Effects of nanowire geometry on light extraction efficiency in nanowire deep-ultraviolet LEDs

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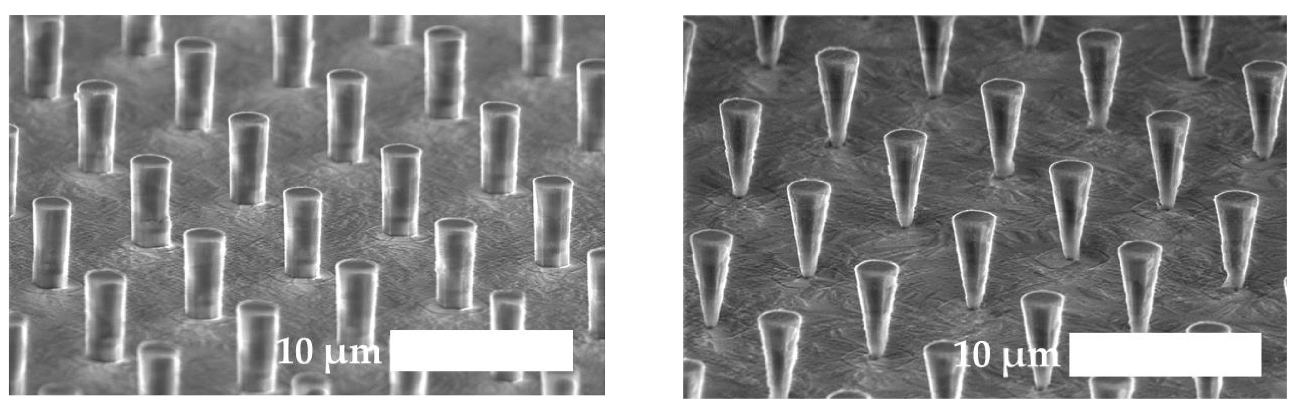
Background and Motivations

Light emitting diodes (LEDs) emitting in the deep ultraviolet range (DUV) (< 280 nm) show great potential for use many applications, ranging from water purification and surface sterilization to microfabrication, resin curing, and communication.[1,2] While DUV LEDs outperform conventional mercury arc lamps in terms of durability, lifespan, switching speed, and many other factors, their poor external quantum efficiencies (EQEs) limit their practical uses.[1,2,3] Improving the EQEs of these devices has been the central focus of DUV LED research over the past several decades.

While extensive research funding has been devoted to improving the efficiencies of visible light LEDs, less effort has been devoted to DUV LEDs. Limited existing research on surface roughening, substrate patterning, microlens arrays, surface nanostructuring, and other methods shows promise for improving the EQEs of these devices.[3] In this work we explore additional the effects of sidewall angle, height, and diameter on light extraction efficiency (LEE).

1. H. Amano, *et al*, *J. Phys. D: Appl Phys.*, 53, 503001 (2020)
2. M. Knissl, *et al*, *Semicond. Sci. Technol.*, 26, 014036 (2011)
3. T. Takano, *et al*, *Appl. Phys. Express*, 10, 031002 (2017)



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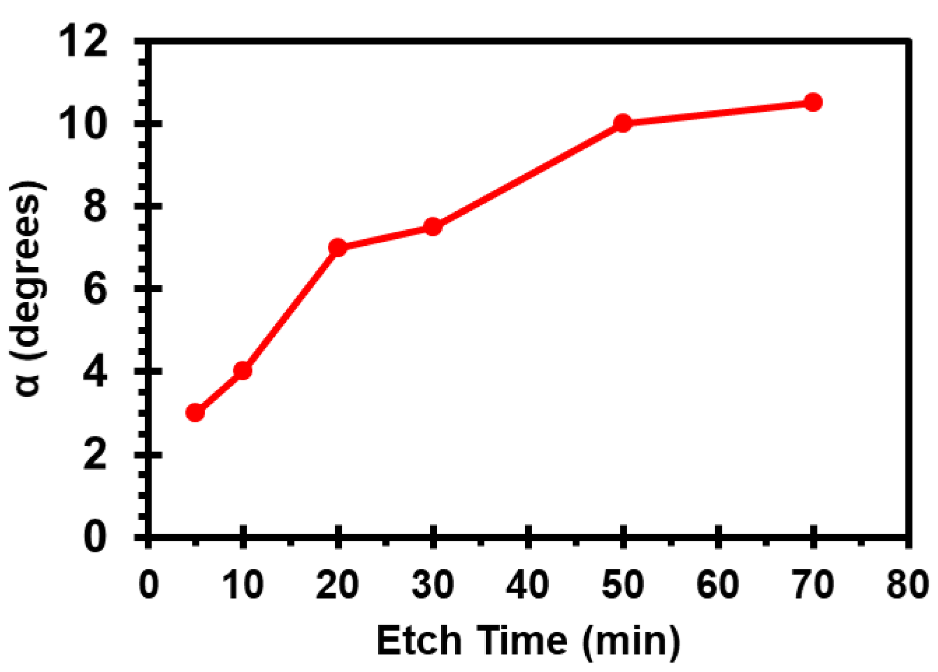
- **Developed wet etch process to form inverse taper in AlGaN based nanowires**
- **Control sidewall angle with etch duration**



