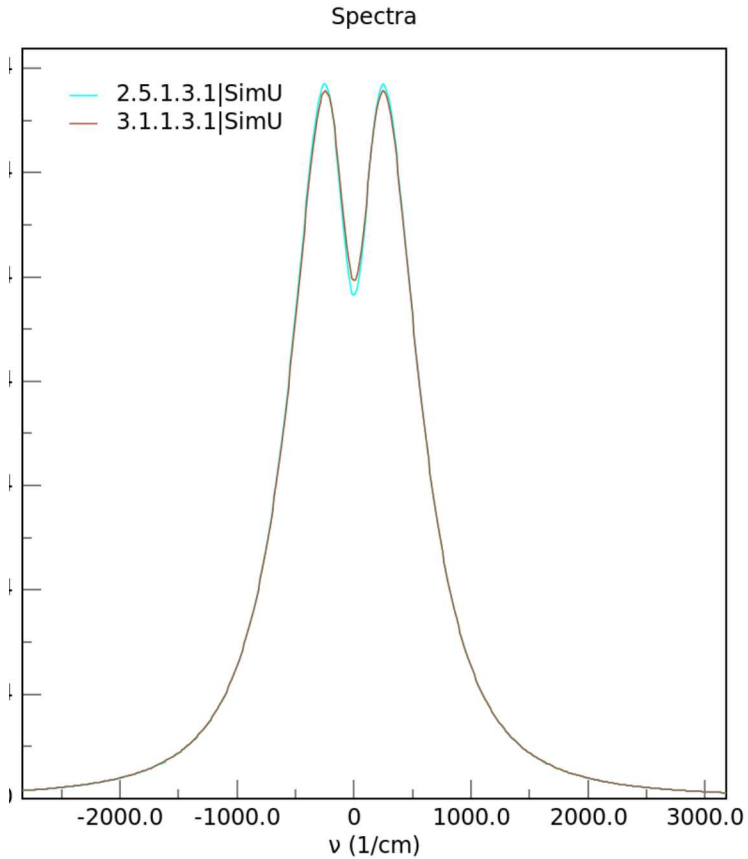
SimU

With and Without Quadrupole Corrections (No Quenching)

