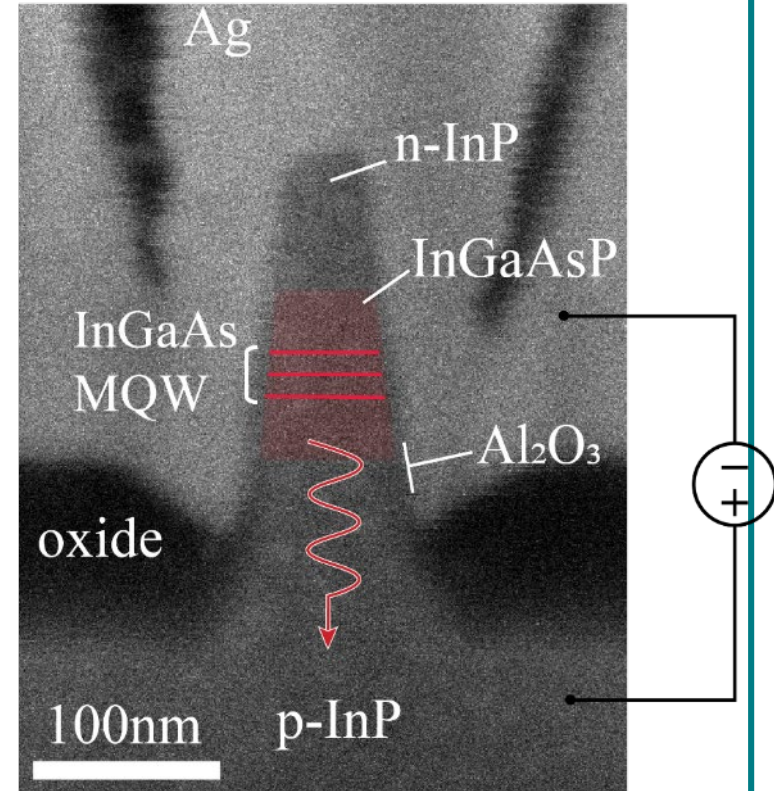
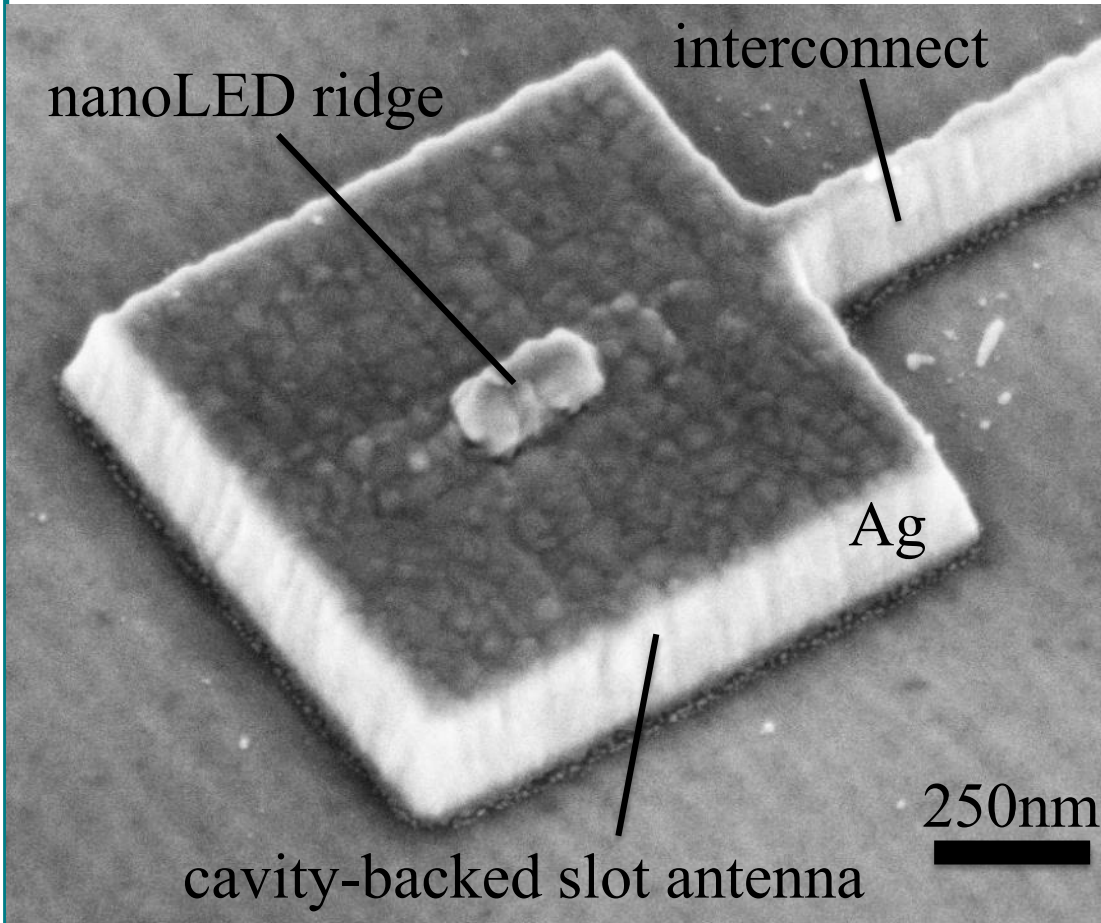