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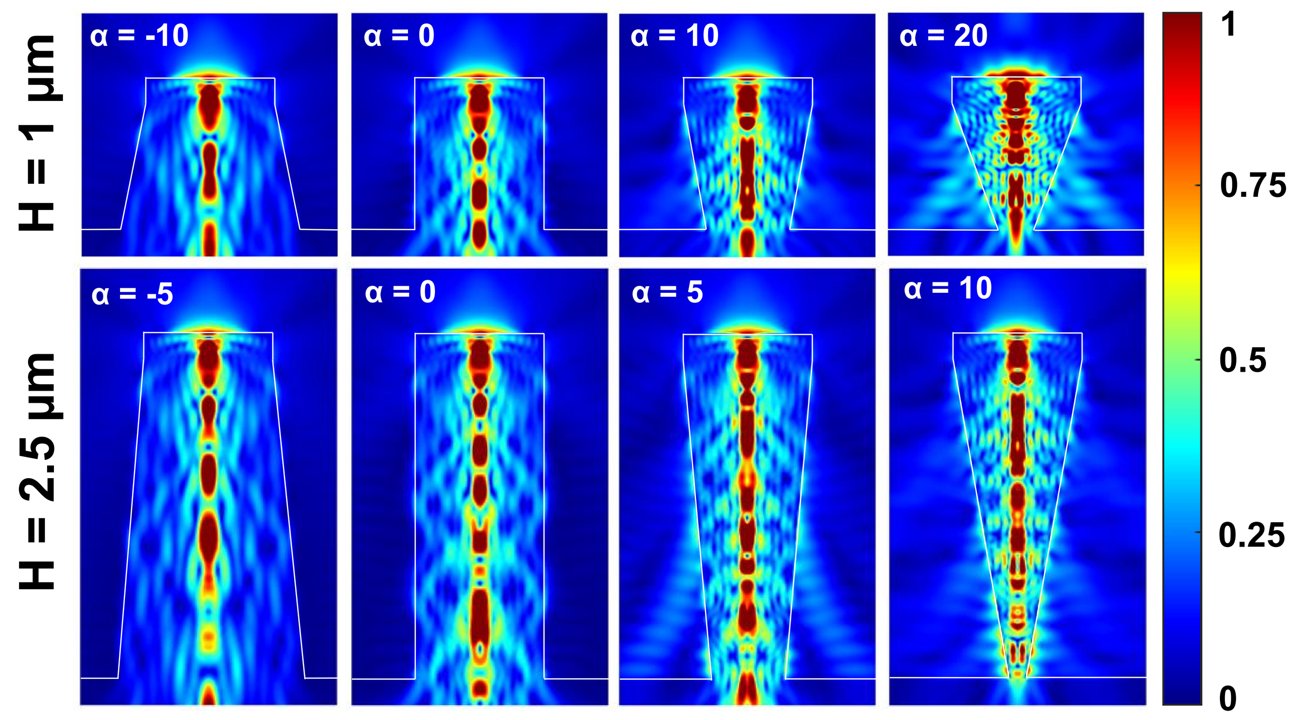