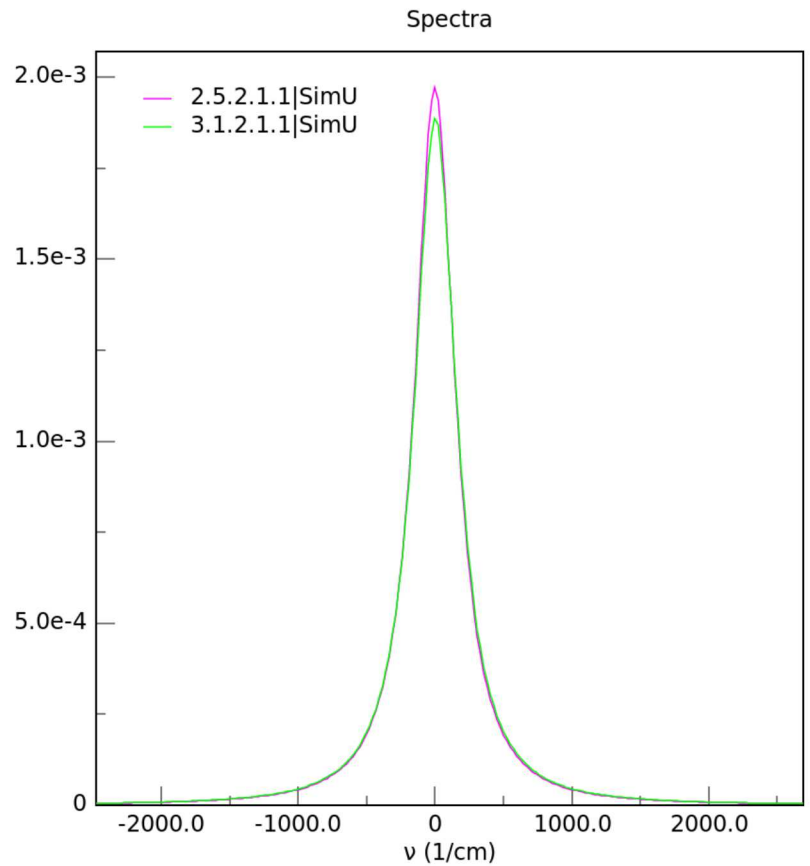
$n_e = 10^{18}$ $T_e = 1eV$

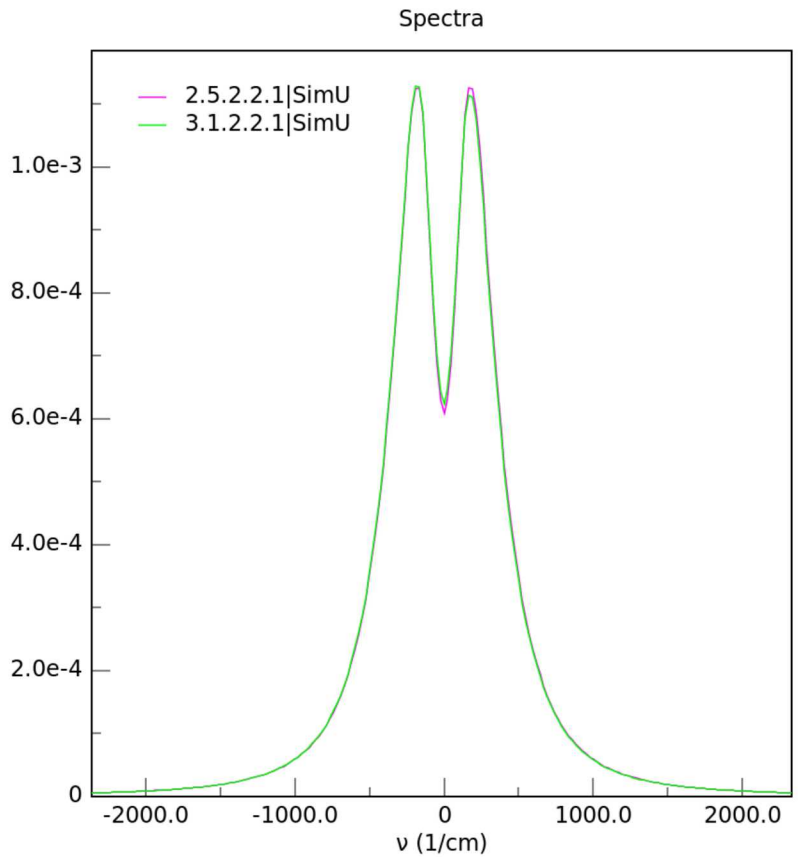


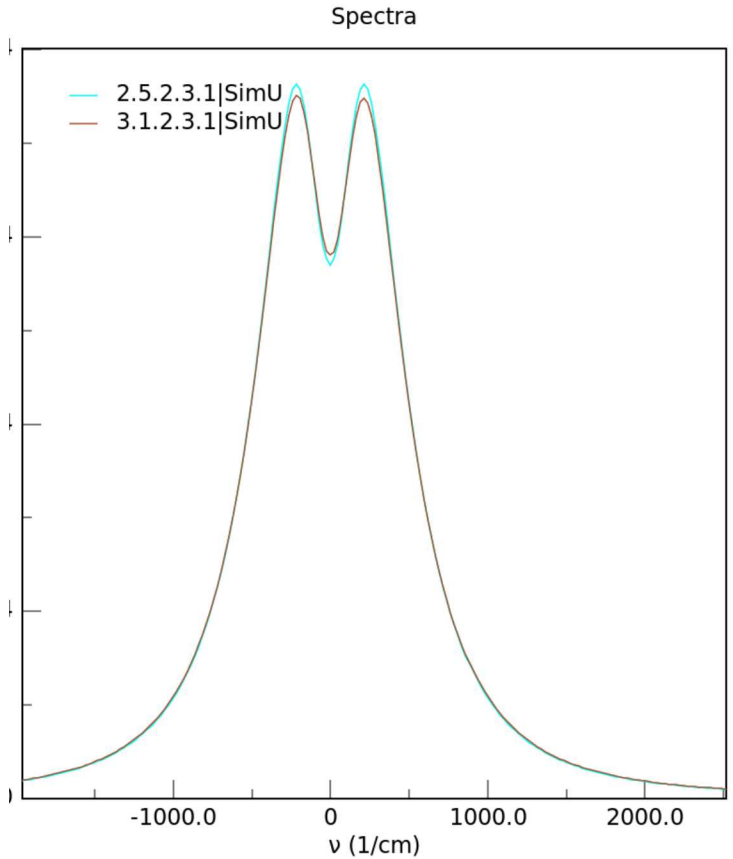




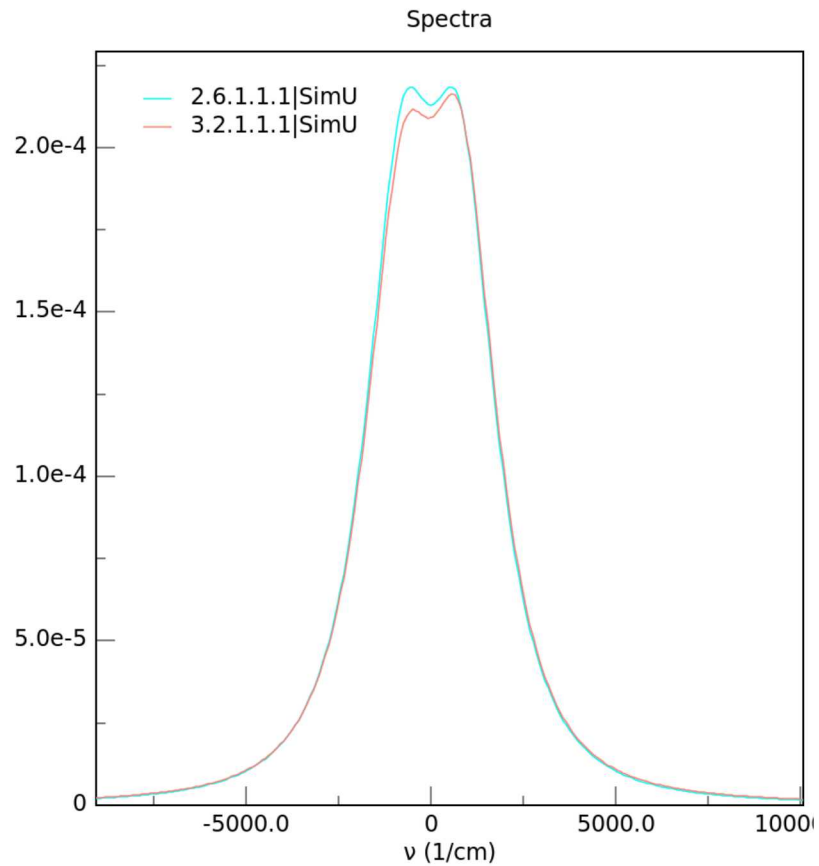
$n_e = 10^{18}$ $T_e = 10eV$

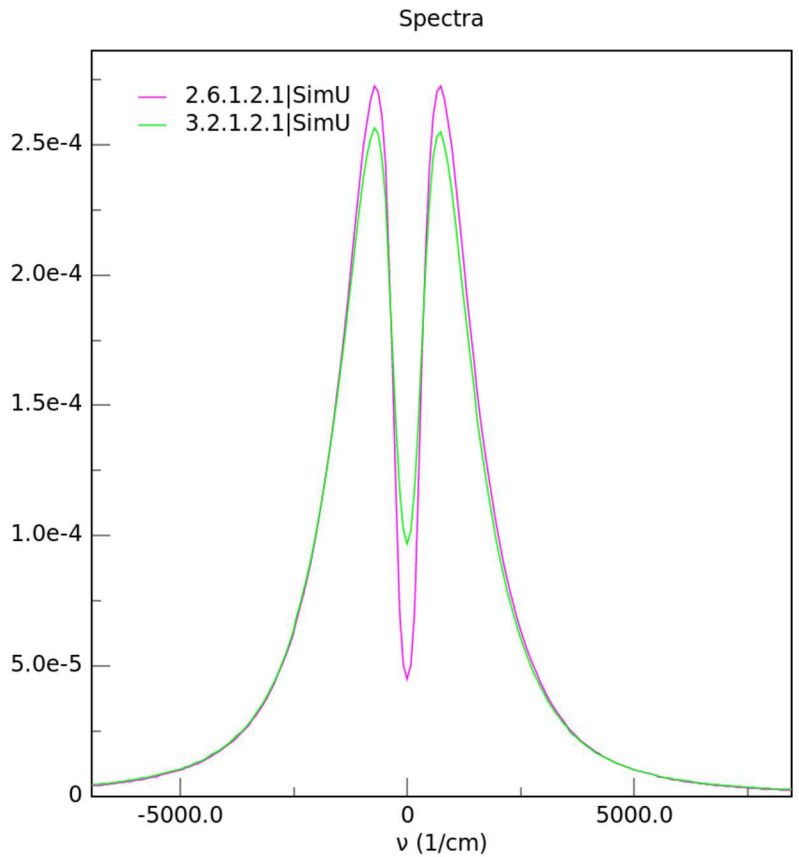


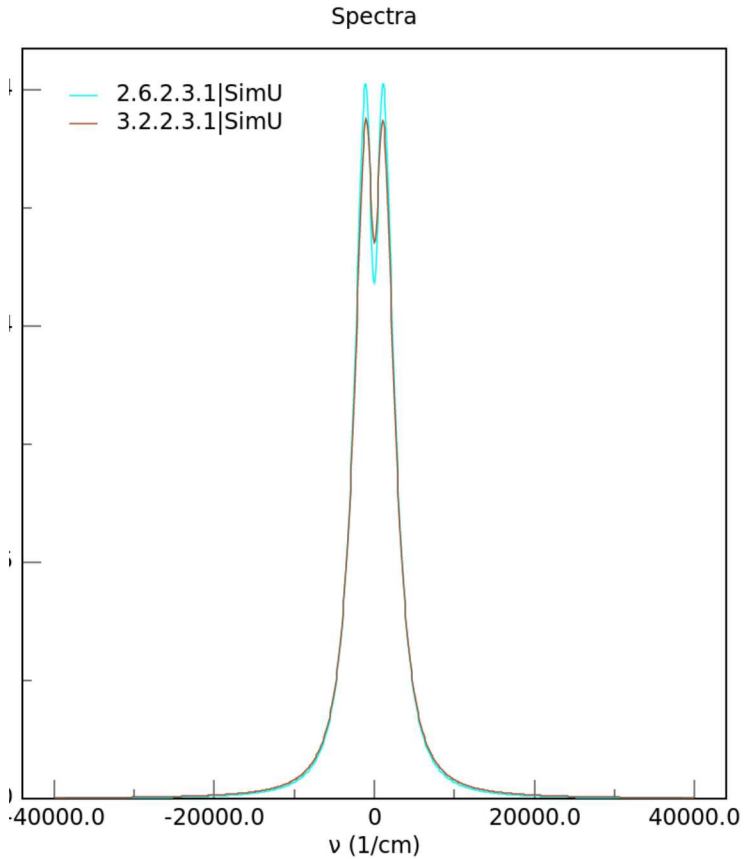




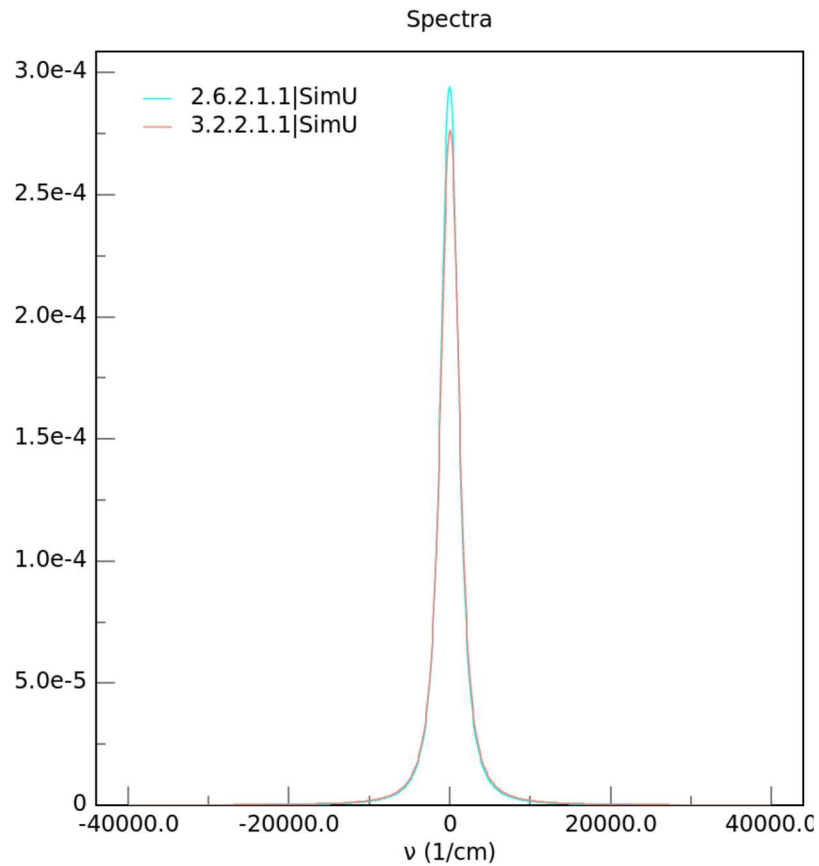
$n_e = 10^{19}$ $T_e = 1eV$

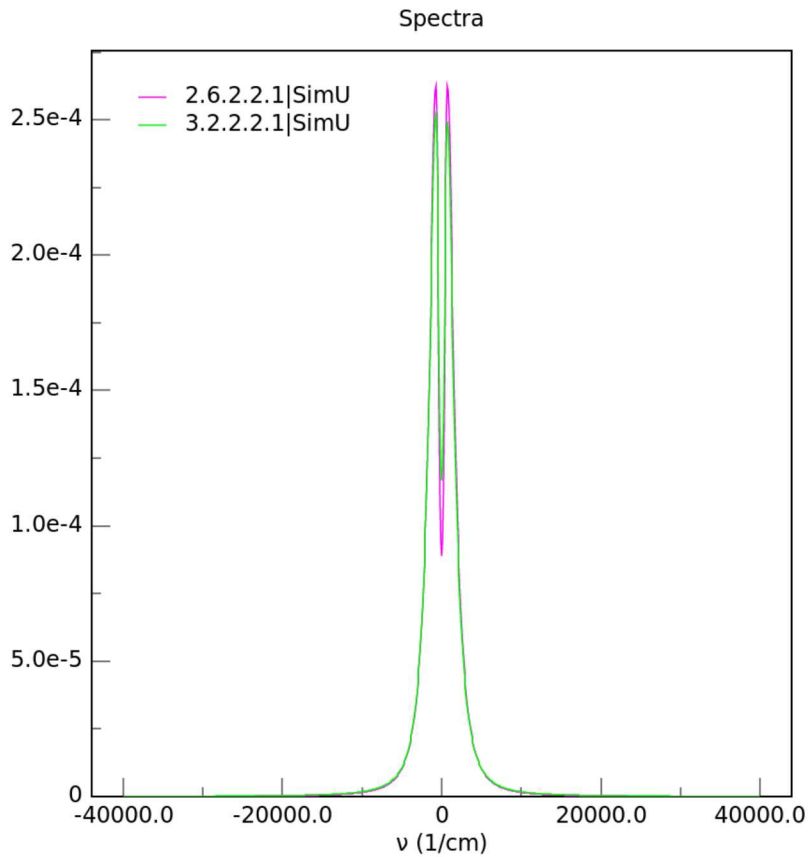


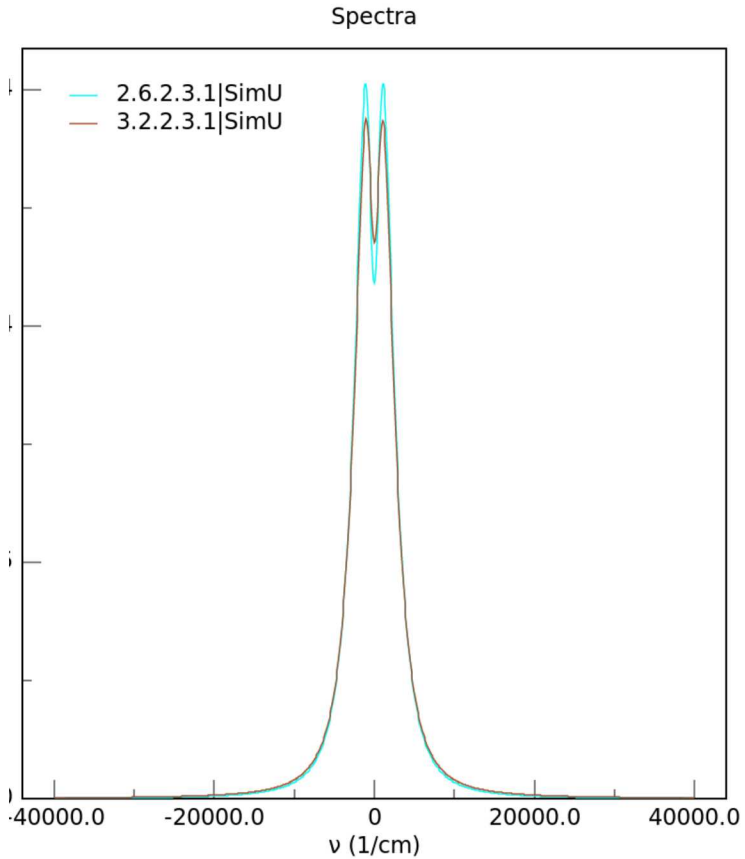




$n_e = 10^{19}$ $T_e = 10eV$



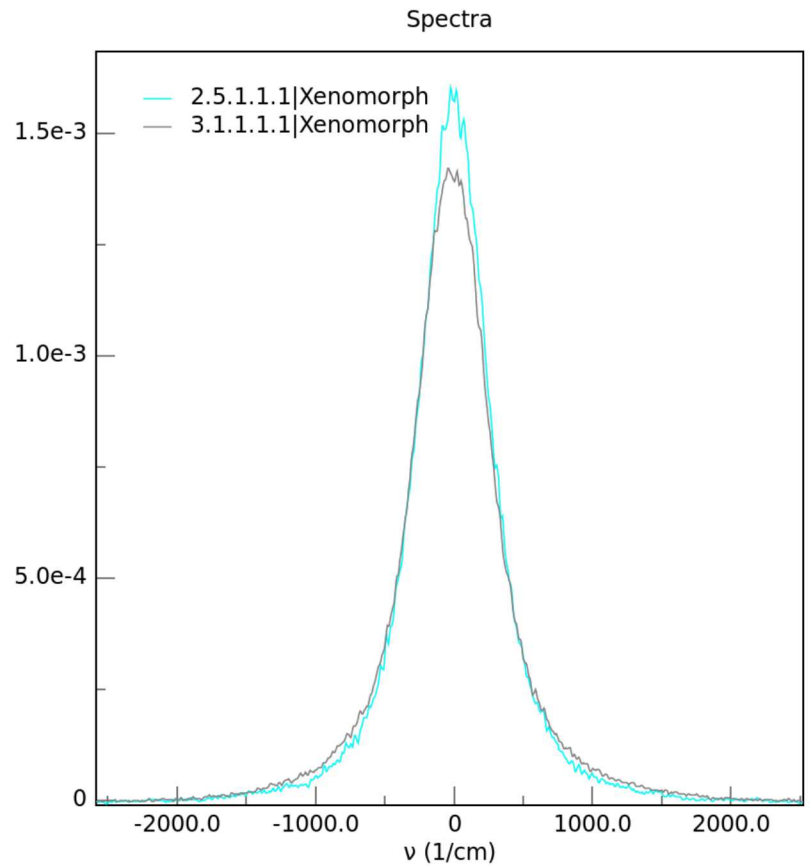


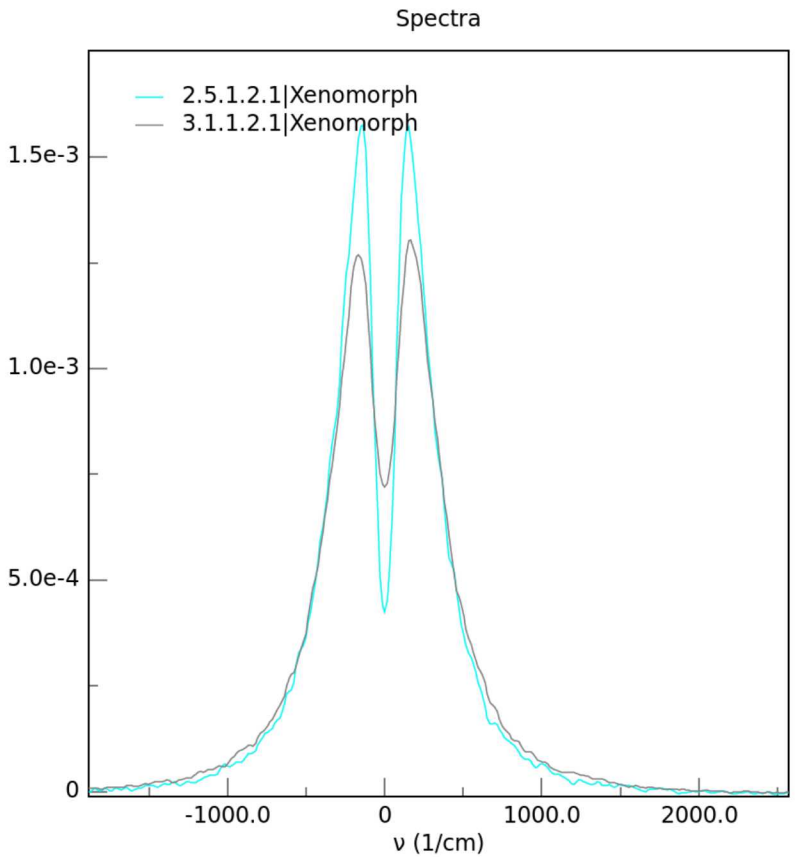


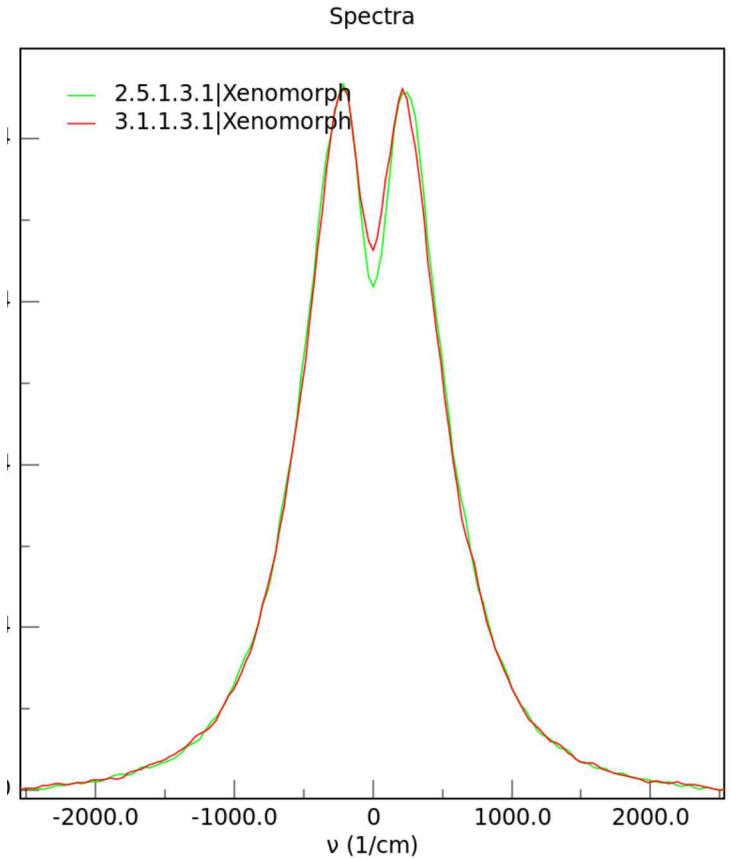
Xenomorph

With and Without Quadrupole Corrections (No Quenching)