Progress on Antenna-Enhanced LEDs

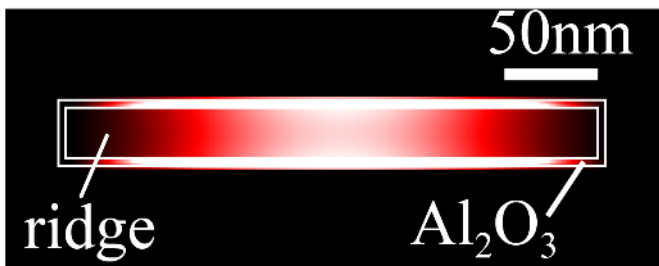
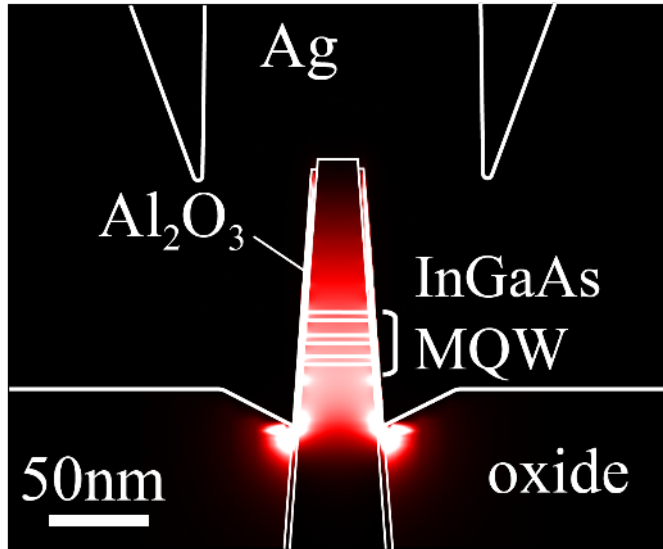
Seth A. Fortuna