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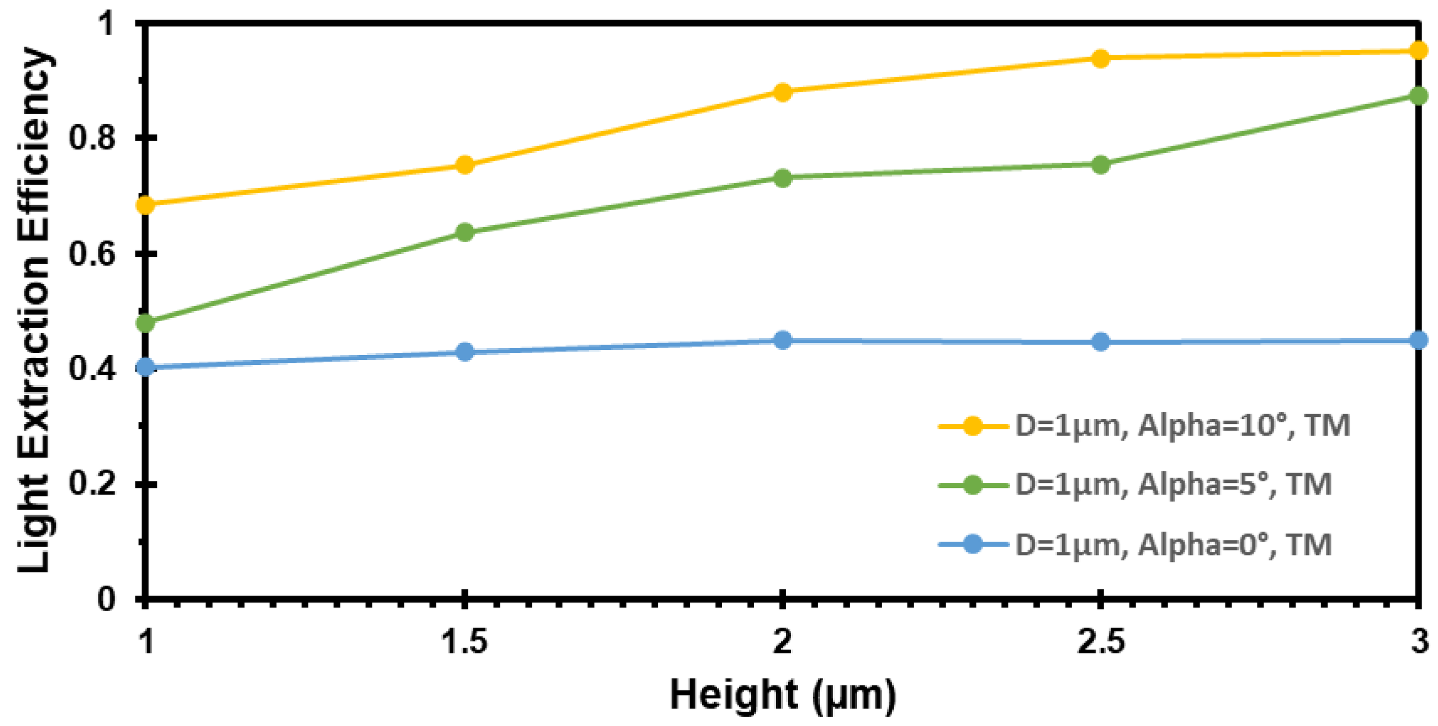
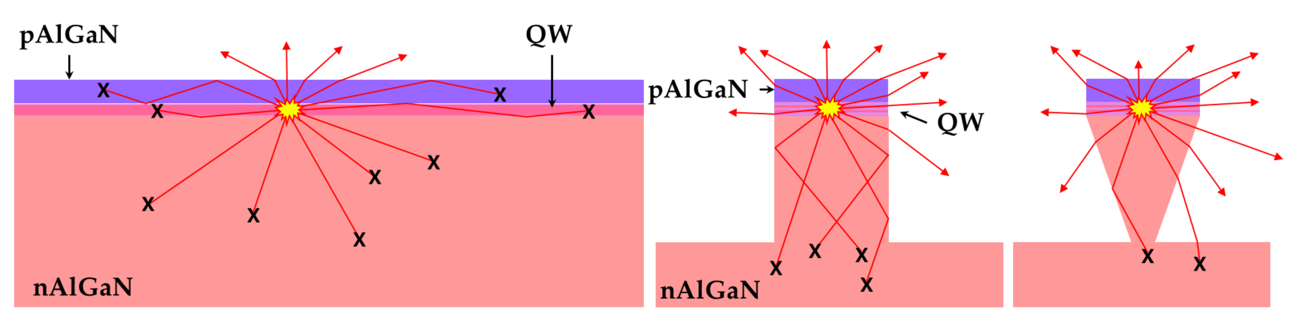
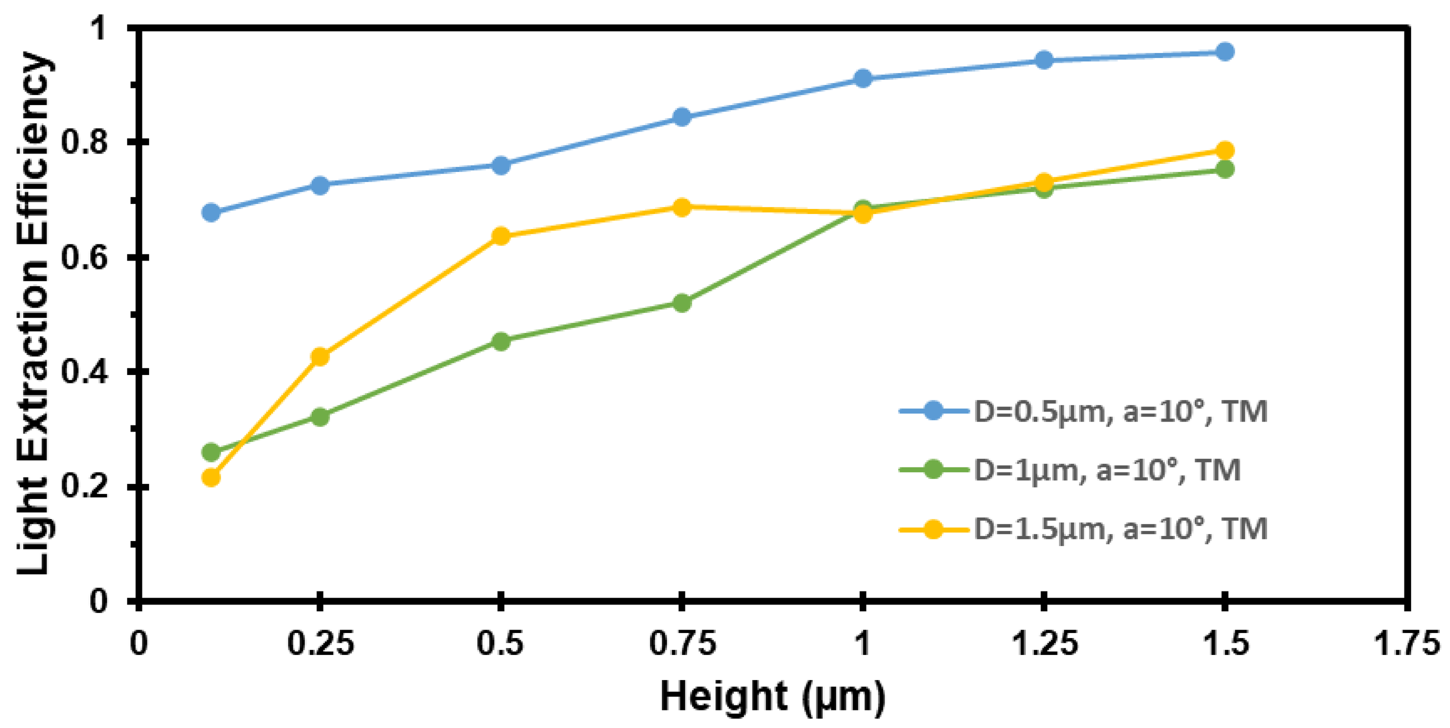
- **Electric field intensity illustrates improved LEE in tapered nanowires**