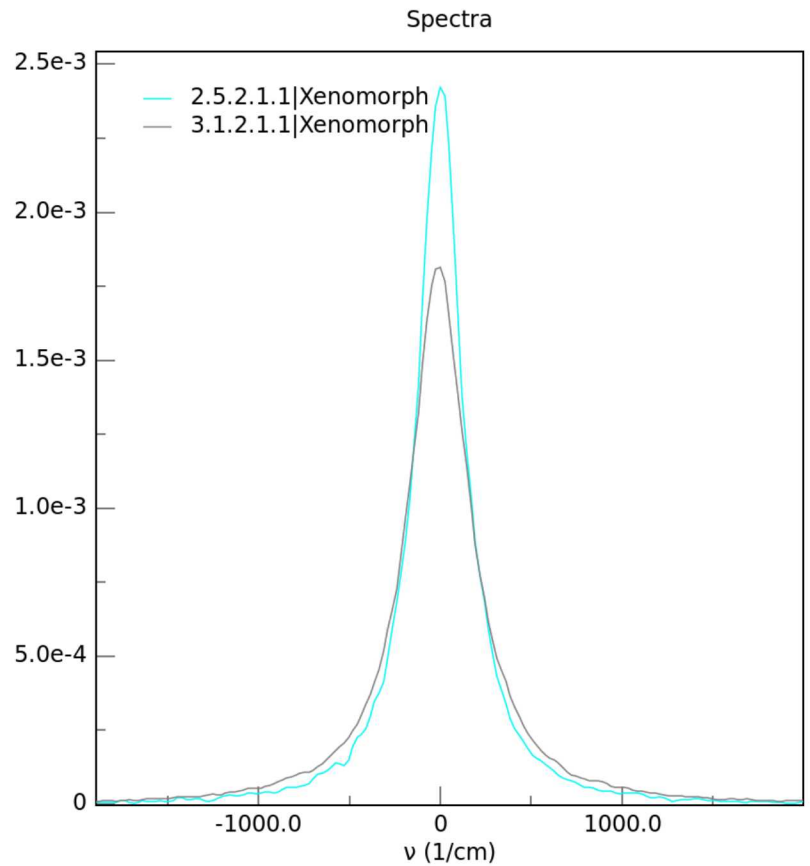
$n_e = 10^{18}$ $T_e = 1eV$

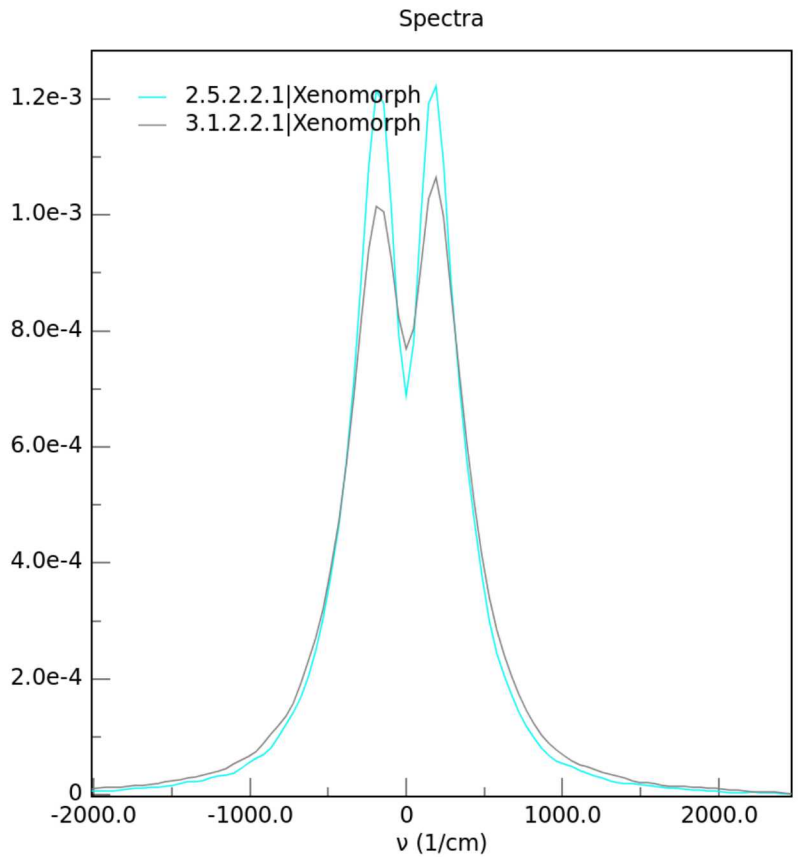


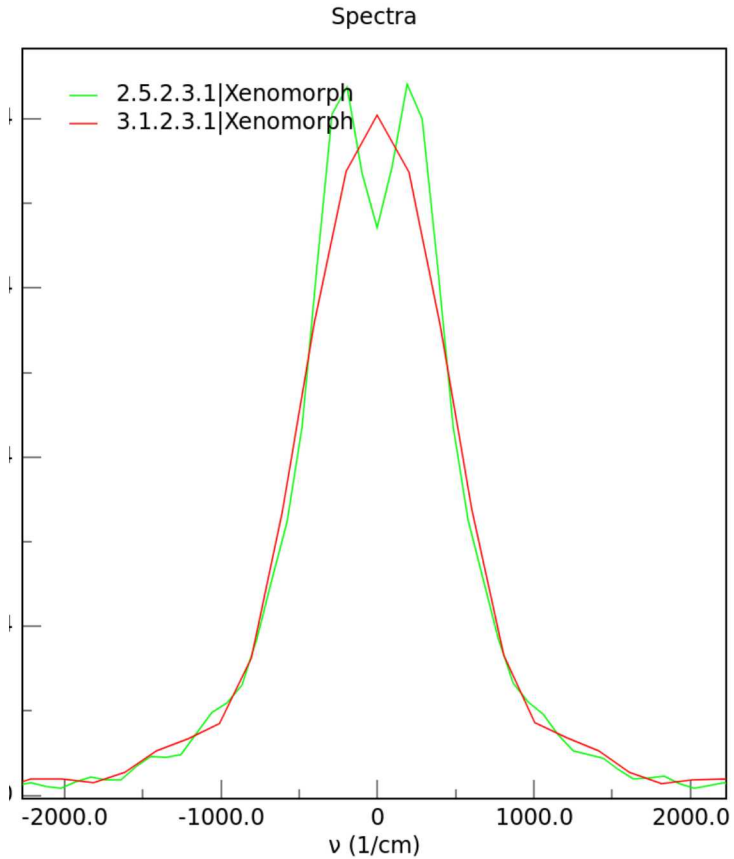




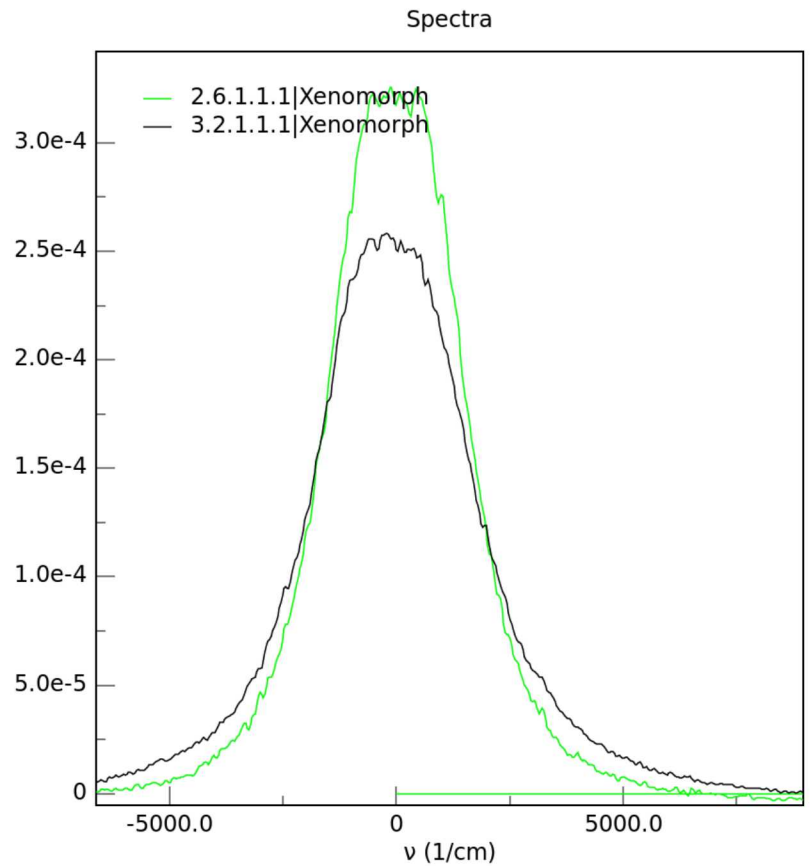
$n_e = 10^{18}$ $T_e = 10eV$

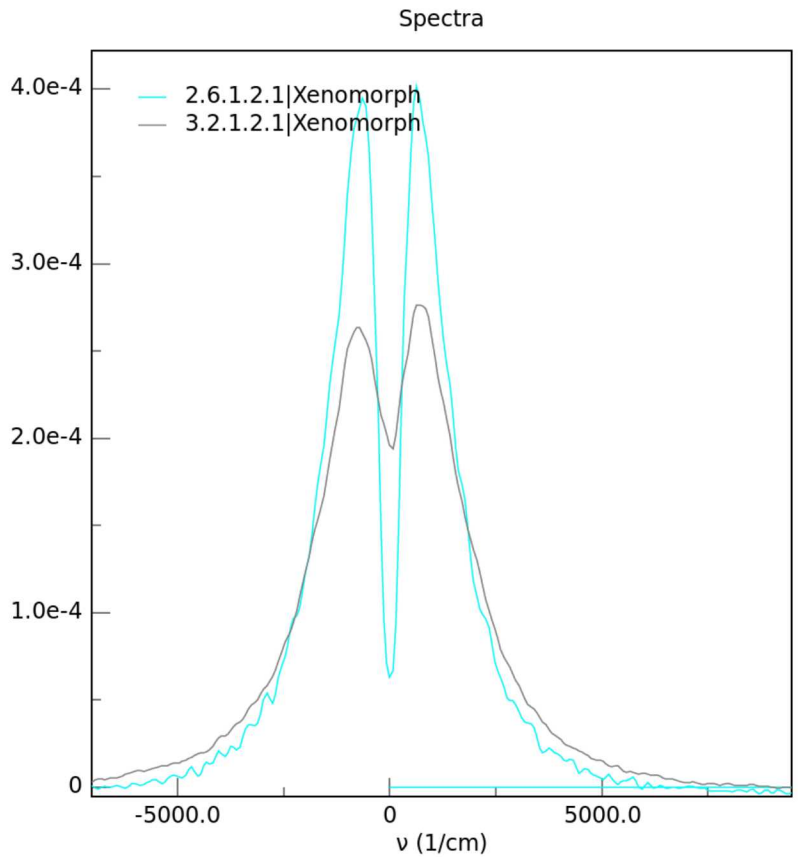


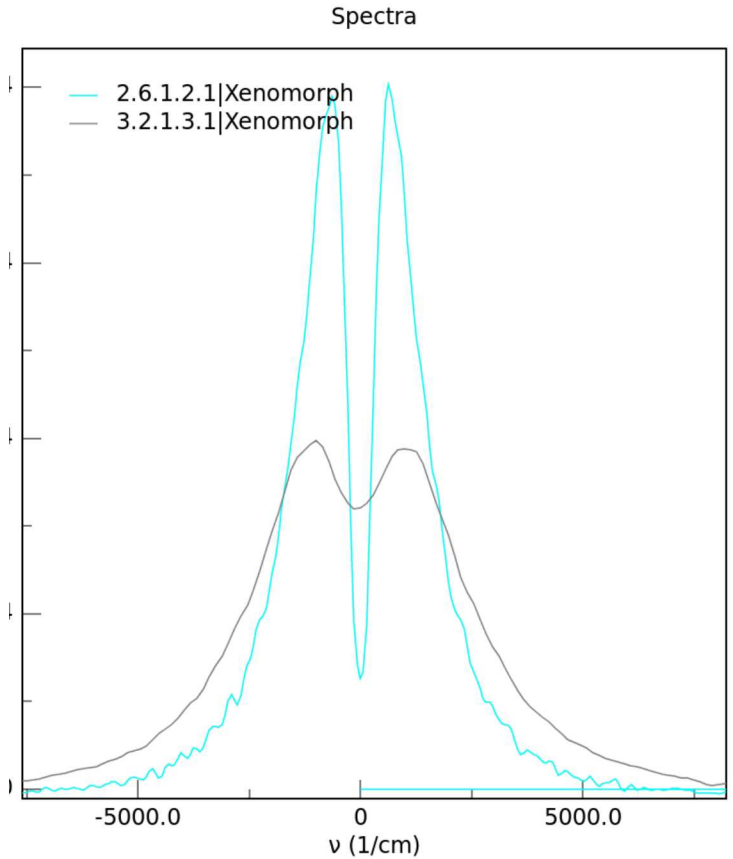




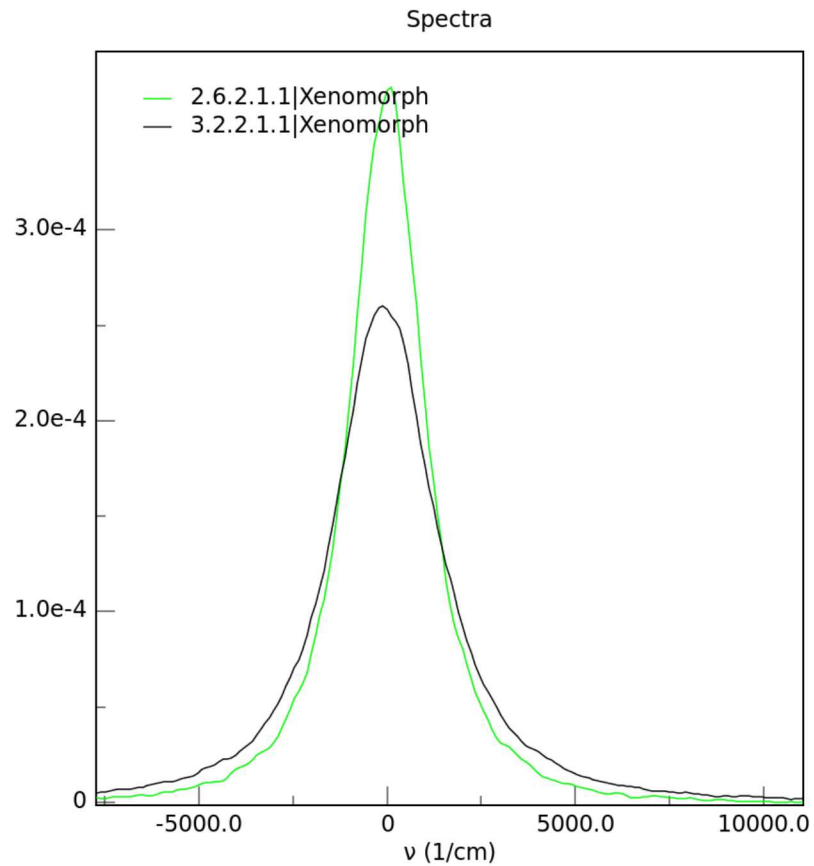
$n_e = 10^{19}$ $T_e = 1eV$

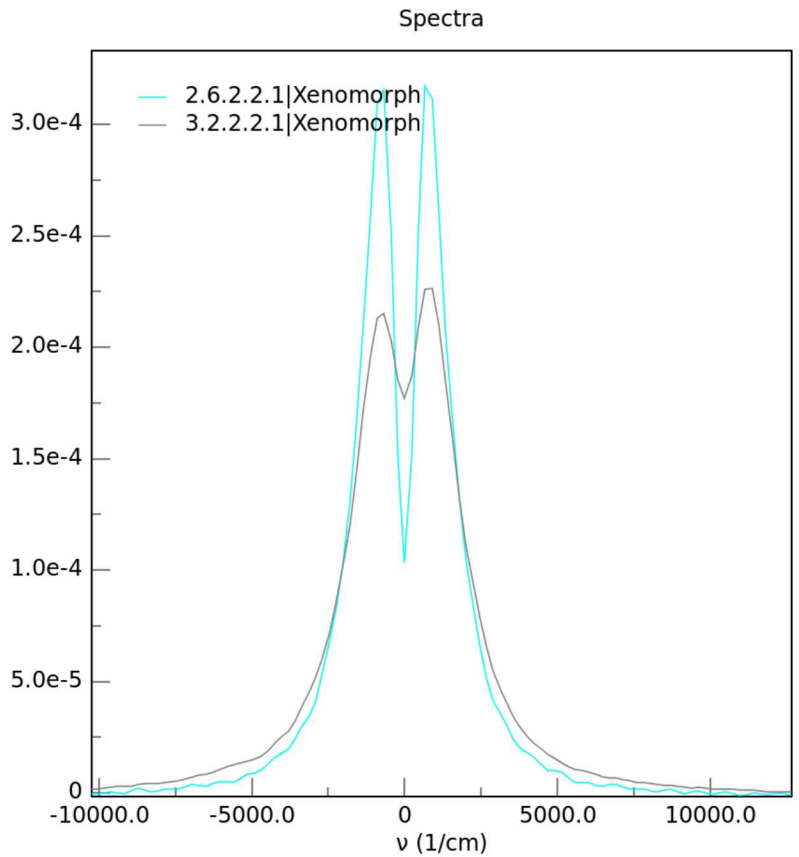


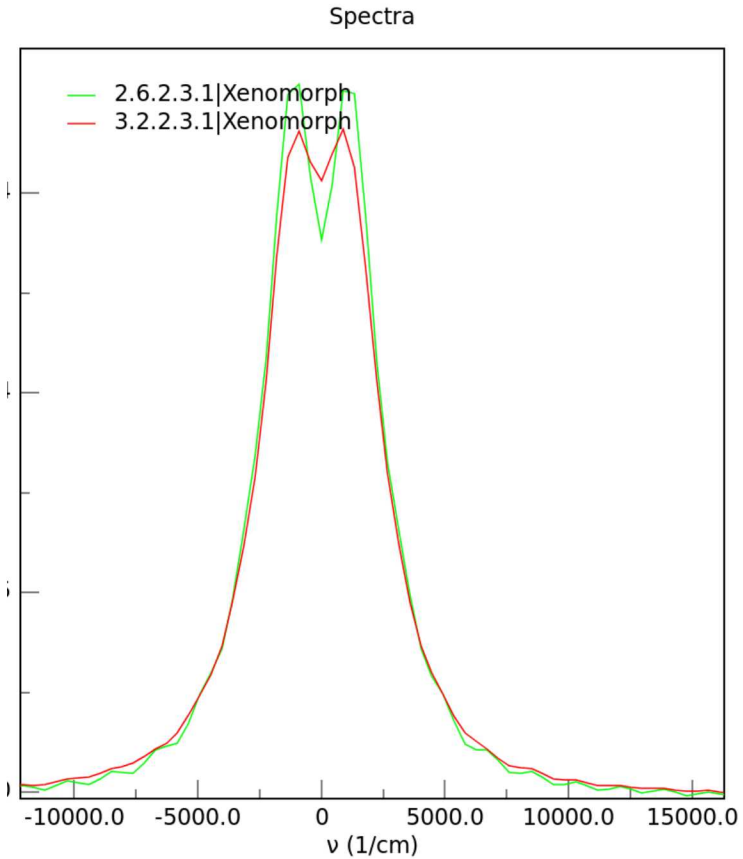




$n_e = 10^{19}$ $T_e = 10eV$







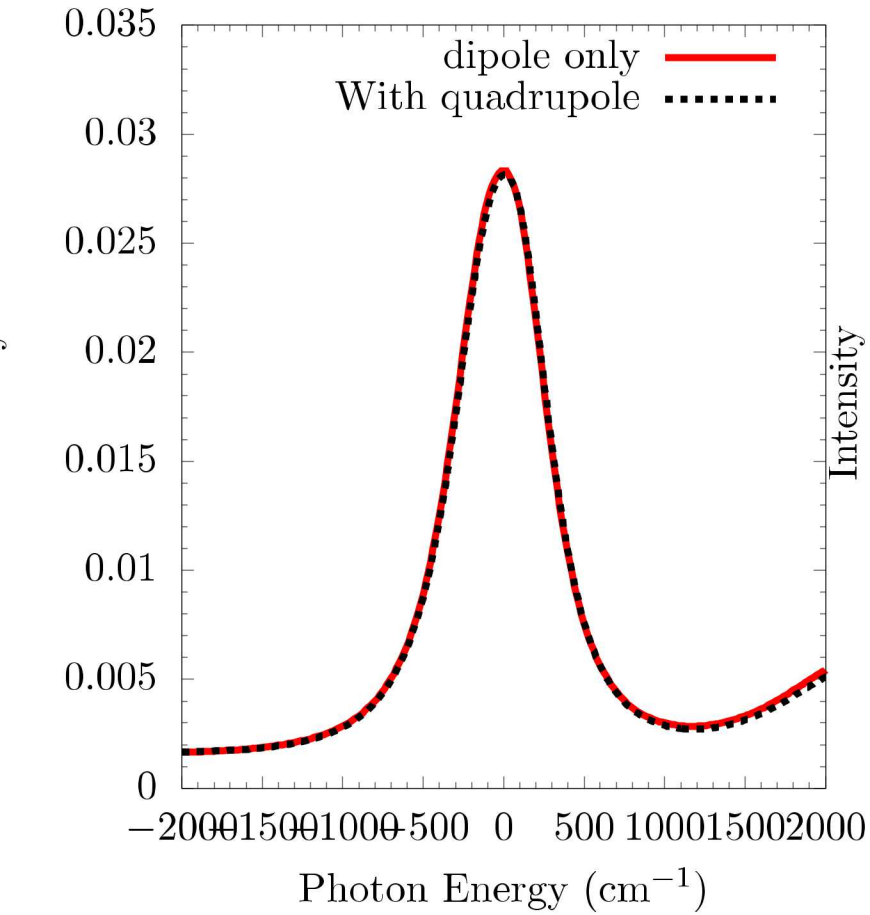
SimU

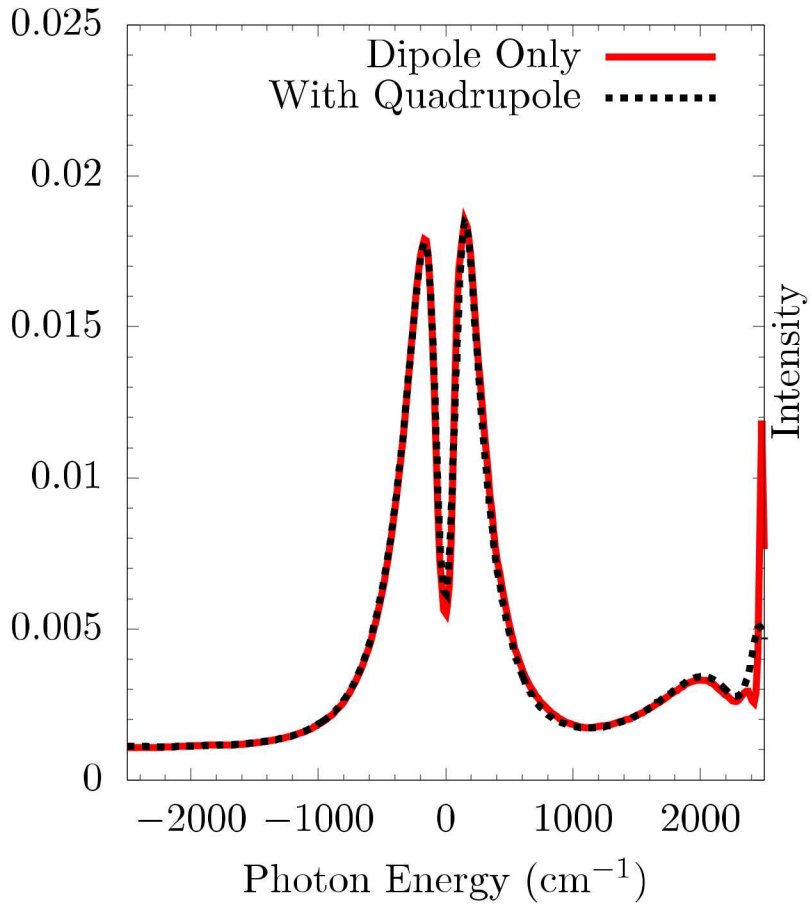
With and Without Quadrupole Corrections (with neighboring states)

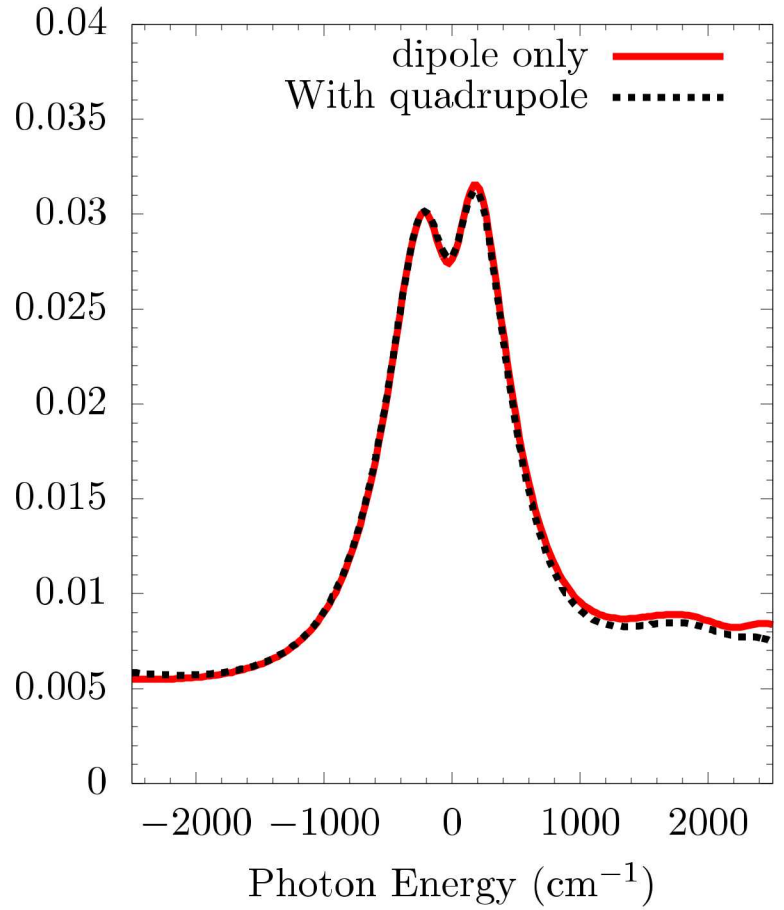
Some Comments

- All of the calculations output the entire spectrum
- Sometimes the continuum is in a different spot and the normalization is dominated by H-alpha
- I tried by best to focus on H-beta, so I artificially (by eye) tried to put the continuum and heights as close as possible to make a useful comparison