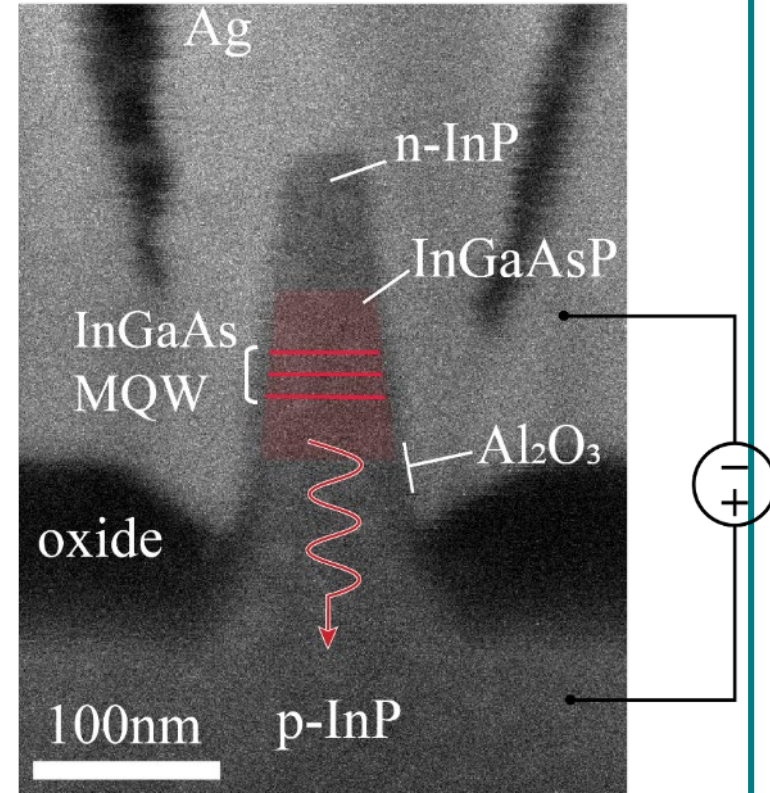
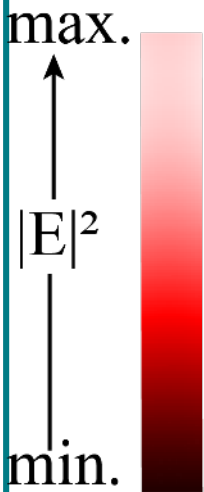
Electrically-injected III-V antenna-LED