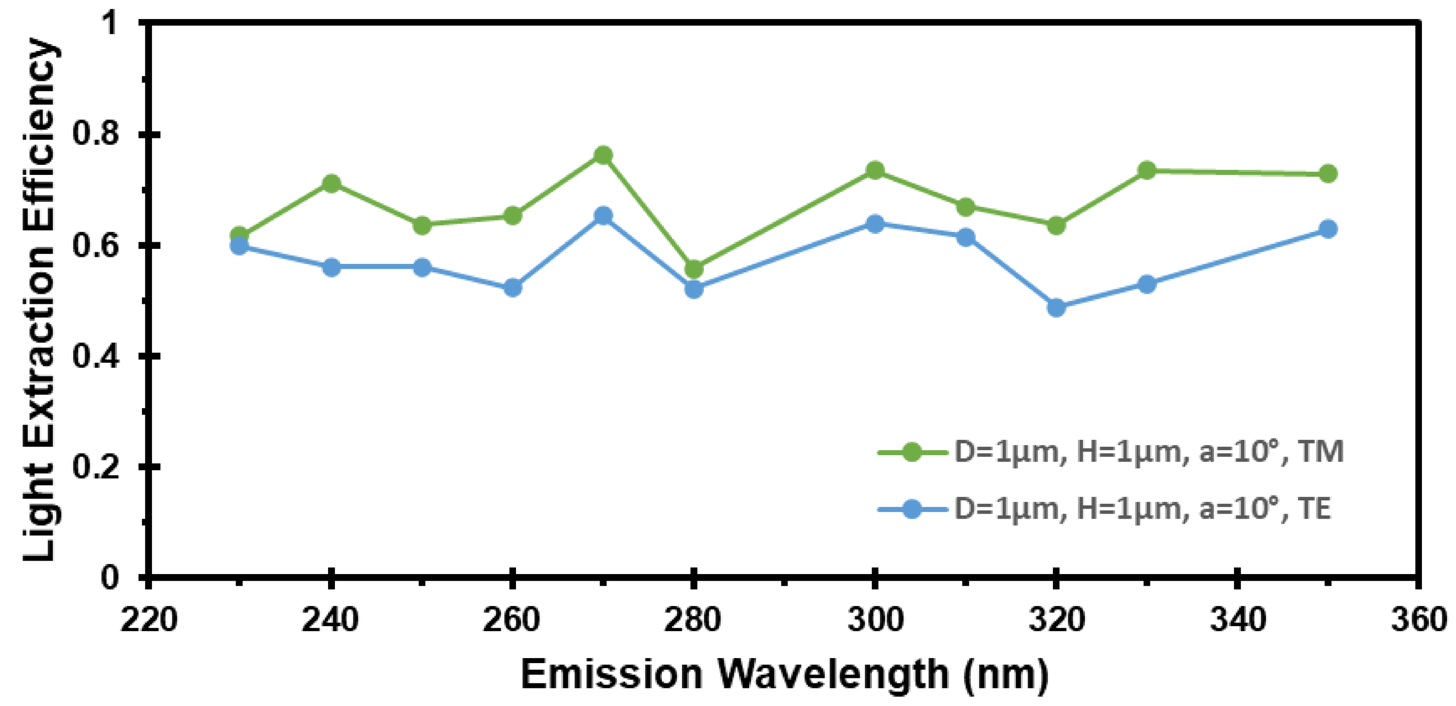
- **Small taper angles lead to significant improvement in LEE**