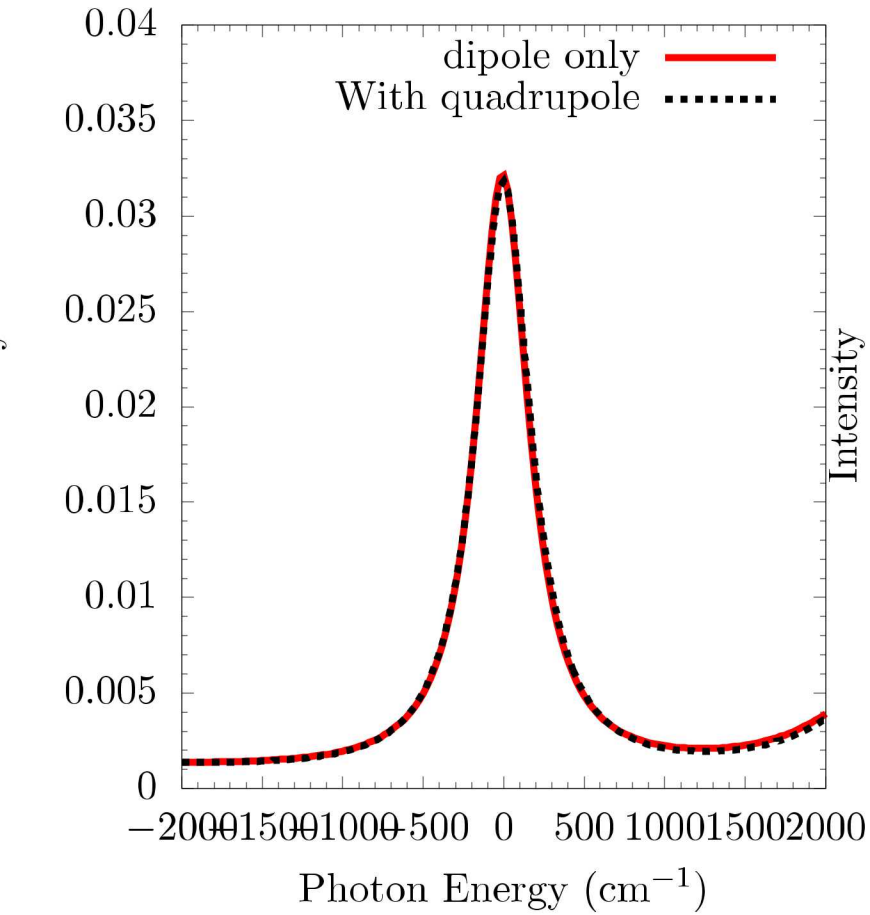
$n_e = 10^{18}$ $T_e = 1eV$

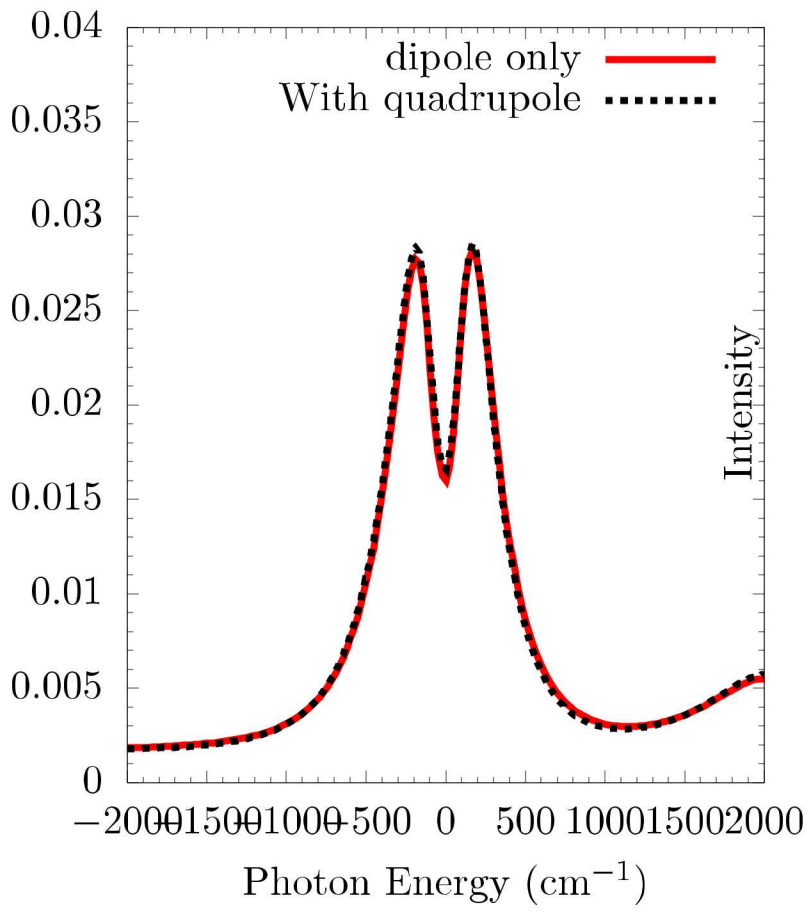


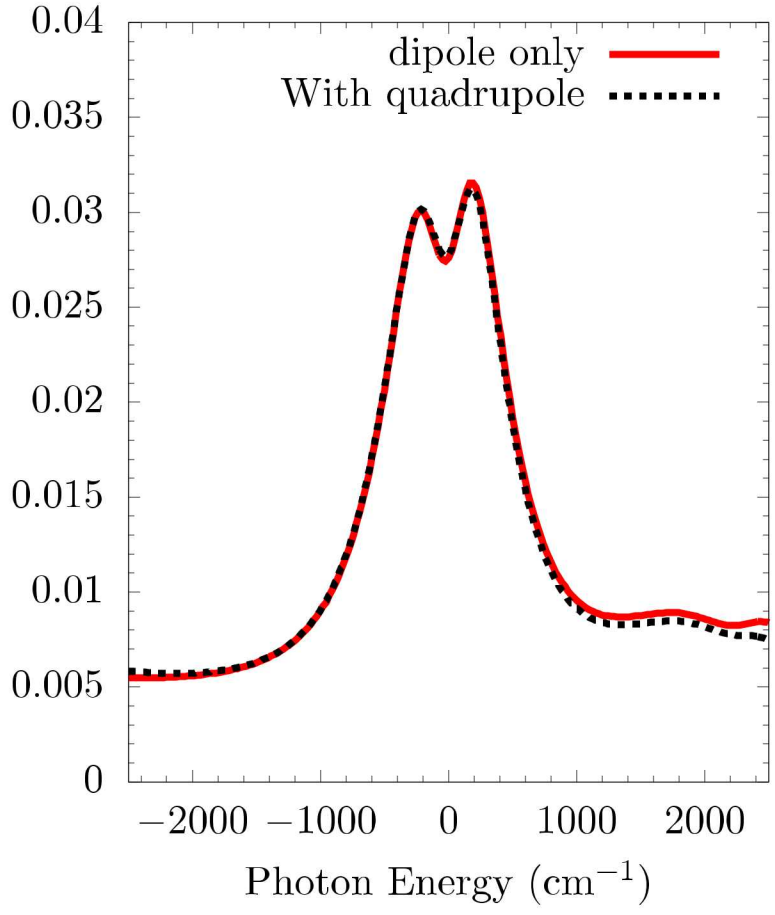




$n_e = 10^{18}$ $T_e = 10eV$



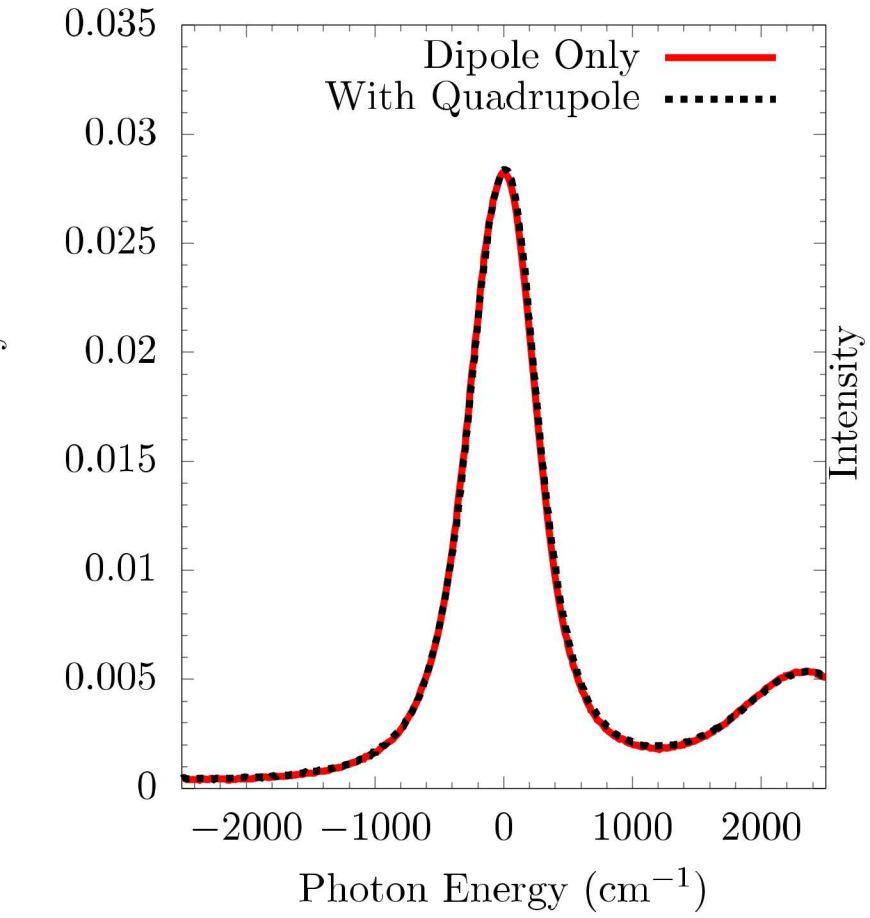


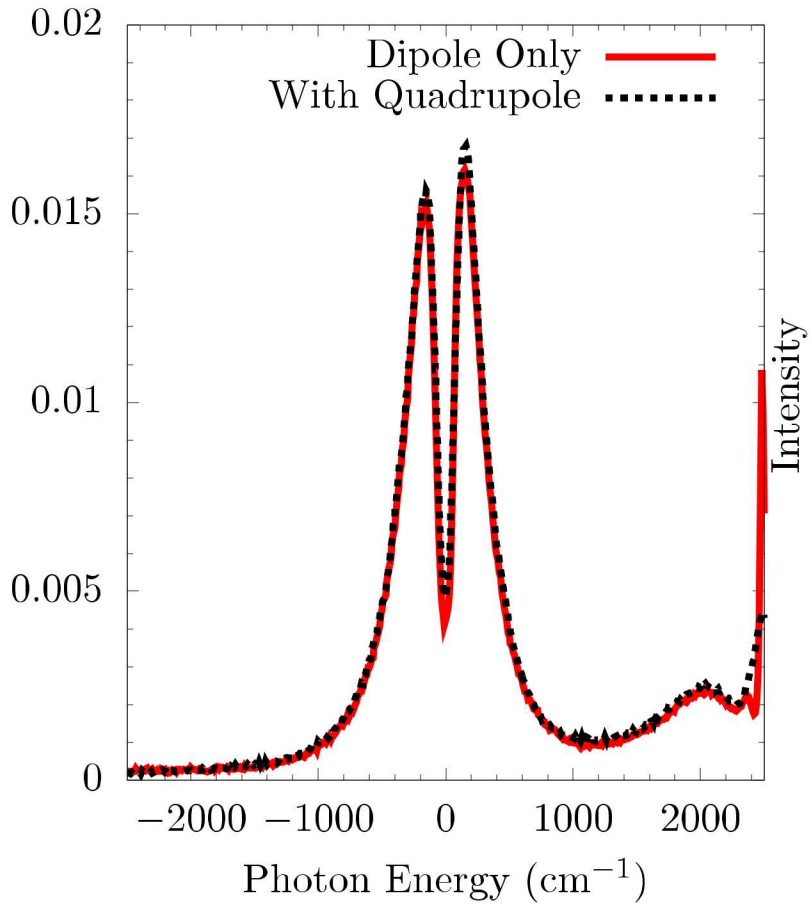


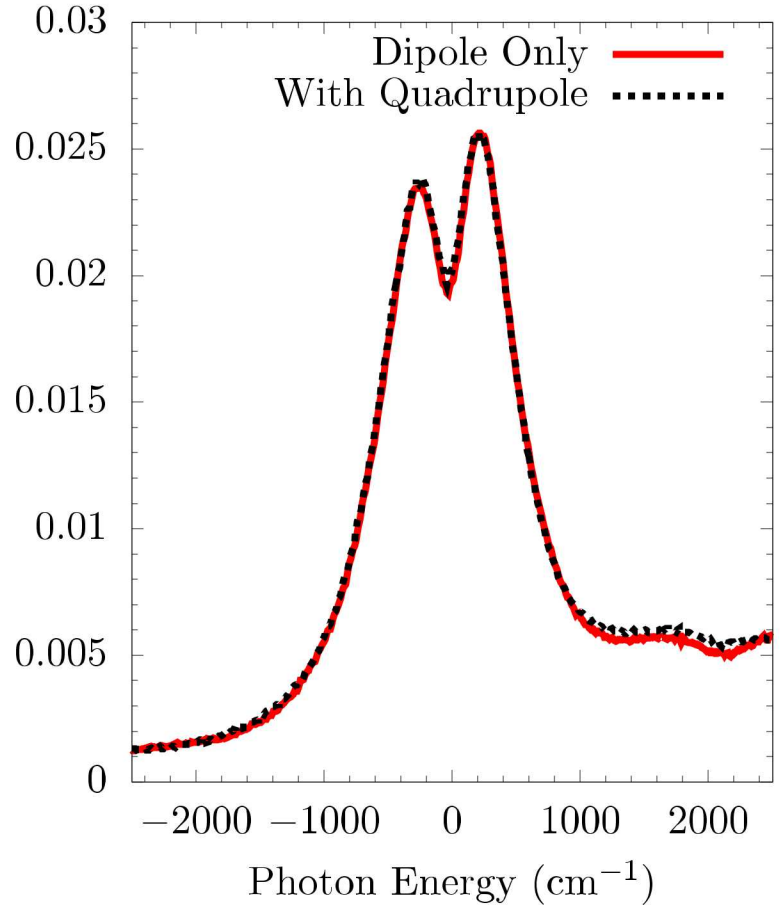
Simulation

With and Without Quadrupole Corrections (with neighboring states)