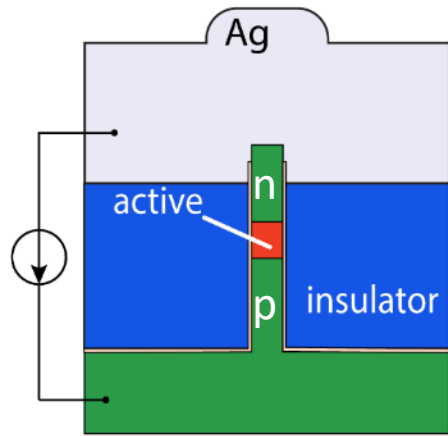
Electrically-injected III-V antenna-LED



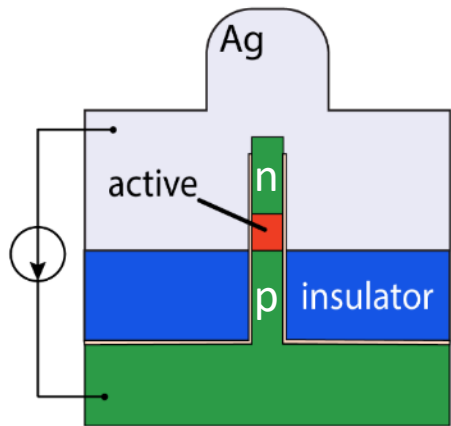
Top view



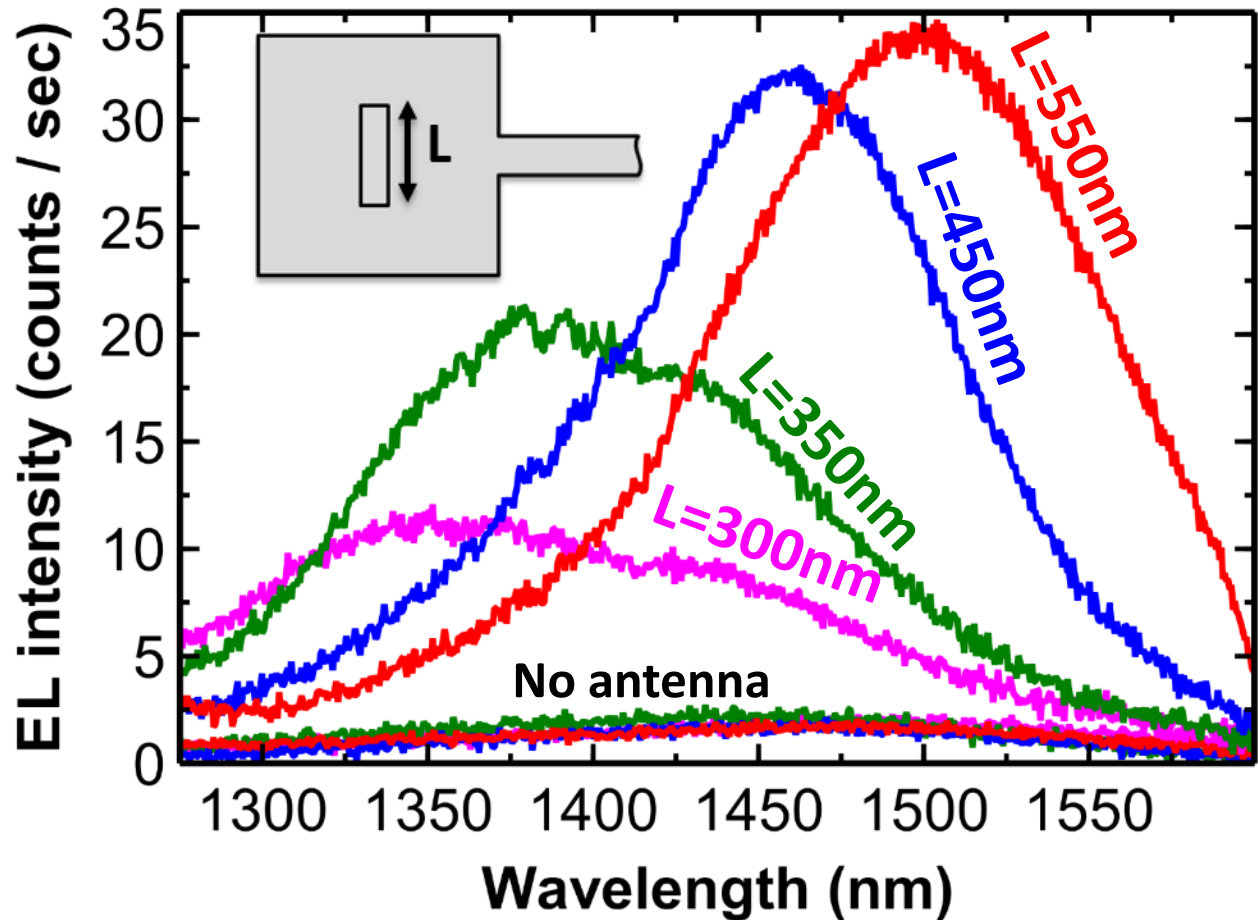
Antenna-enhanced electroluminescence



No antenna



Antenna-LED

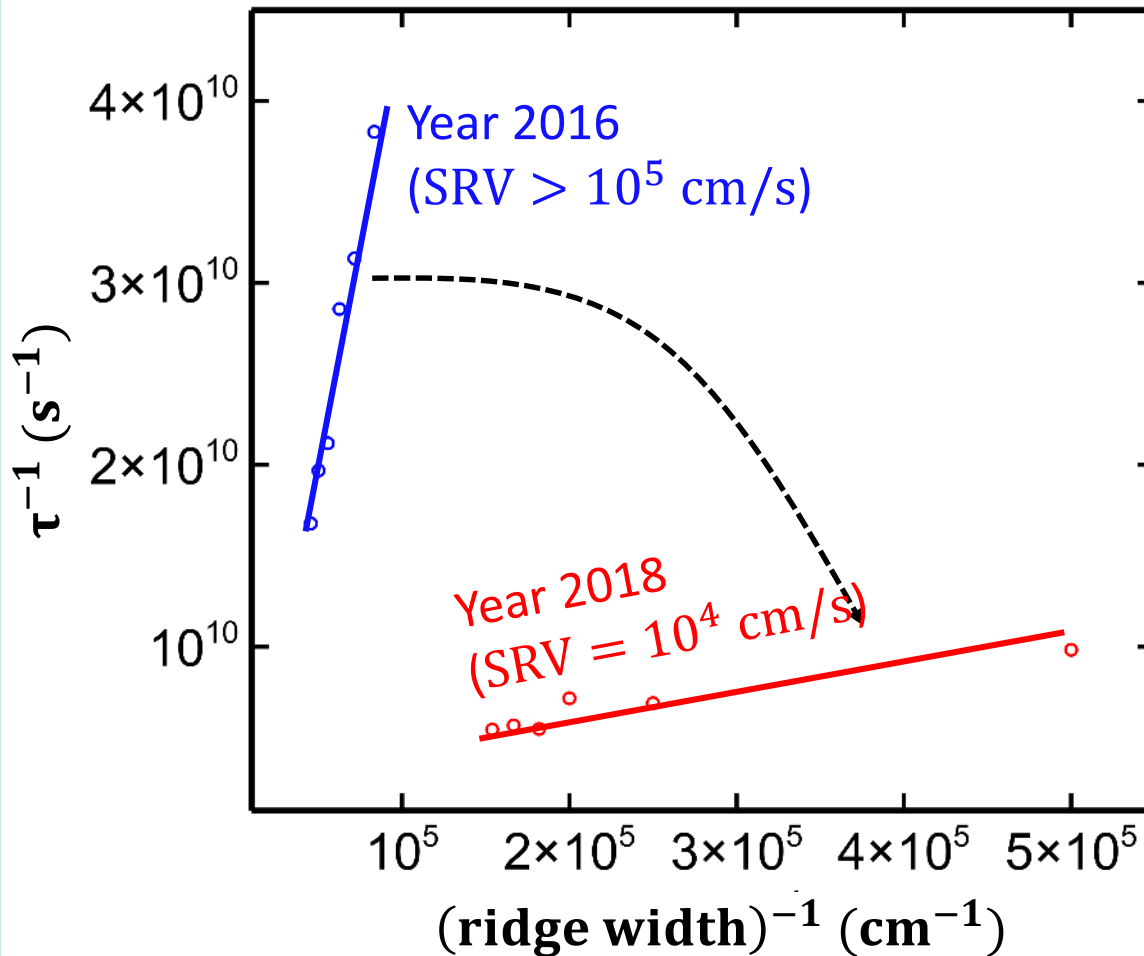