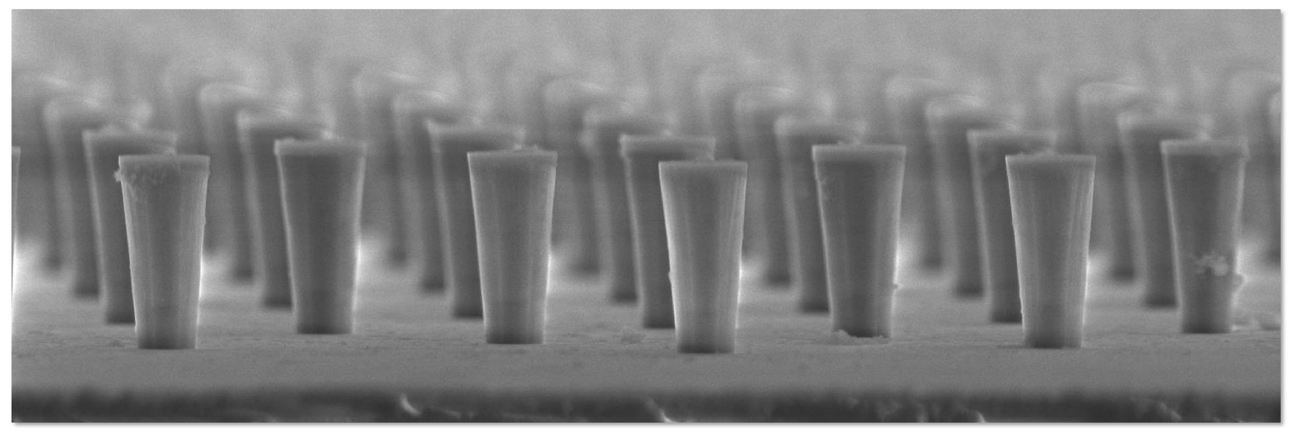
- **Mesa LED → internal absorption, poor LEE**
- **Nanowire LED → improved LEE**
- **Inverse taper LED → additional LEE improvement**



- **Increasing nanowire height increases LEE**



- **Simulations show no wavelength dependence on LEE**
- **Complex standing waves within nanowire**
- **Wavelength specific optimization required**



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Conclusions

- **Nanowires and micropillars with inverse taper exhibit higher extraction efficiency for both TE and TM polarized emission.**
- **Taller nanowires → Increased LEE**
- **Narrower nanowires → Increased LEE**
- **Tuning of taper angle, height, and diameter can allow for significant improvements in light extraction efficiency in nanowires and micropillars emitting in the DUV regime between 200 and 280 nm.**

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