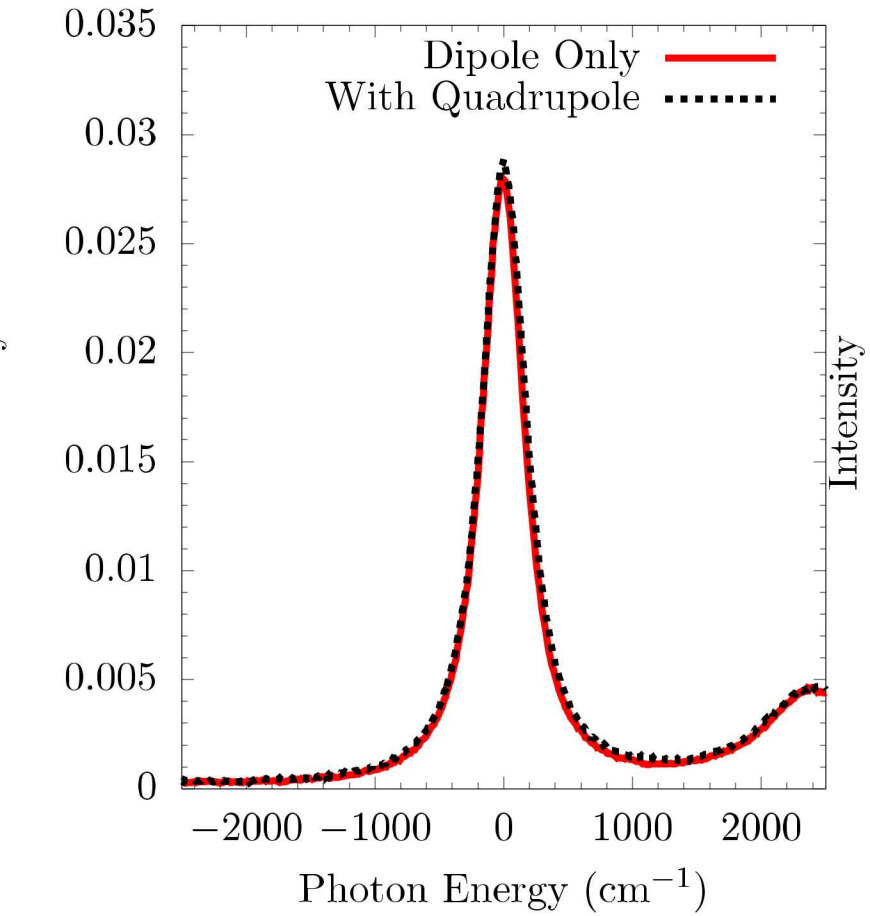
$n_e = 10^{18}$ $T_e = 1eV$

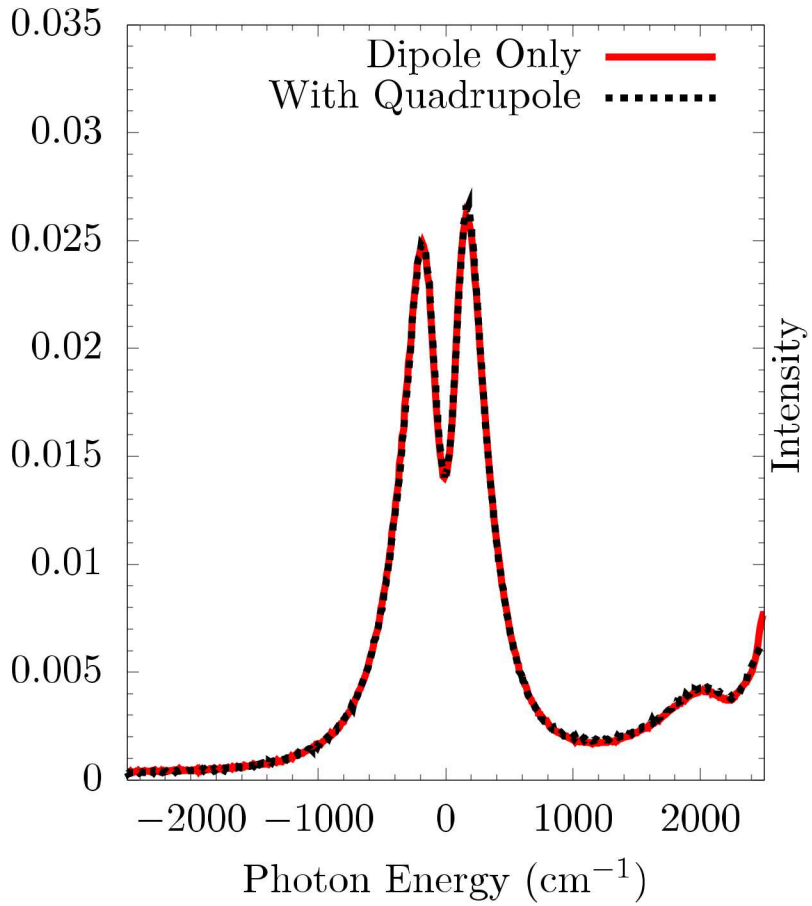


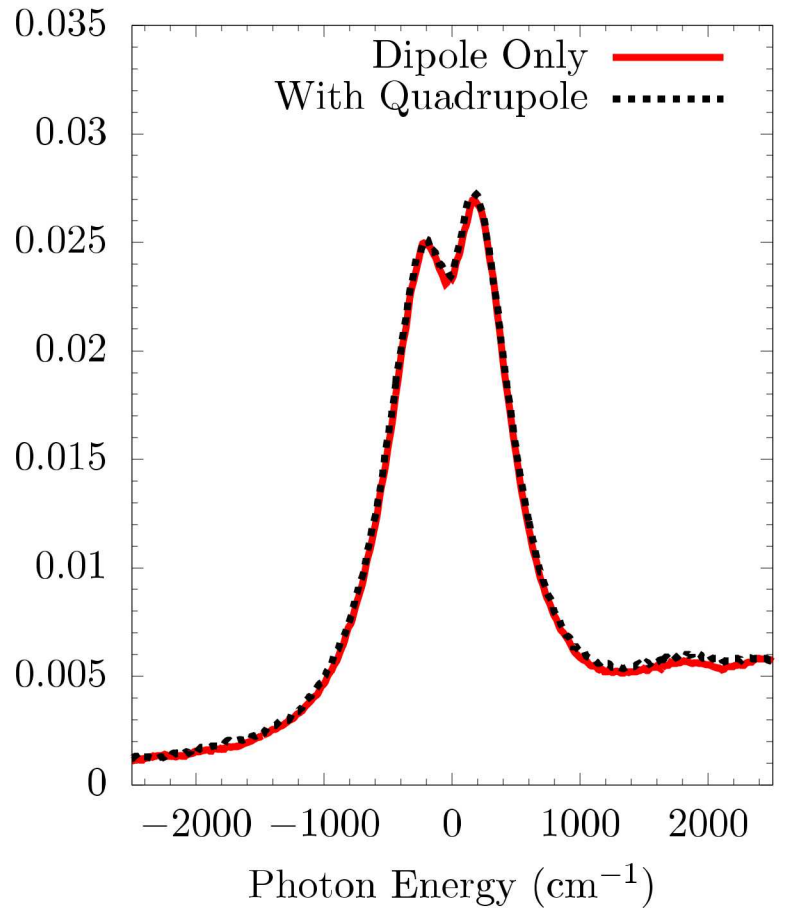




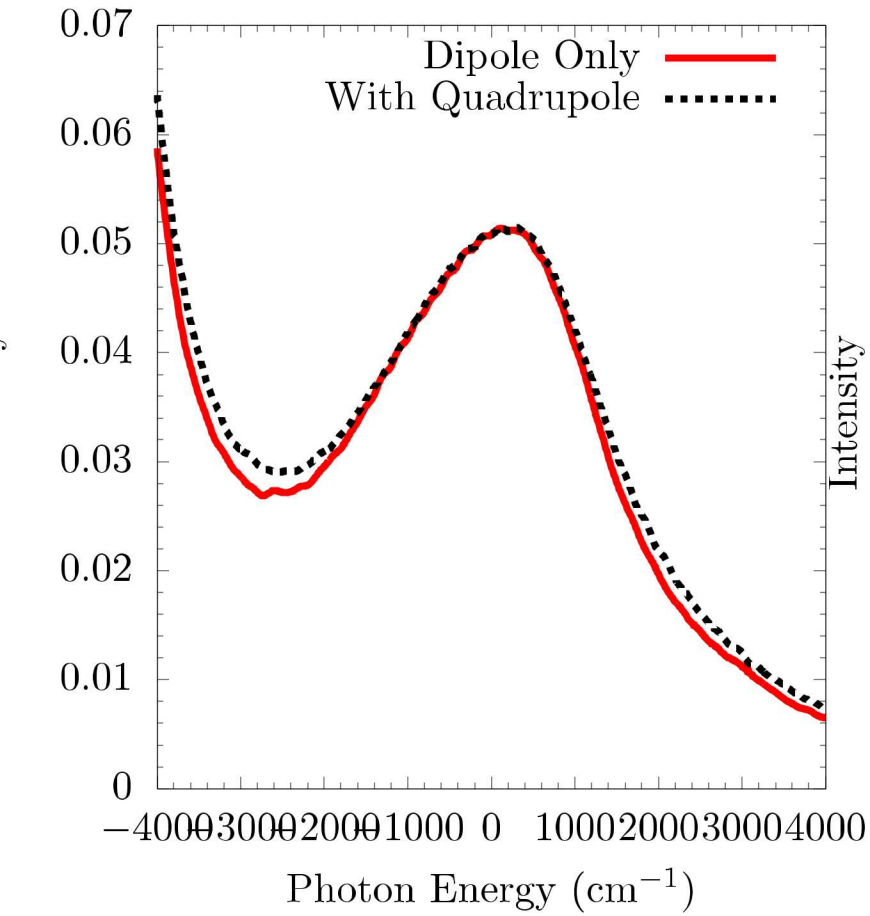
$n_e = 10^{18}$ $T_e = 10eV$

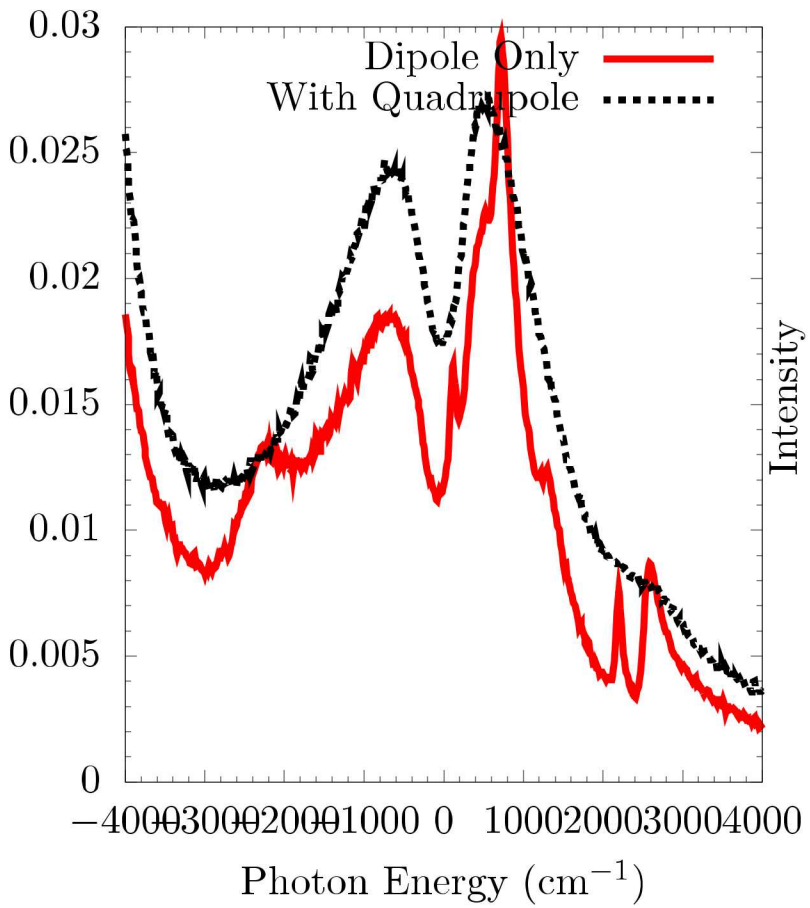


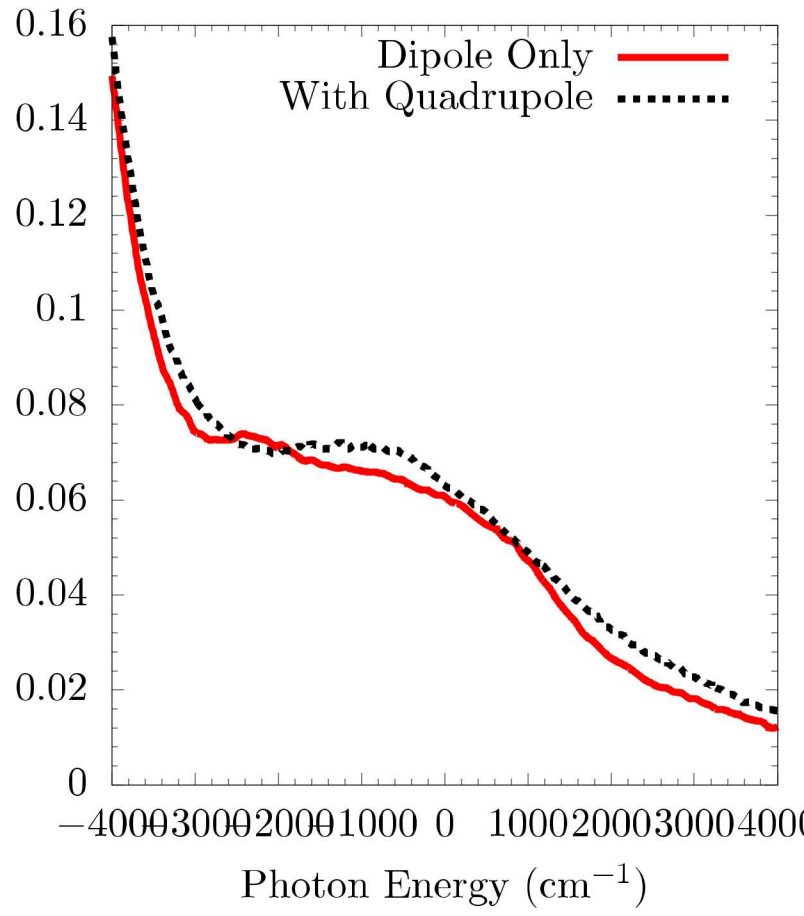




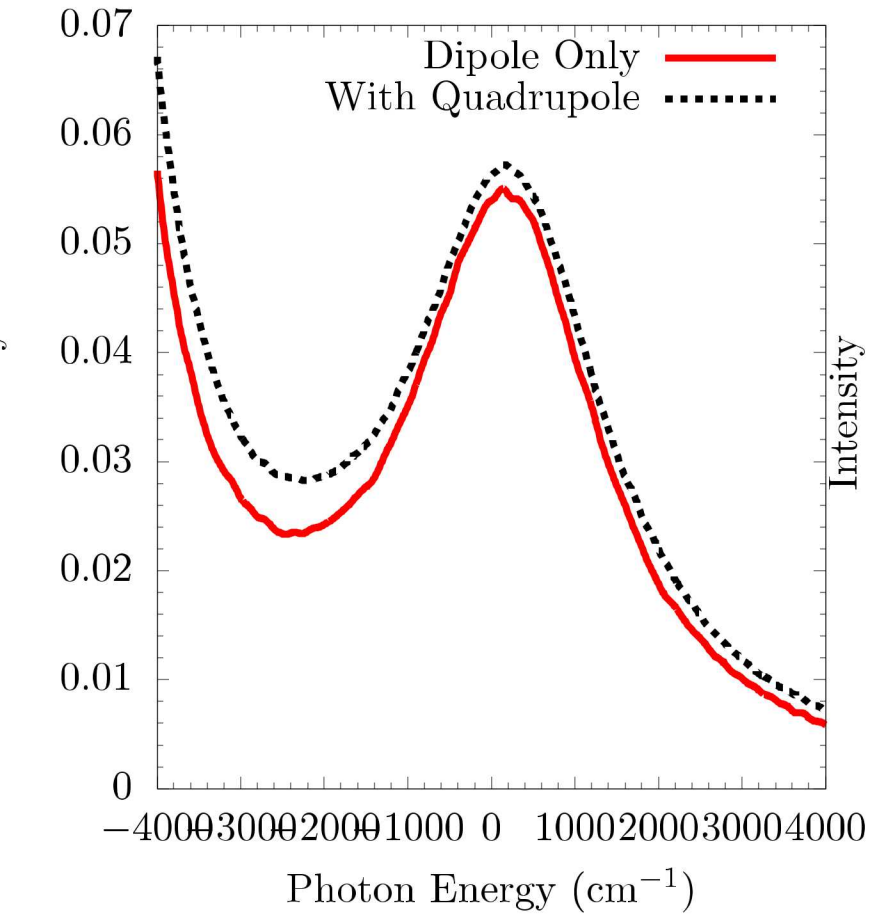
$n_e = 10^{19}$ $T_e = 1eV$

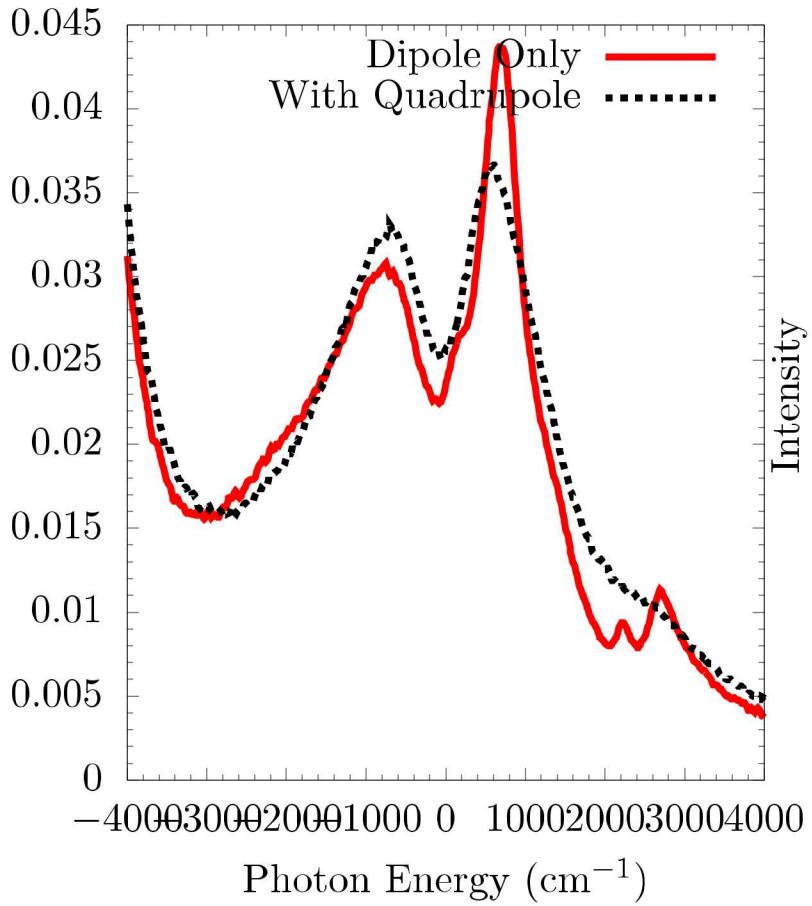


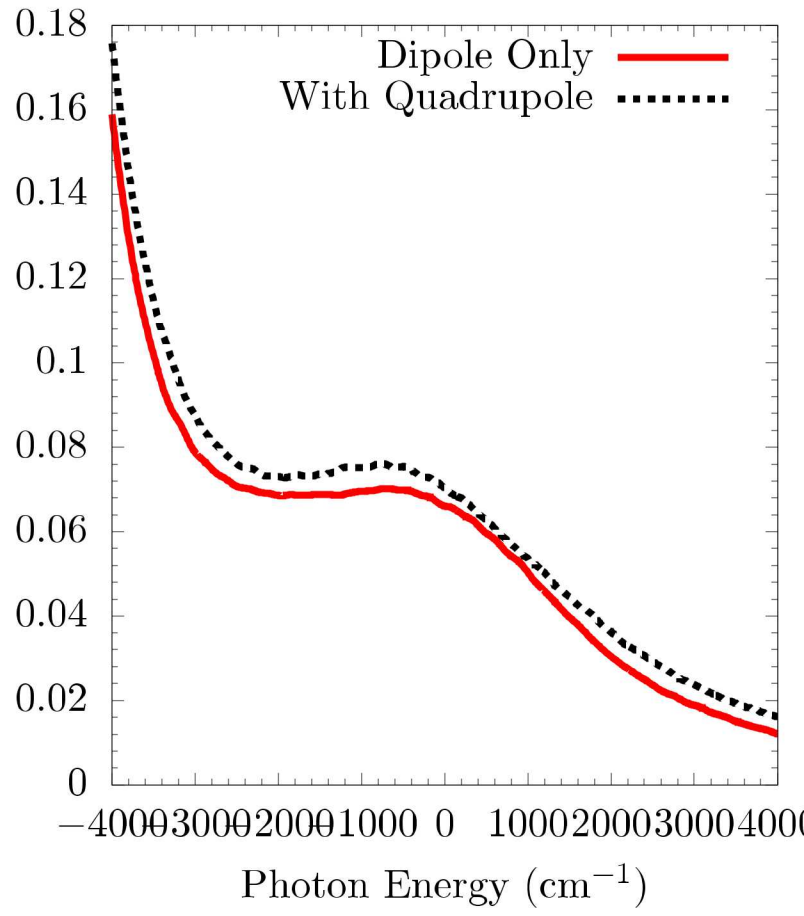




$n_e = 10^{19}$ $T_e = 1eV$



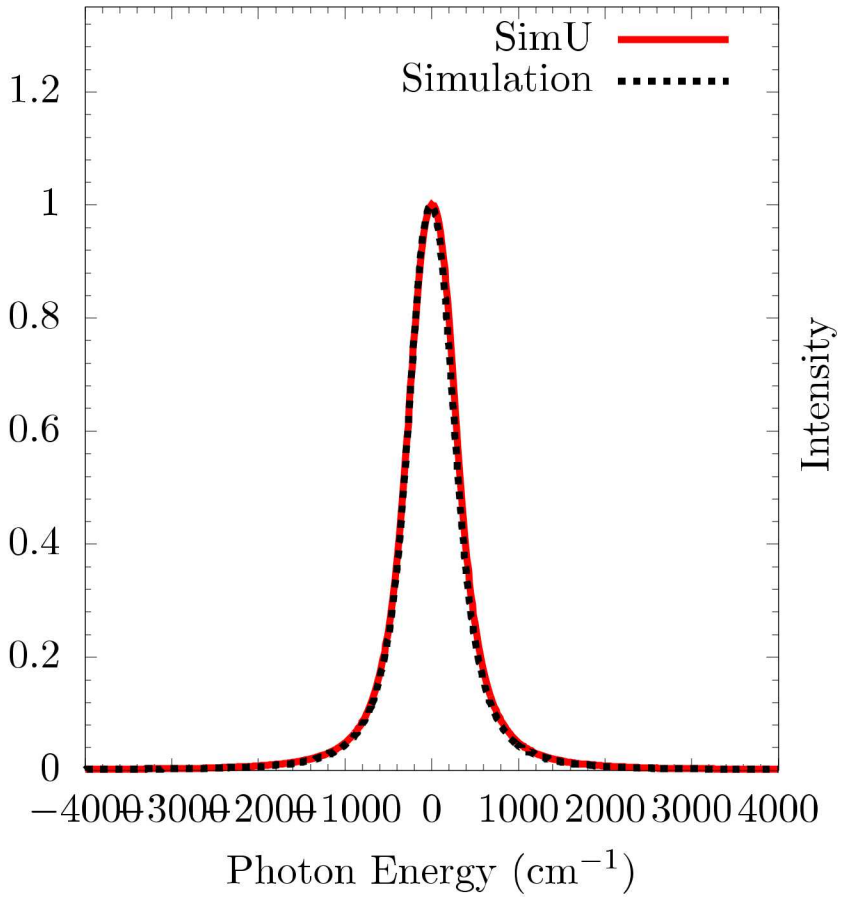


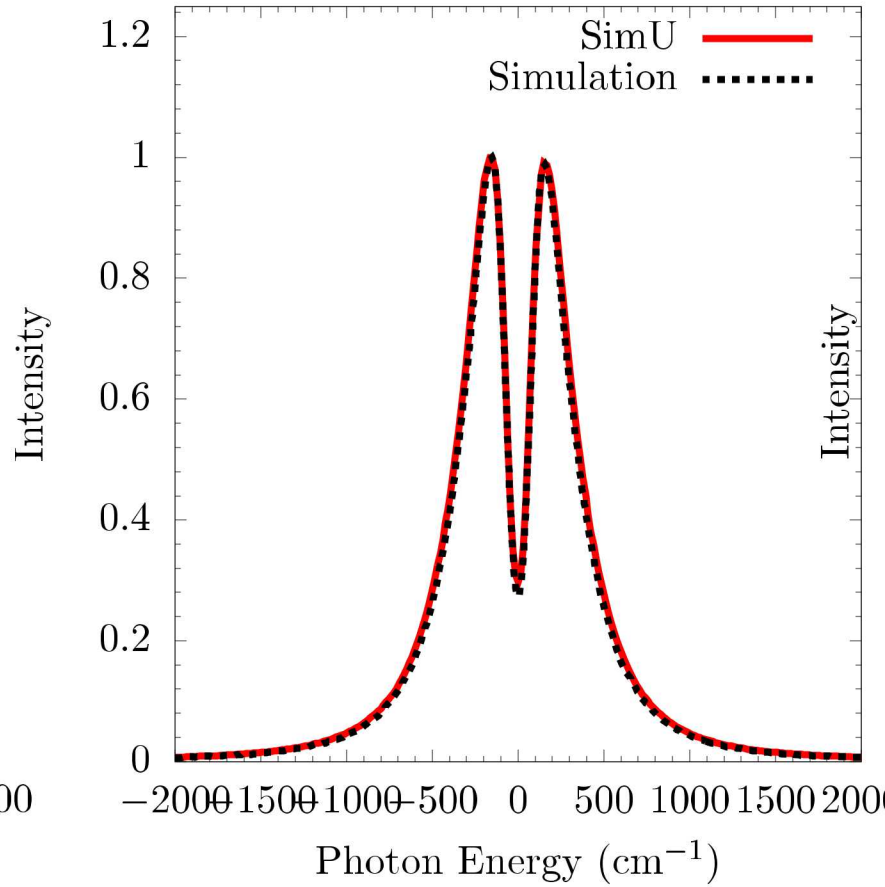


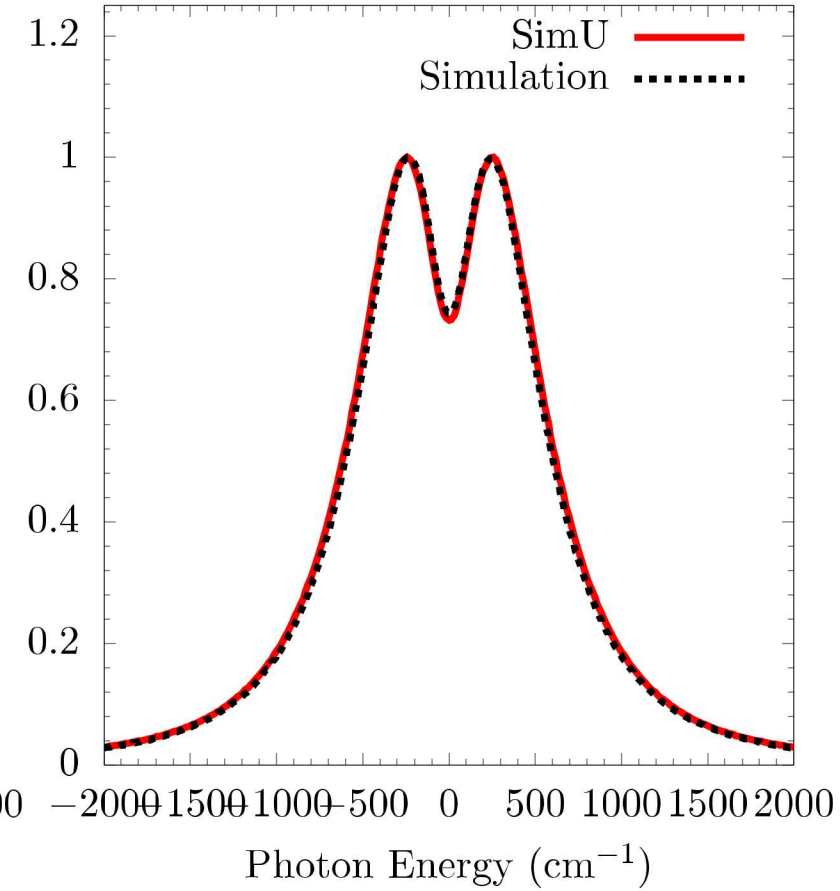
Simulation Vs SimU

With Quadrupole Corrections (No Quenching)

