Errata

Erratum to "InGaN Quantum Dot Superlattices as Ratchet Band Solar Cells"

Luc Robichaud and Jacob J. Krich

After publication of the original article [4], we found a unit-conversion error in the calculations of absorption cross sections. None of the equations in the original article are incorrect, but our numerical implementation of the dipole matrix elements of (2) made their calculated values too large by a factor of 25.6. The absorption cross sections σ depend on the matrix element squared, so they are all overstated by a factor of 656. The corrected Fig. 4 is changed only in the vertical-axis labels.

The absorptivity α is proportional to σ, and α enters the absorptance a only when multiplied by the number of layers of quantum dots, N_{L}, as given in (9). Therefore, all results from the original manuscript can be considered to be correct if the values of N_{L} are multiplied by 656. For example, the base case of $N_{\mathrm{L}} = 200$ becomes $N_{\mathrm{L}} = 1.3 \times 10^5$. Figs. 7 and 10 are then relabeled to represent the appropriate number of layers, with the changes being only in the labeling and not in the curves. This rescaling of the number of layers can be applied in the following places in the original manuscript.

1) Section I, fourth paragraph, which stated "...construct absorptances of systems with 1–200 QD layers..."
2) Section III, first paragraph following (9), which stated "We begin by considering a strongly absorbing system with 200 layers of QDs. . ."
3) Section IV, before last paragraph, which stated "The above efficiency analyses included 200 dot layers to enable..."
4) Section IV, before last paragraph, which stated "In the case of the EO system, we can decrease the number of layers down to 50–100 and only lose..."
5) Section IV, last paragraph, which stated "However, in a standard p-i-n structure and 200 layers of dots..."
6) Section V, last paragraph, which stated "Absorptances were constructed from the cross sections systems of up to 200 layers of QDs..."
7) Fig. 5 caption, which stated "...calculated from the $\mathbf{k} \cdot \mathbf{p}$ model with 200 layers..."
8) Fig. 9 caption, which stated "Detailed balance efficiency as function of doping for the CR (blue) and EO (red) systems with 200 layers of dots. . ."

Fig. 11 shows a for the clear ratchet (CR) structure if one correctly used $N_L = 200$, rather than Fig. 5, which is valid only for $N_L = 1.3 \times 10^5$. The CI absorption in this structure is low, which in turn leads to a small detailed balance power conversion efficiency of 6%.

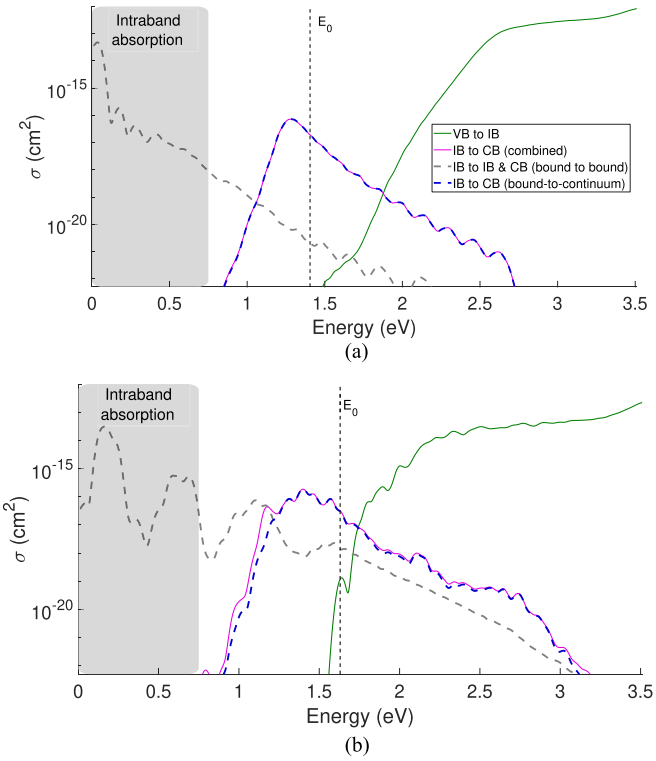

Fig. 4. Absorption cross sections calculated using the bound-to-bound, bound-to-continuum, and combined approaches for (a) CR system and (b) EO system. In the CR system, the combined result for σ_{CI} overlaps with the bound-to-continuum result. Regions in gray represent intraband absorption that do not contribute to current generation. Vertical-dashed lines show E_0 as defined in Fig. 2. Fermi level is fixed such that there are 4.9 electrons in each QD for the CR system and 6.1 for the EO.