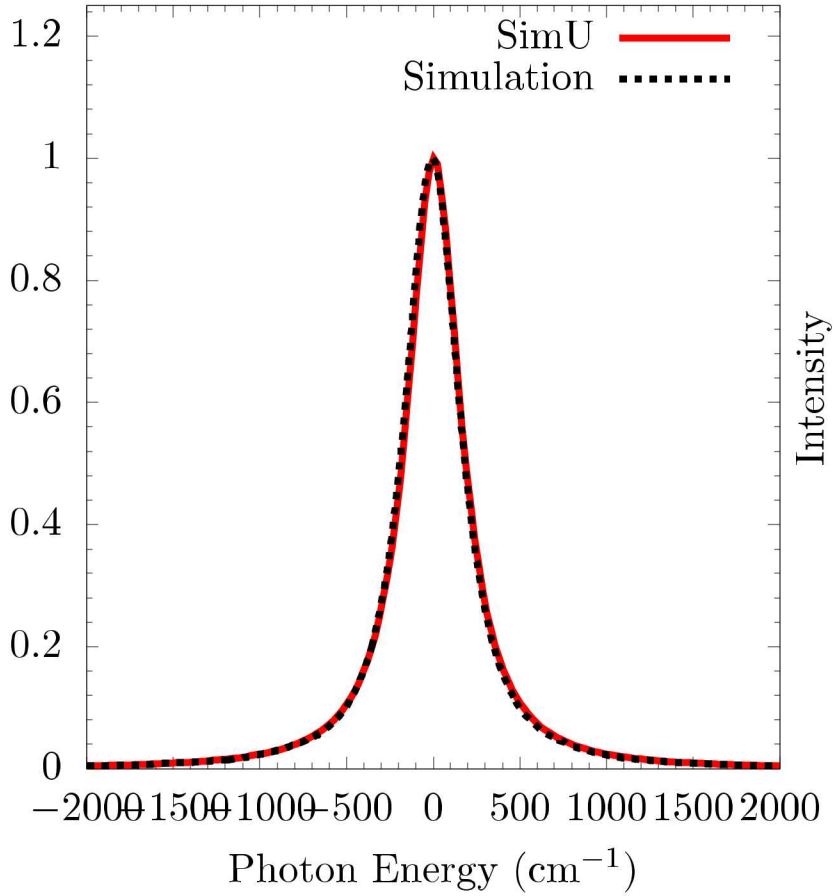
$n_e = 10^{18}$ $T_e = 1eV$

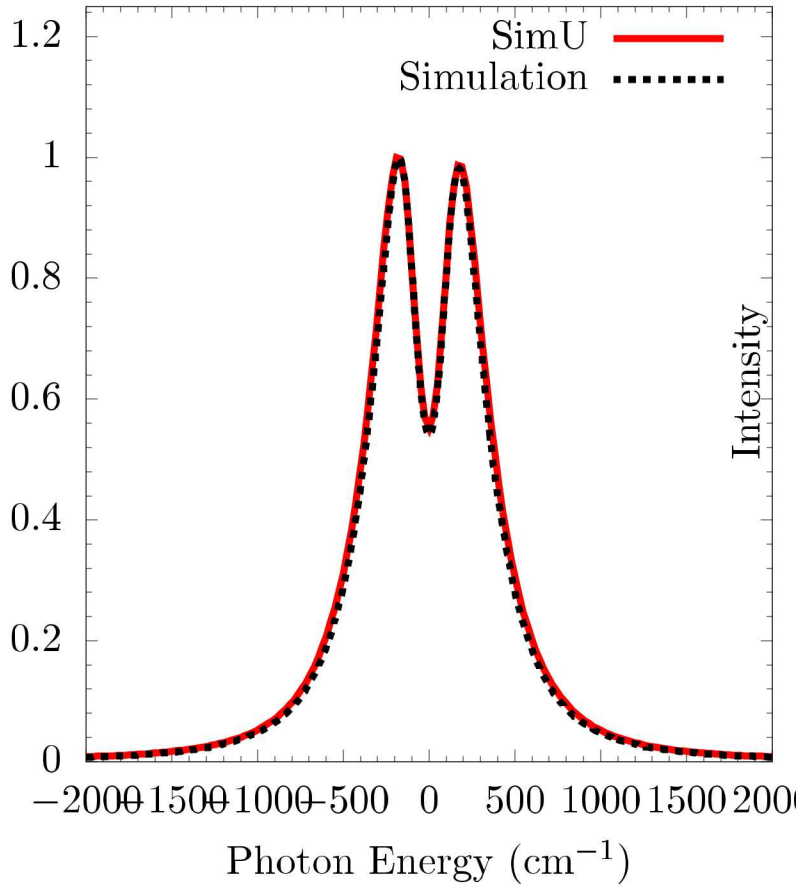


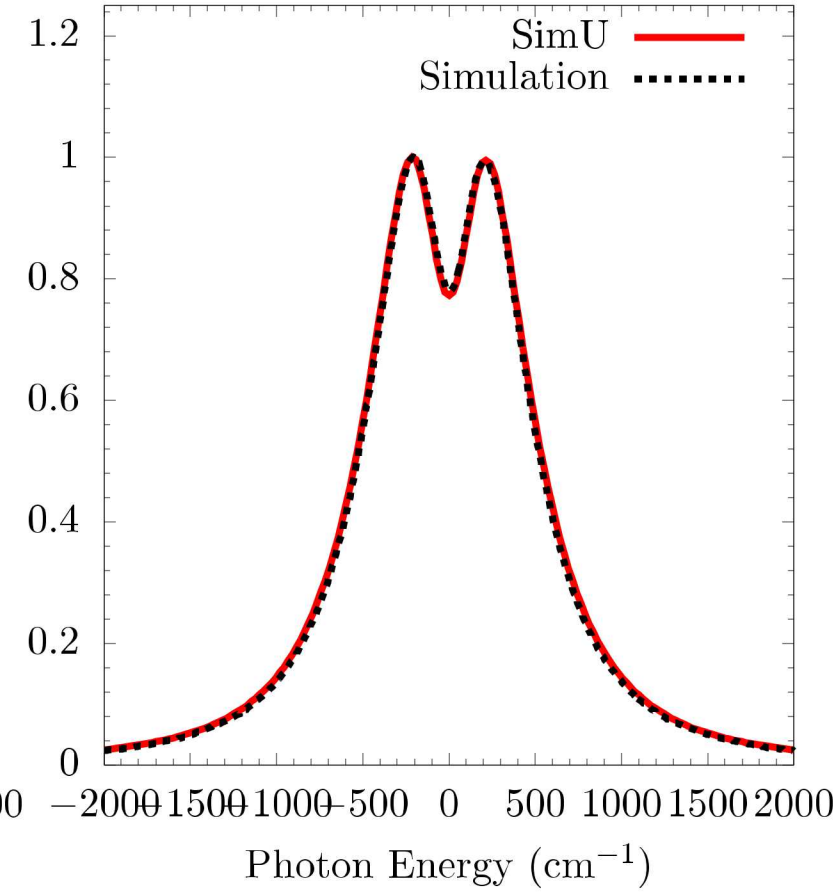




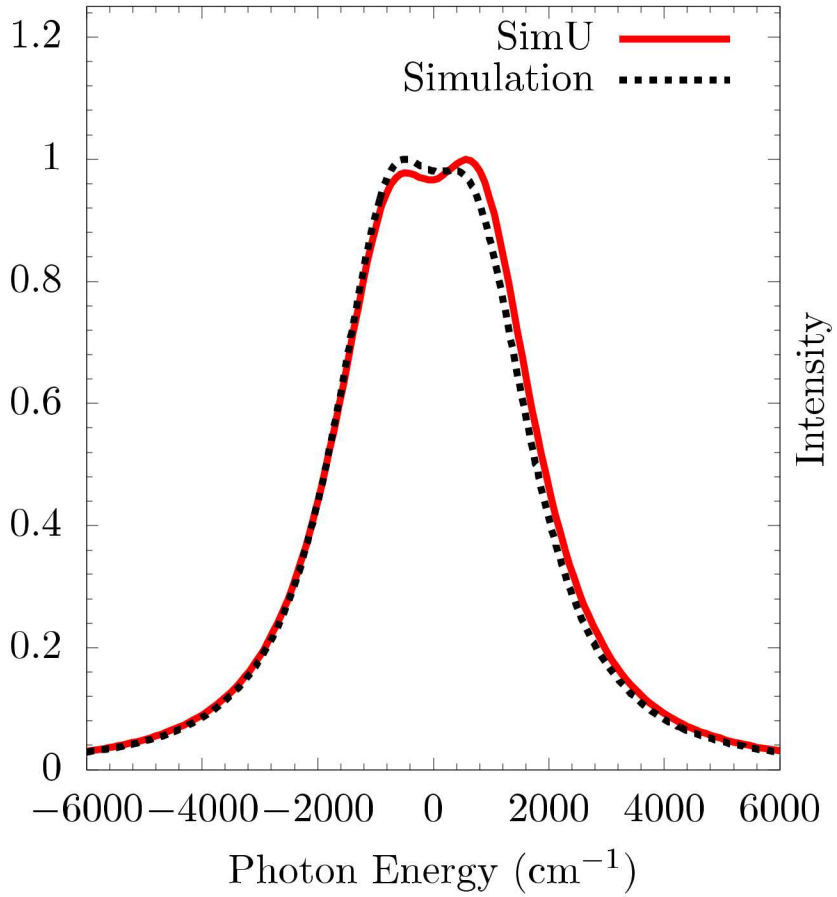
$n_e = 10^{18}$ $T_e = 10eV$

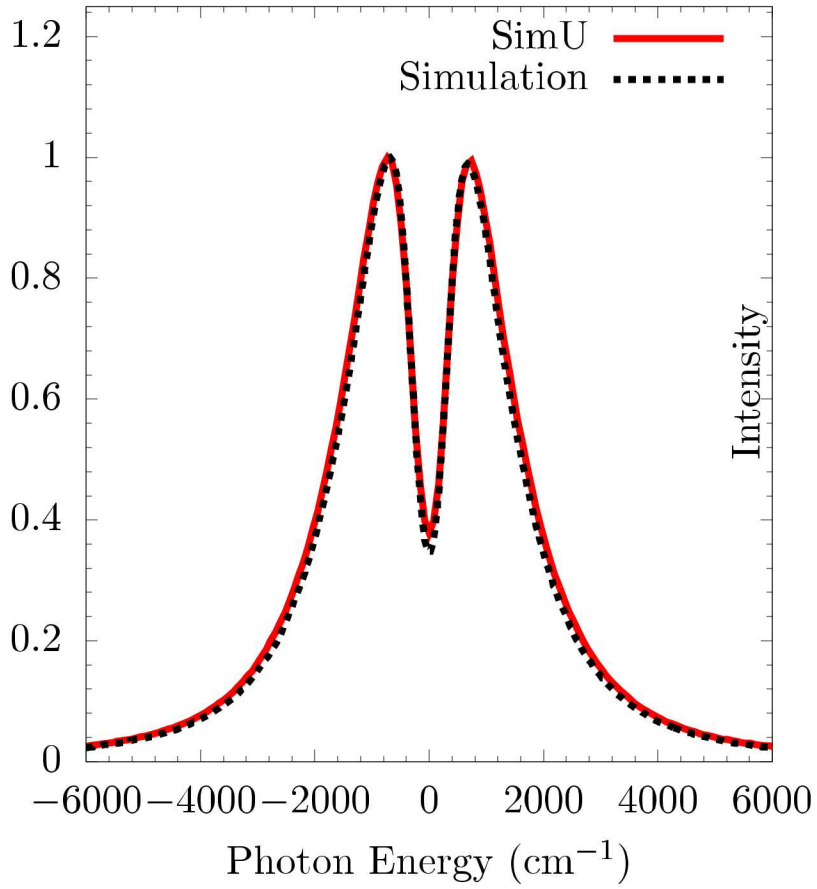


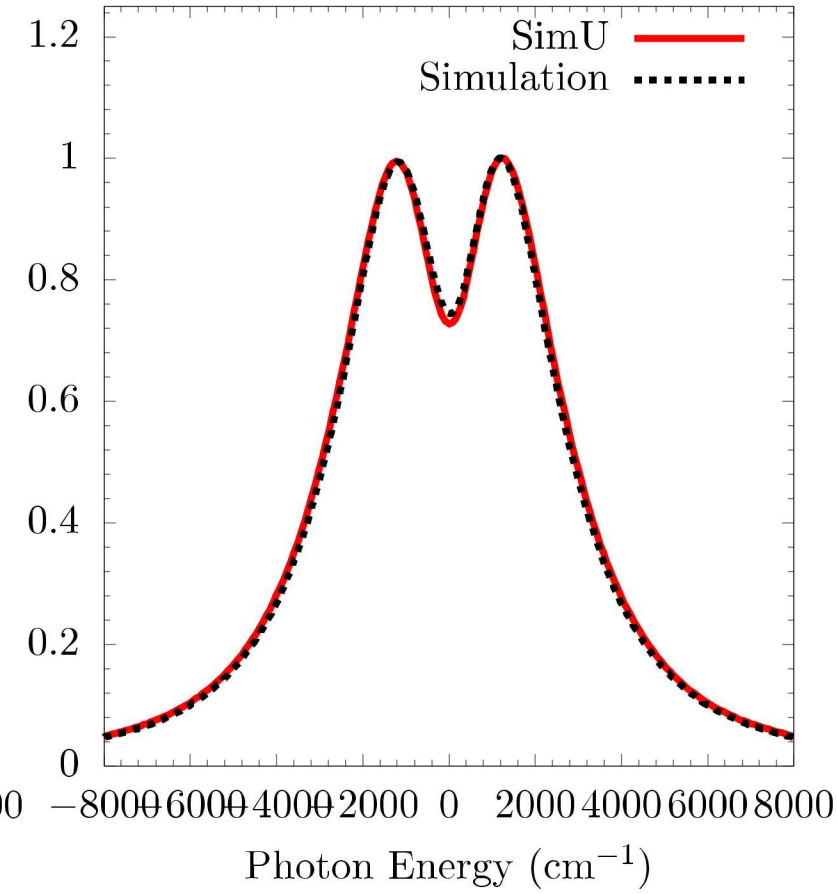




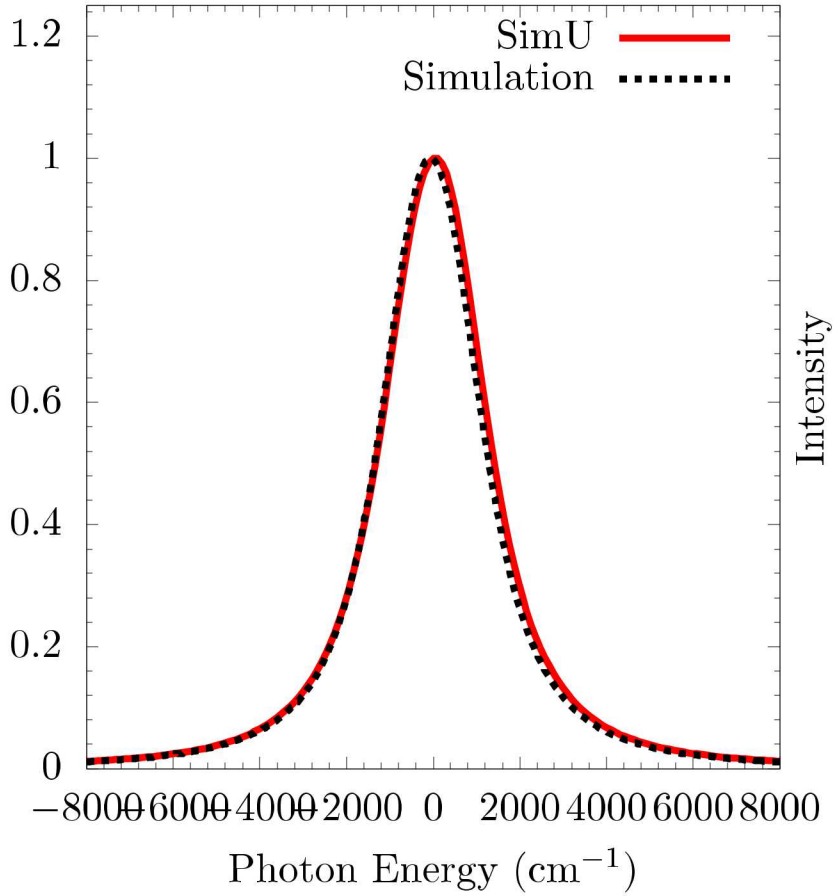
$n_e = 10^{19}$ $T_e = 1eV$

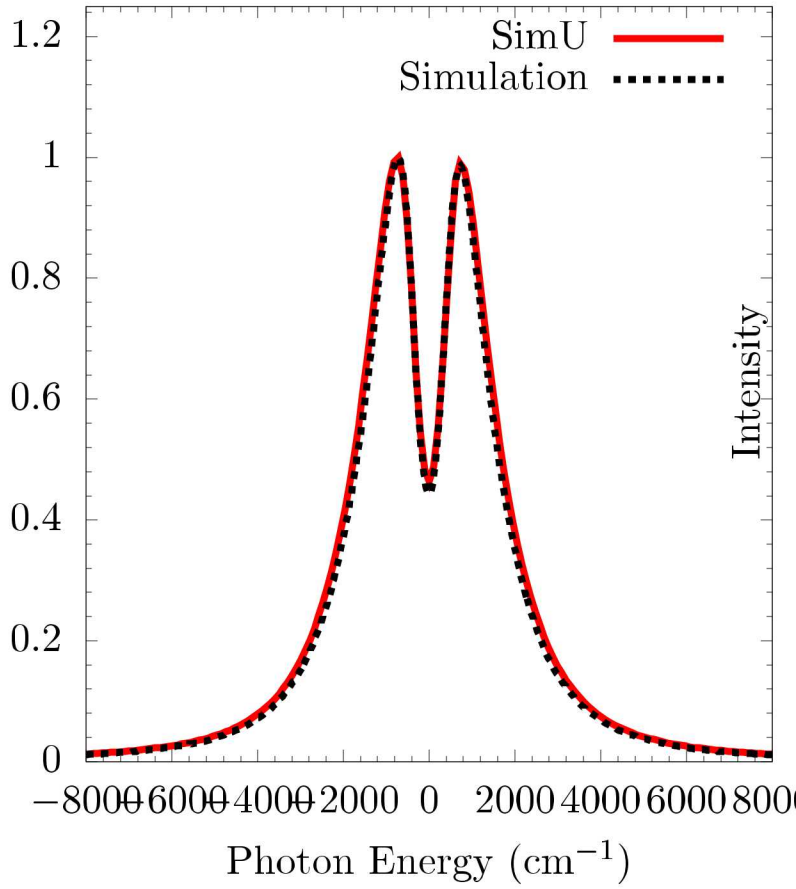


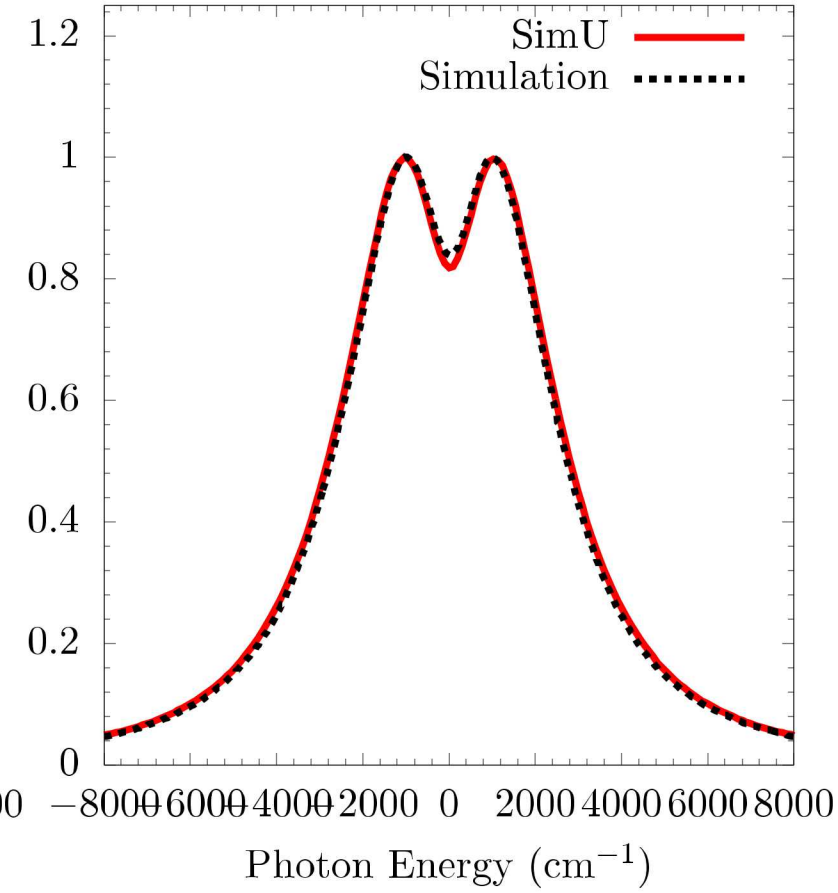




$n_e = 10^{19}$ $T_e = 10eV$



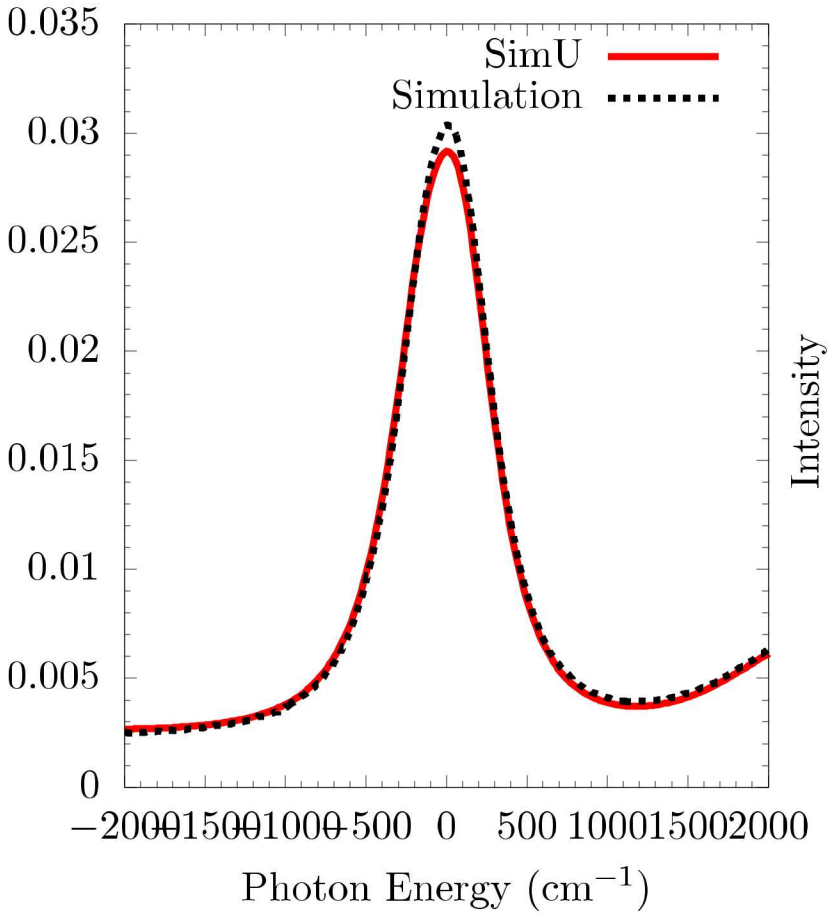


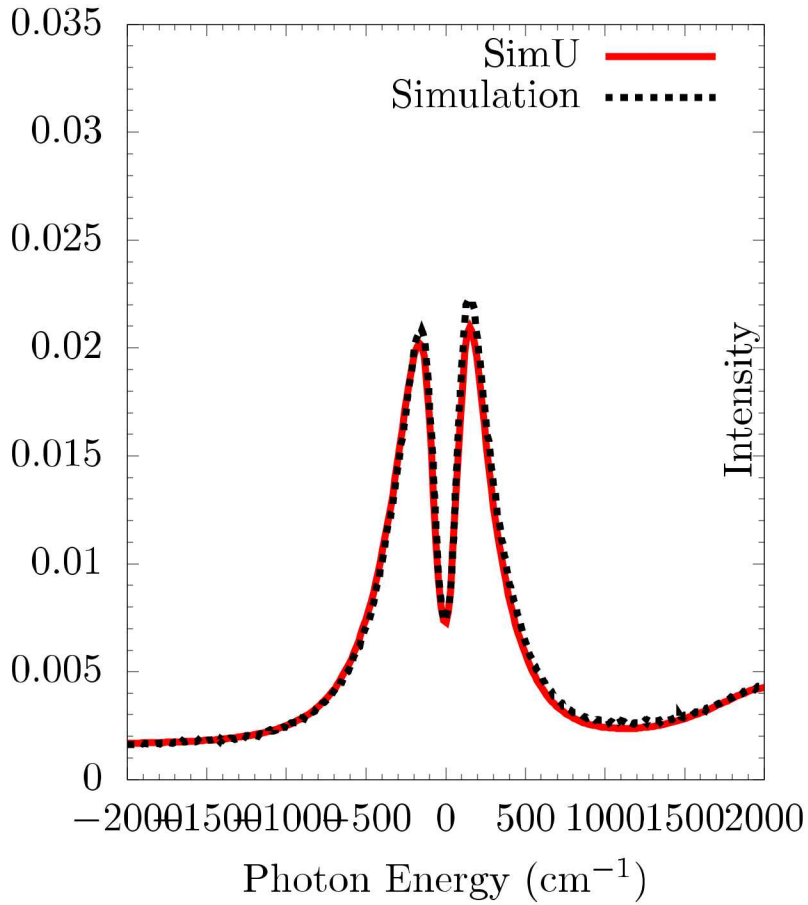


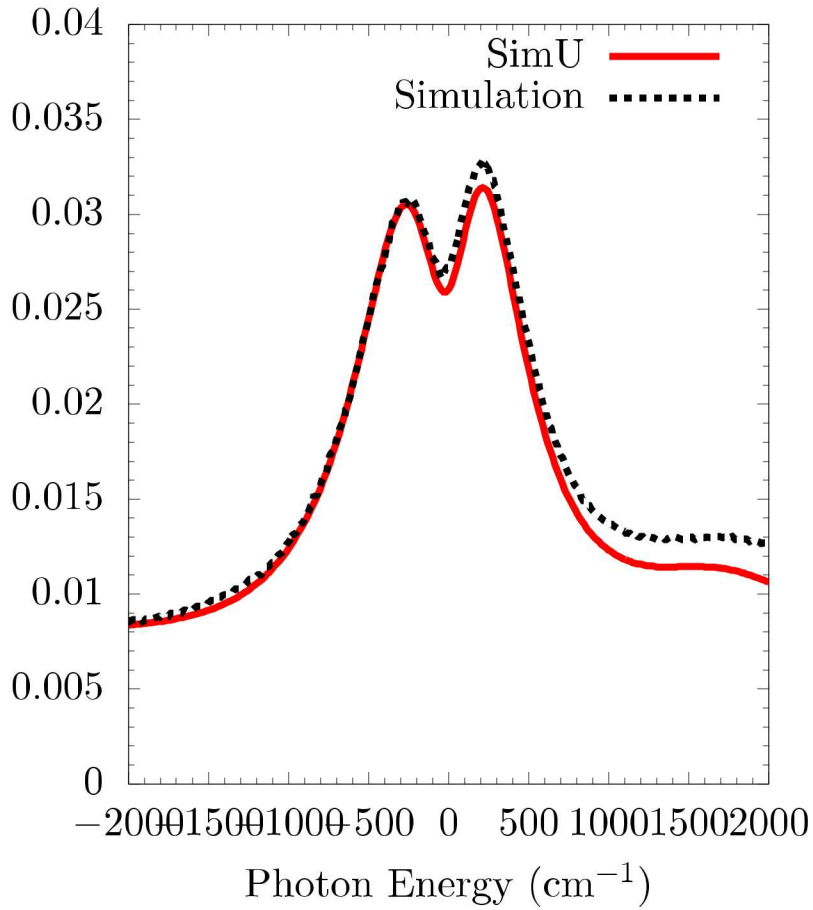
Simulation Vs SimU

With Quadrupole Corrections (With Neighboring States)

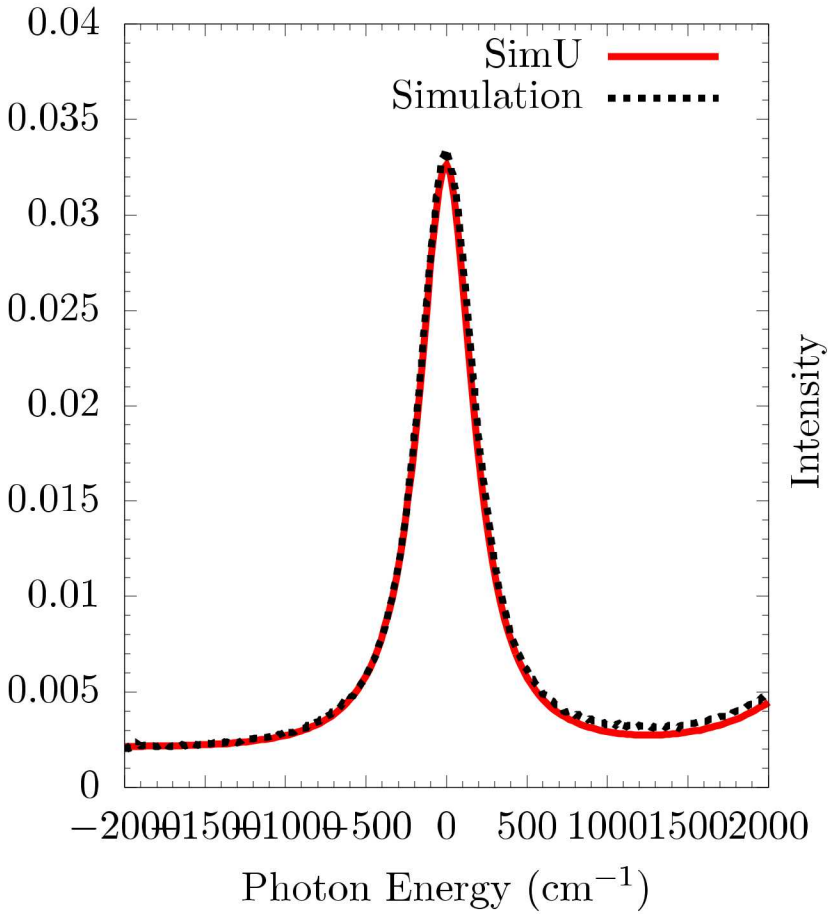
$n_e = 10^{18}$ $T_e = 1eV$

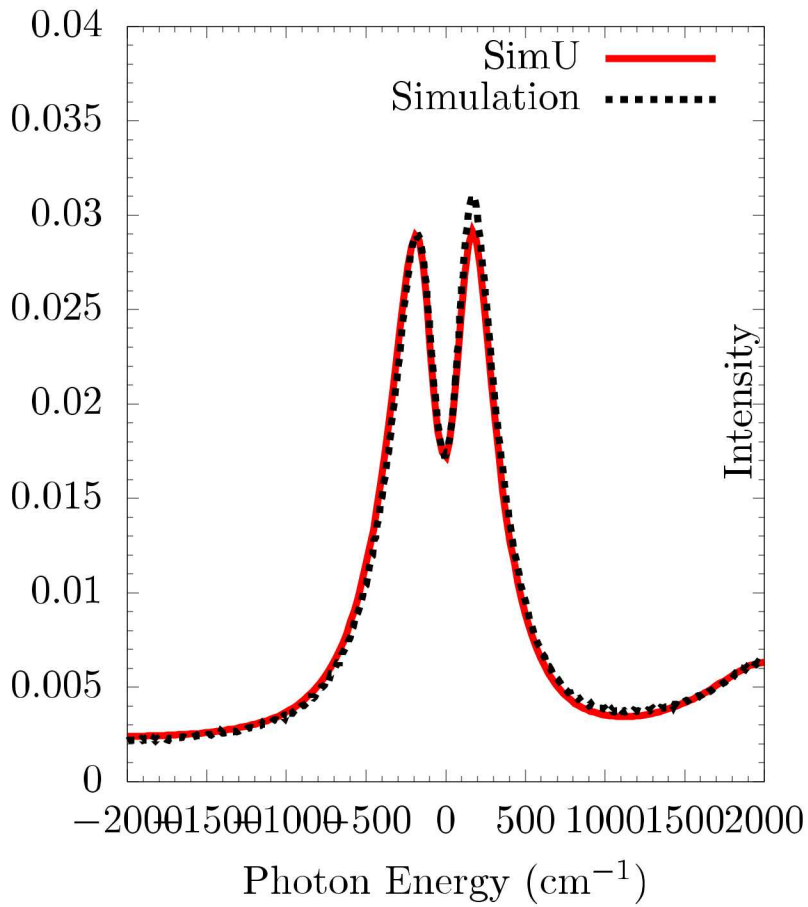


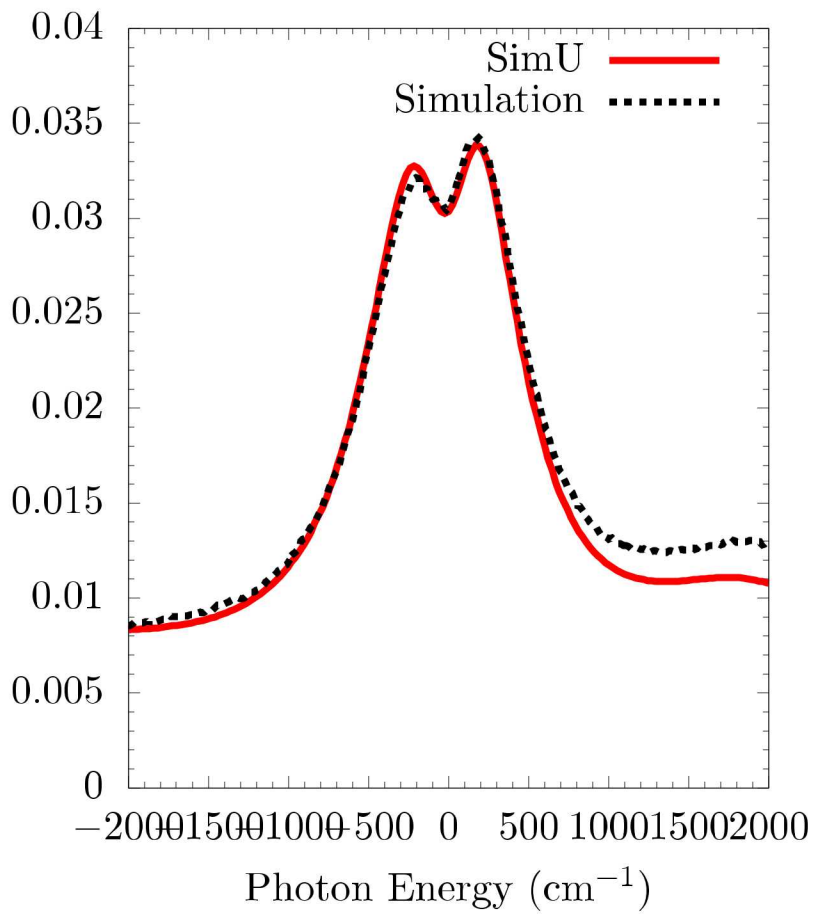




$n_e = 10^{18}$ $T_e = 1eV$



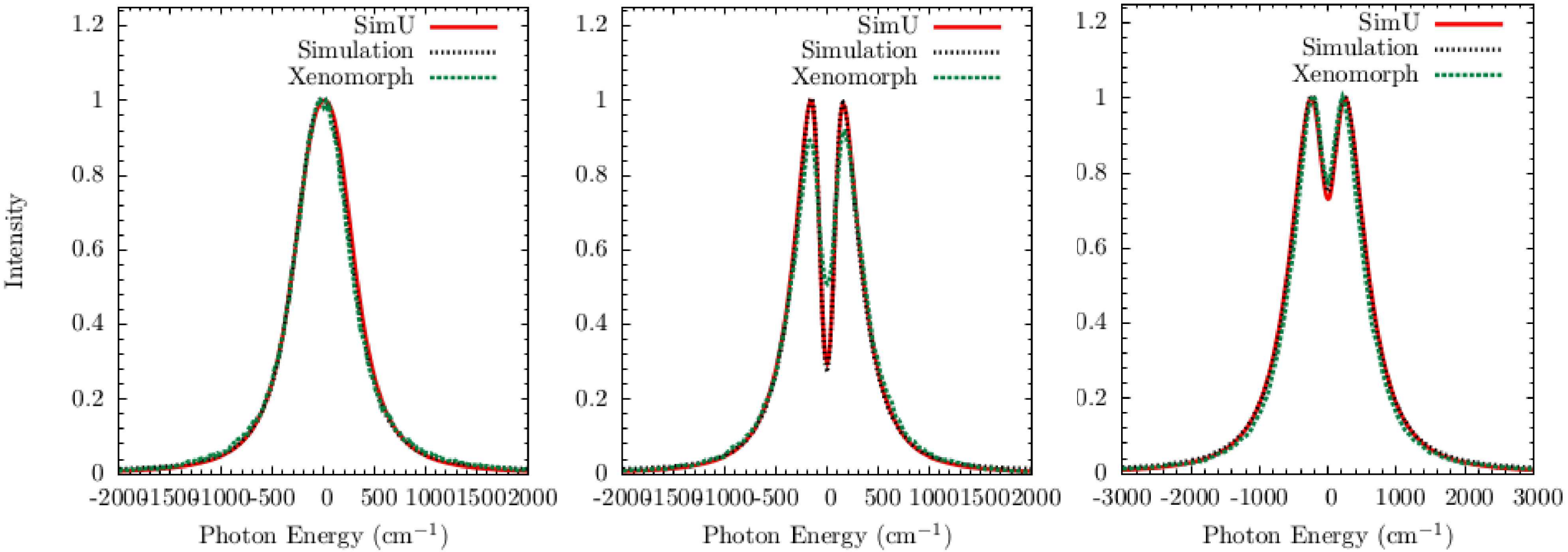




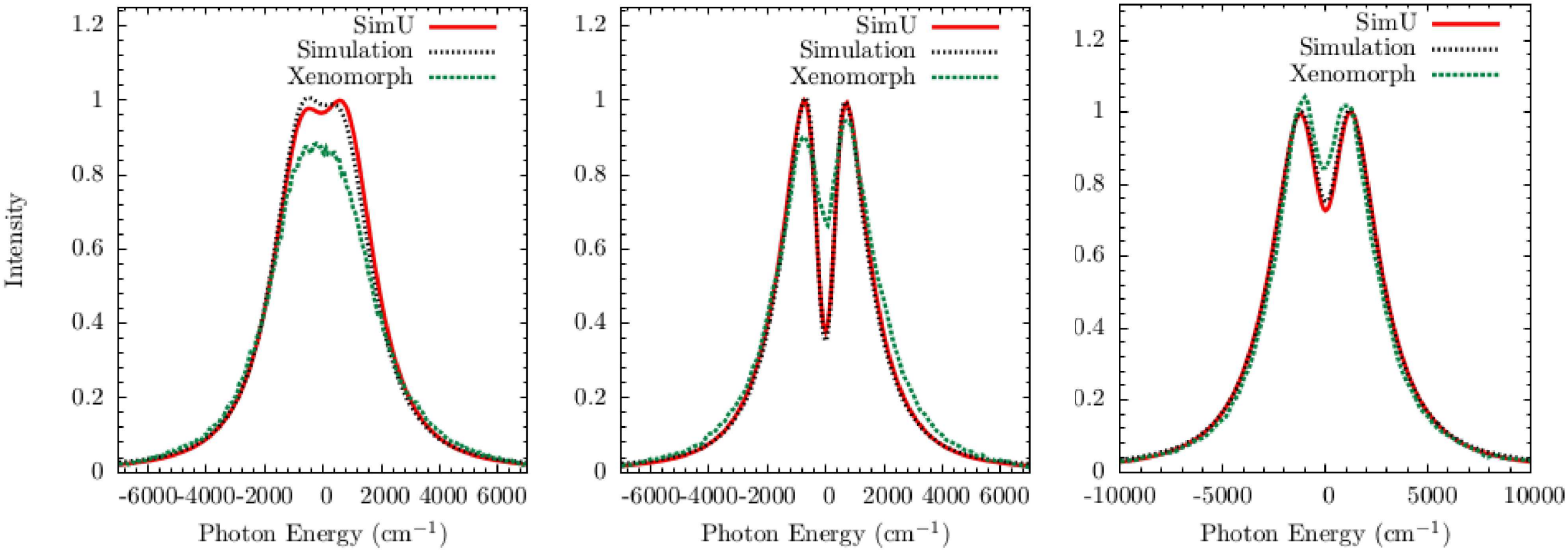
SimU vs Simulation vs Xenomorph

With Quadrupole Corrections (No Quenching)

$n_e = 10^{18}$ $T_e = 1eV$



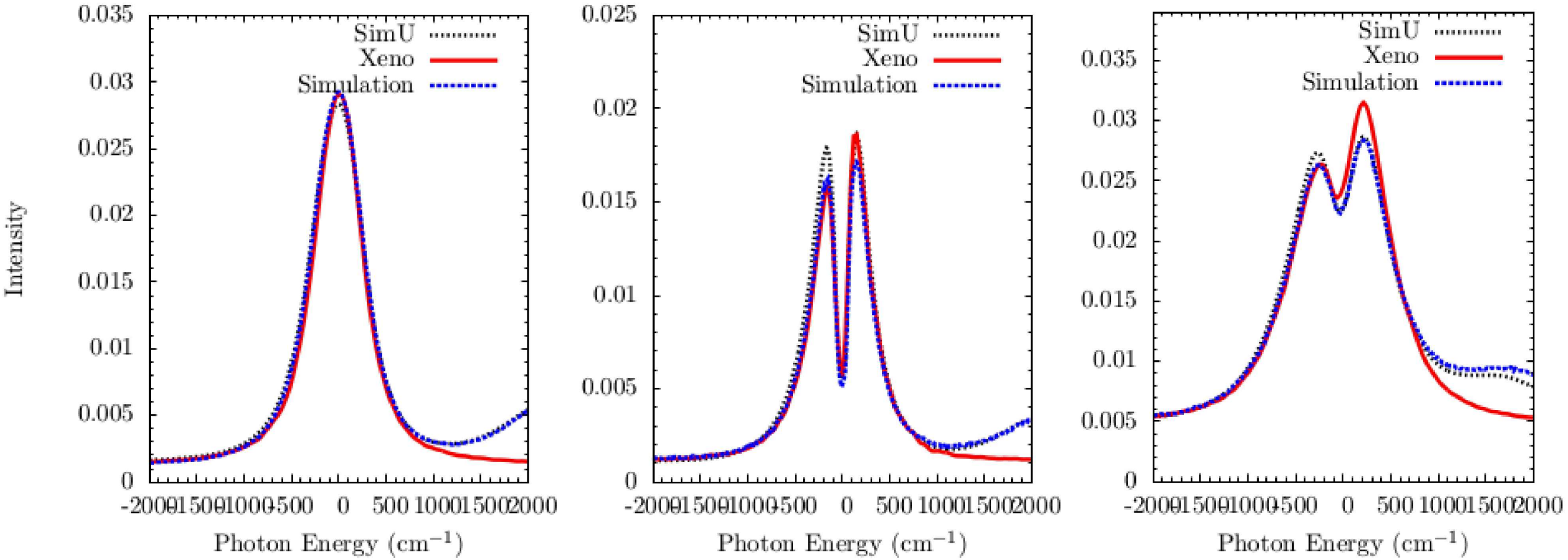
$n_e = 10^{19}$ $T_e = 1eV$



SimU vs Simulation vs Xenomorph

Dipole Only Interactions (With Neighboring States)