Following this correction, the structures proposed in the original article still have a ratchet band but can achieve high efficiency only with N_L too large to be practical. The structures are easily modified to restore high efficiency and retain the original conclusions. We consider a new ratchet system where we have kept the 125-Å dot height to maintain the spatial ratchet but increased the indium fraction to 59%, radius to 100 Å, and increased the doping to $2 \times 10^{19}\mathrm{cm}^{-3}$, which populates each QD with 400 electrons at 300 K, to increase the CI absorption. Heavier n-type doping than this has been achieved in InGaN/GaN systems [1]–[3]. Fig. 12 shows the electronic structure of this new system, where the wavefunction of the 400th electron is the solid red line, showing the preservation of the ratchet. Fig. 13 shows the absorptances of this system with $N_L = 200$, leading to a detailed balance efficiency of 33%.

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The authors are with the University of Ottawa, Ottawa, ON K1N 7N9, Canada (e-mail: lrobi019@uottawa.ca; jkrich@uottawa.ca).

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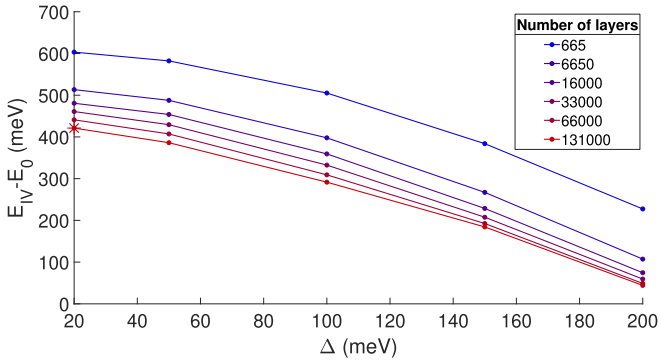

Fig. 7. IV transition energy threshold E_{IV} relative to E_0 as function of linewidth broadening Δ for the CR system. Different curves are for varying number of layers of QDs. Star marker indicates the default parameters of Δ=20 meV and N_{L}=131 000 used unless otherwise specified. EO system has no spatial ratchet, as determined from Fig. 6, and is therefore not shown. Temperature is 300 K and the Fermi level is such that there is 4.9 electrons per QD.

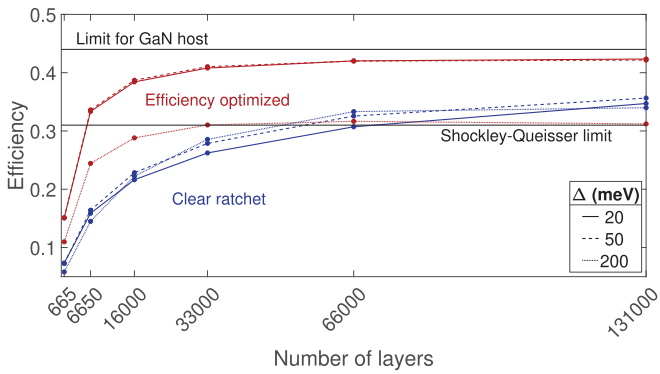

Fig. 10. Detailed balance efficiency of the CR (blue) and EO (red) systems for varying number of QD layers and linewidth broadening Δ. Thin black lines are the Shockley–Queisser limit and the efficiency limit for a RBSC with a GaN host material and perfect nonoverlapping absorptions under a 1-sun 6000-K black-body spectrum. Temperature is 300 K and Fermi level is fixed such that the CR system contains 4.9 electrons per QD and 6.1 for the EO.