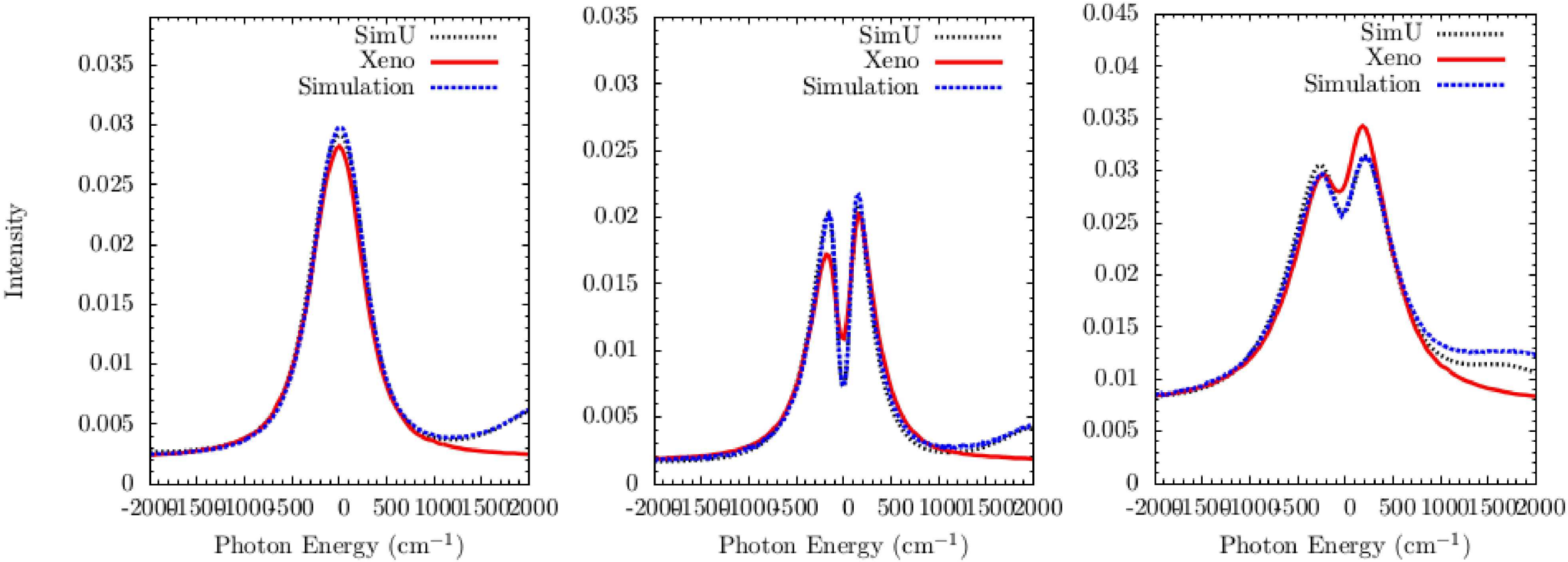
$n_e = 10^{18}$ $T_e = 1eV$



SimU vs Simulation vs Xenomorph

With Quadrupole Interactions (With Neighboring States)

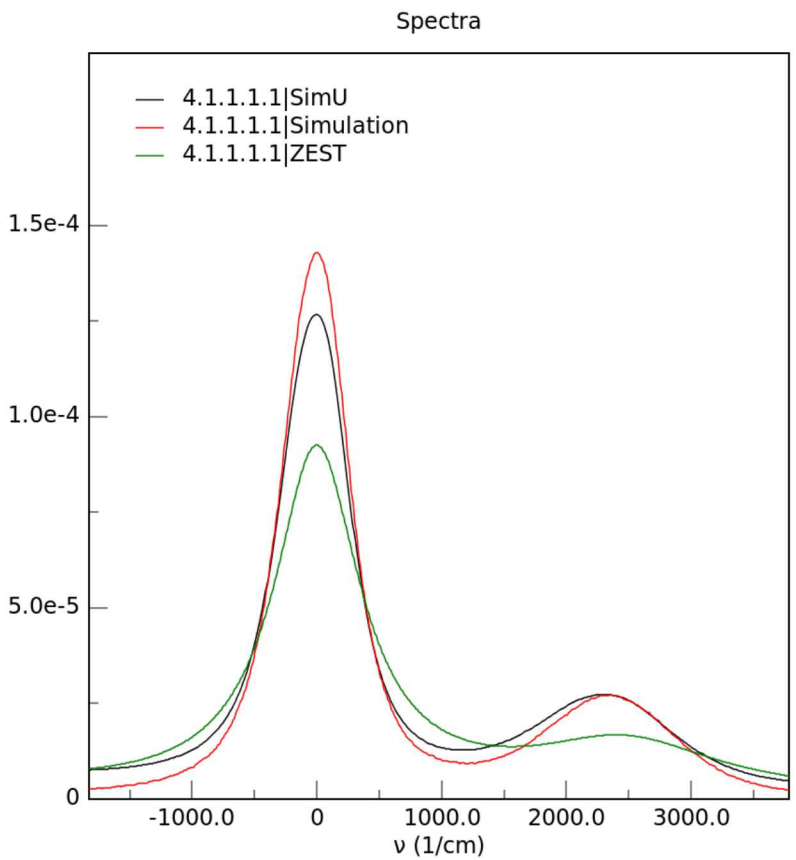
$n_e = 10^{18}$ $T_e = 1eV$

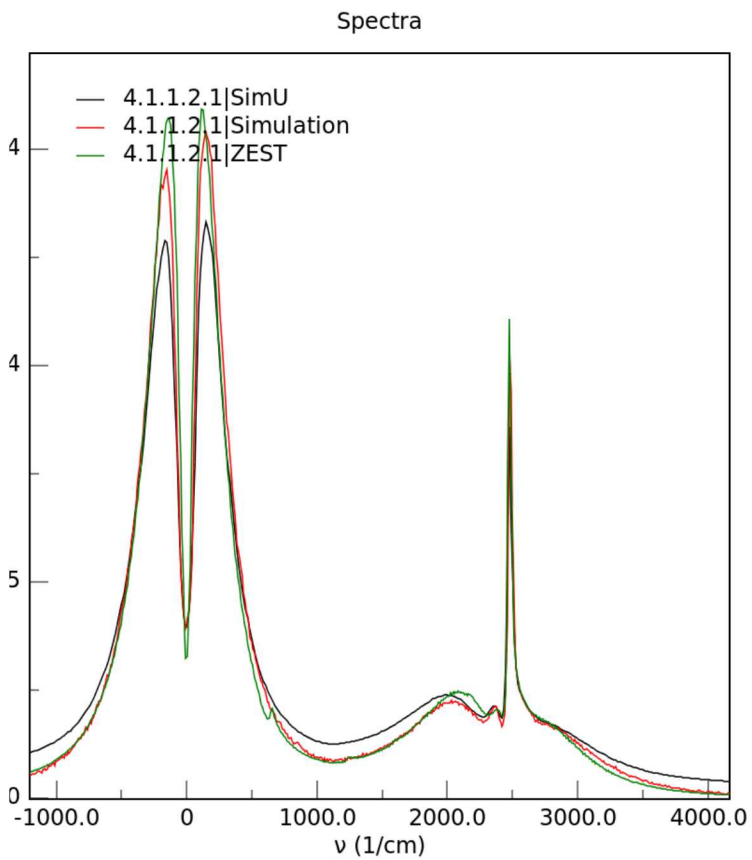


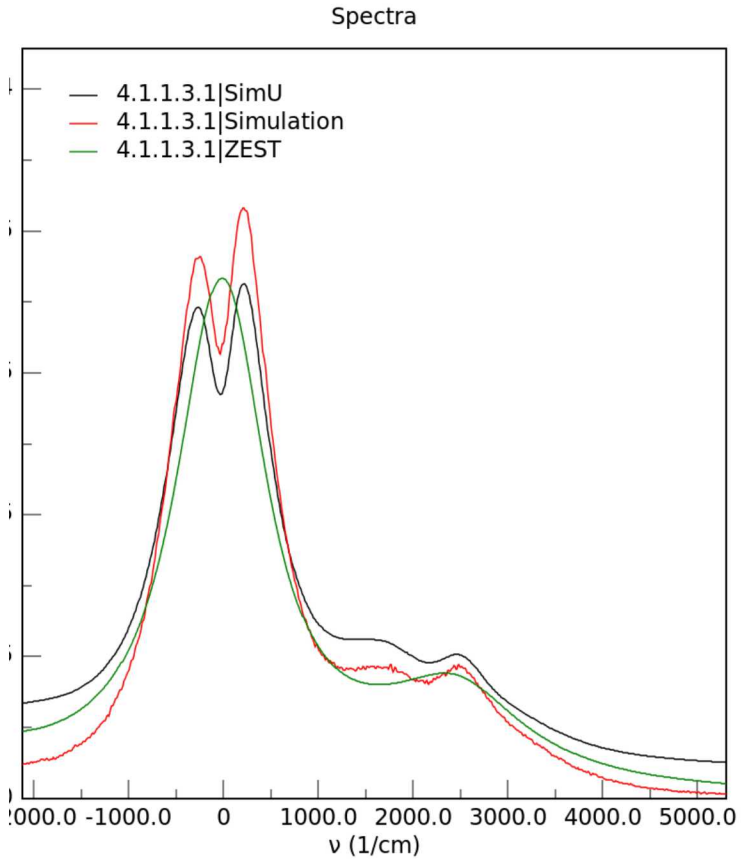
SimU vs Simulation vs ZEST

With Dipole Only (With Neighboring States)

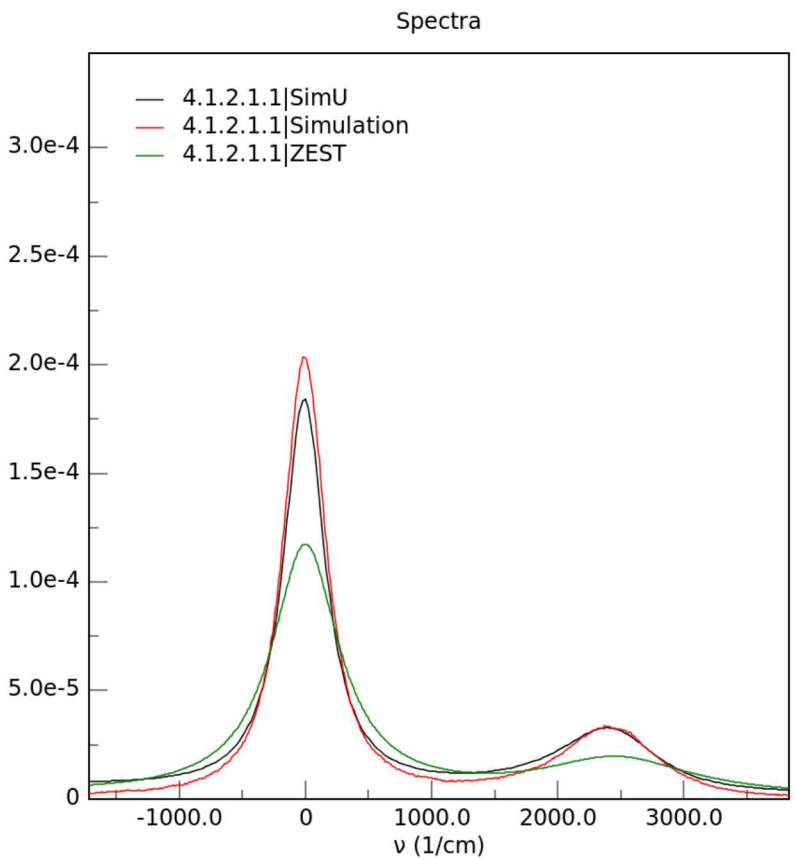
$n_e = 10^{18}$ $T_e = 1eV$

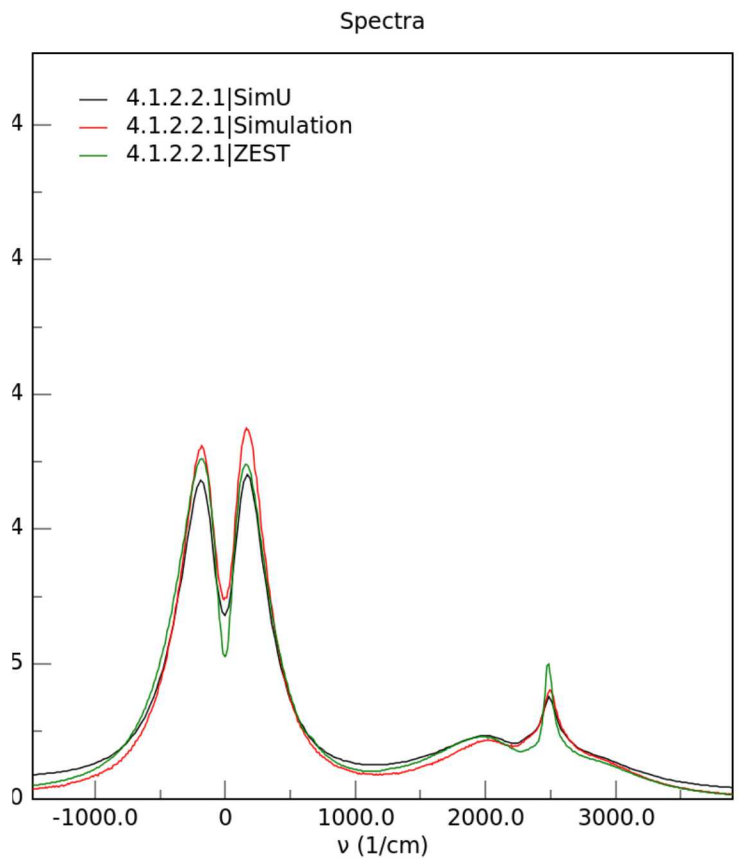


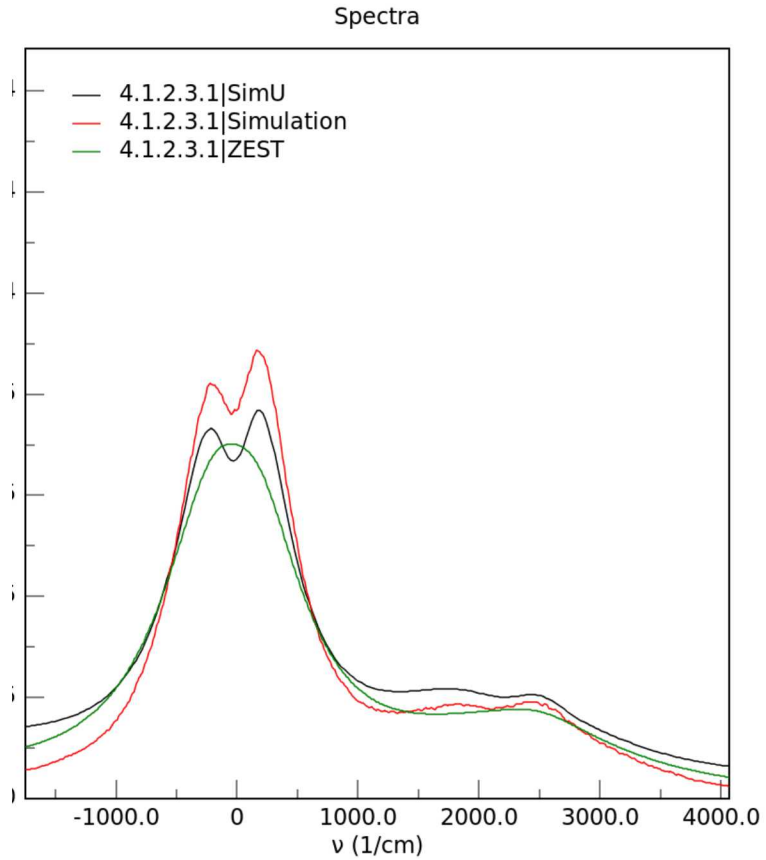




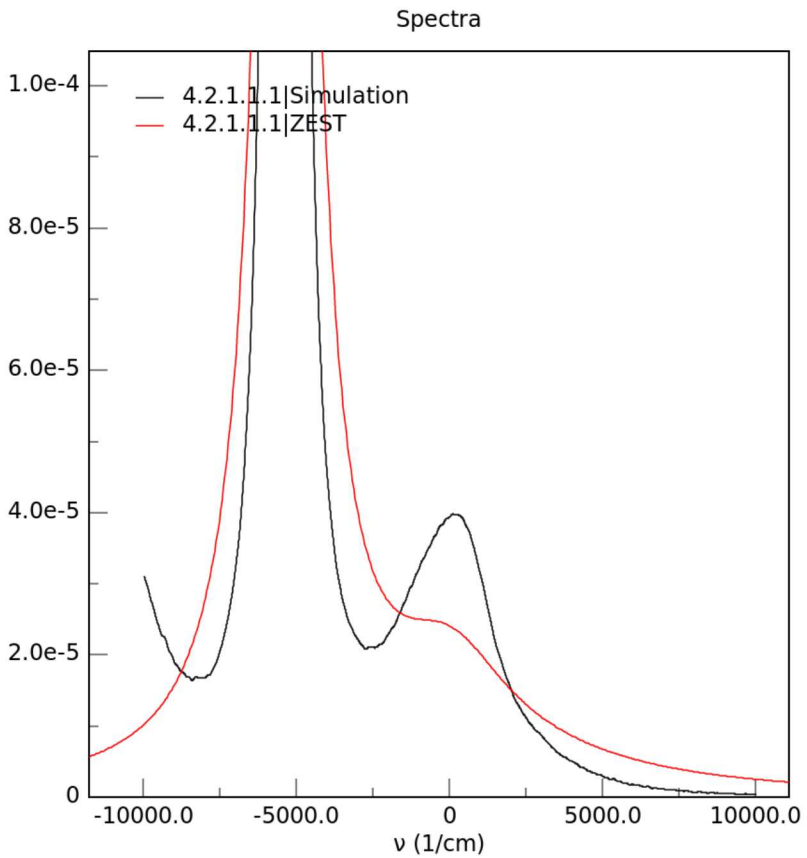
$n_e = 10^{18}$ $T_e = 10eV$

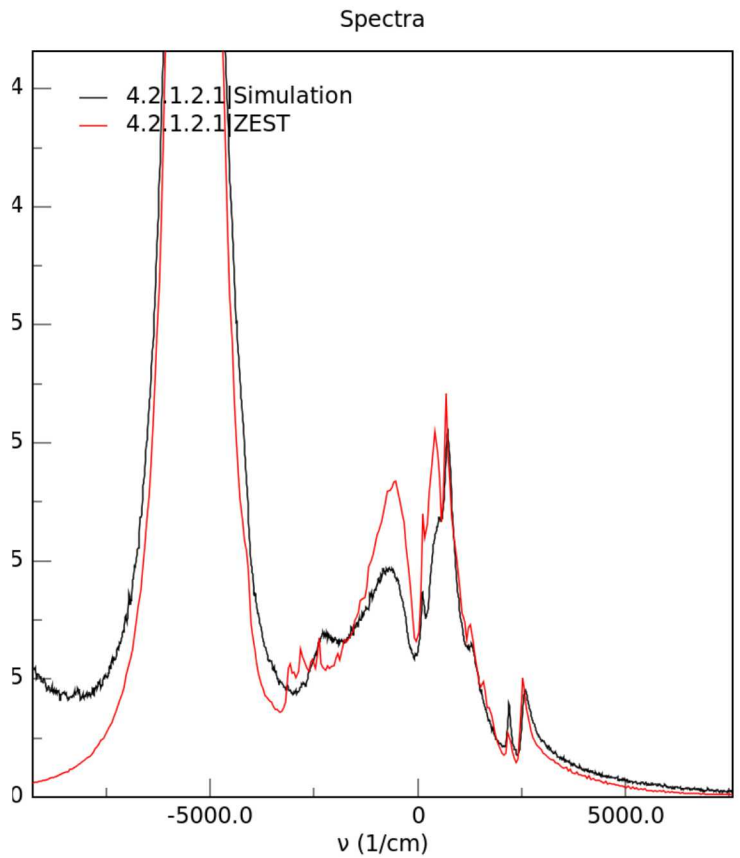






$n_e = 10^{19}$ $T_e = 1eV$





$n_e = 10^{18}$ $T_e = 10eV$