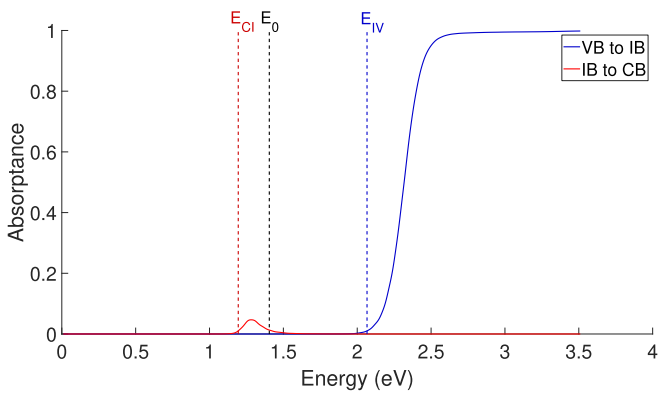

Fig. 11. Absorptances of the originally proposed CR system with 200 layers after correcting the absorption cross sections. Detailed balance efficiency is found to be 6%.

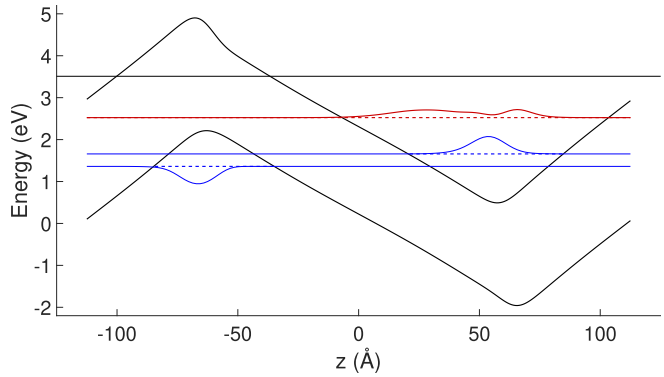

Fig. 12. Electronic structure of the new CR system with 400 electrons per QD at 300 K. Blue-dashed lines are the energy levels of the lowest electron and hole states, and the solid blue lines are their wavefunctions. Red lines indicate the energy level (dashed) and wavefunction (solid) of the 400th electronic state. The electron wavefunction is still well-isolated from the highest hole state, meaning the spatial ratchet is preserved.

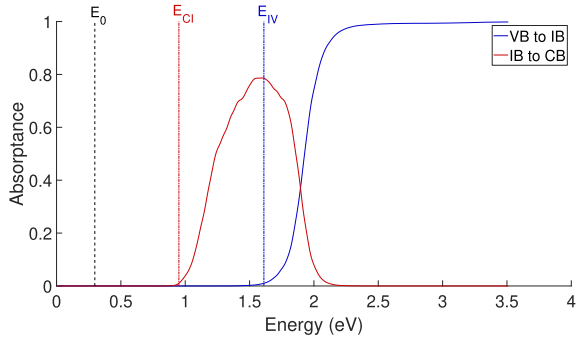

Fig. 13. Absorptances of the new CR system with $N_{\mathrm{L}} = 200$ and 400 electrons per QD. This increased doping restores the CI absorption. The modified QD radius and indium fraction gives good solar spectrum matching, leading to a detailed balance efficiency of 33%.

We conclude that InGaN quantum dots in GaN still have potential to realize ratchet band solar cells with high efficiency attainable with a reasonable number of dot layers. The ratchet effect exists regardless of the number of layers. However, this correction shows that a higher doping of the dots than we originally suggested is preferable in order to achieve high efficiencies.

References

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[2] K. Kumakura *et al.*, "Minority carrier diffusion lengths in MOVPE-grown n- and p-InGaN and performance of AlGaN/InGaN/GaN double heterojunction bipolar transistors," *J. Cryst. Growth*, vol. 298, pp. 787–790, 2007.

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