Fortuna et al. ISLC 2016



Controlling non-radiative recombination at surface

Photolumuminescence decay time vs ridge width

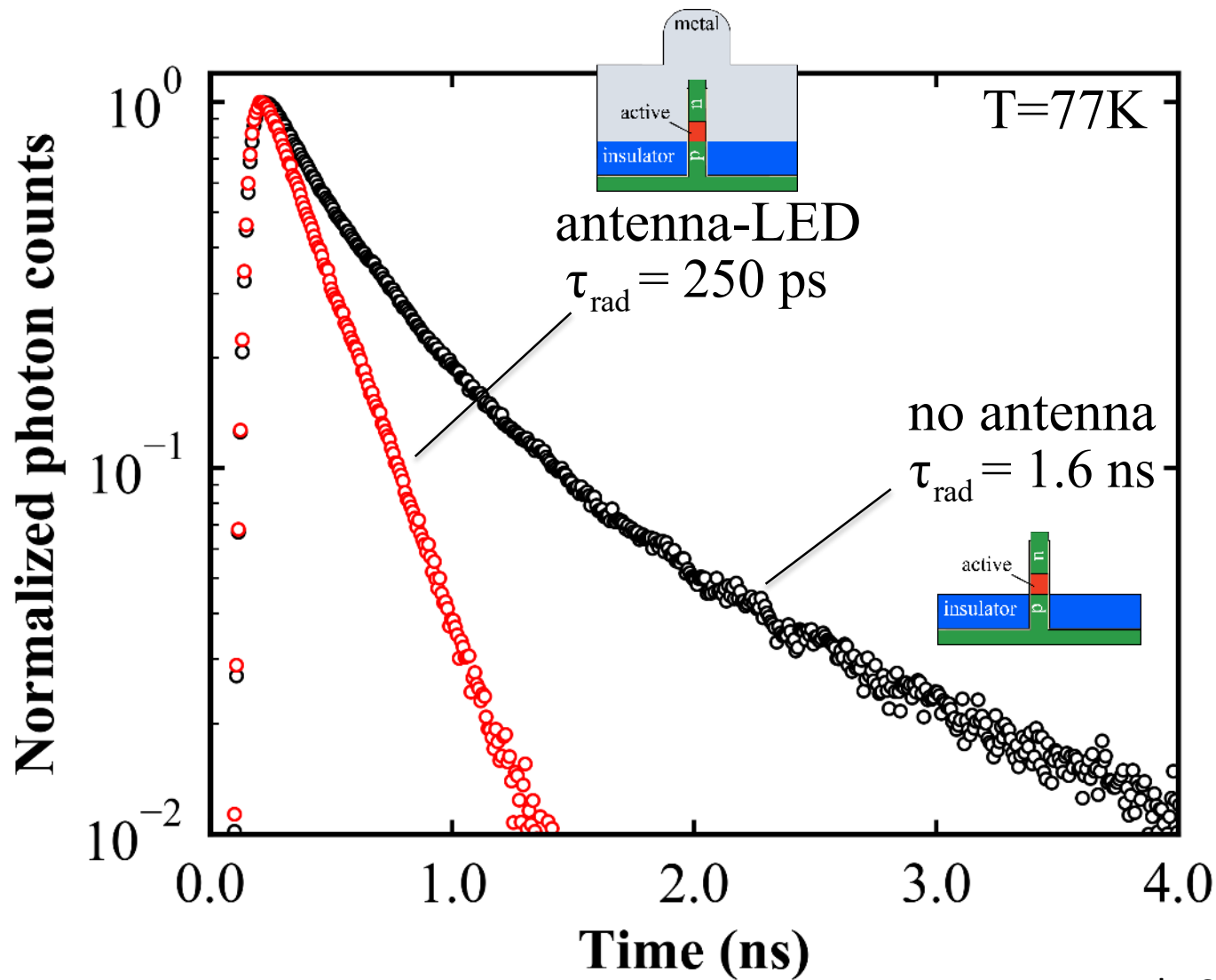


Key process steps:

- ① Post-etch surface clean:
Dilute TMAH followed by buffered HF leaves behind pristine surface.
- ② Surface protection:
“Thick” 15nm ALD-deposited Al₂O₃ protects active region surface.
- ③ Active region passivation
Ammonium sulfide treatment followed by low-temperature (150°C) Al₂O₃ ALD.



250 ps spontaneous emission lifetime

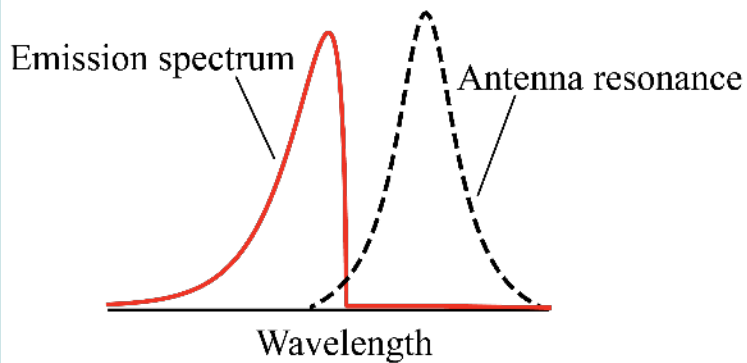


Fortuna et al. ISLC 2018

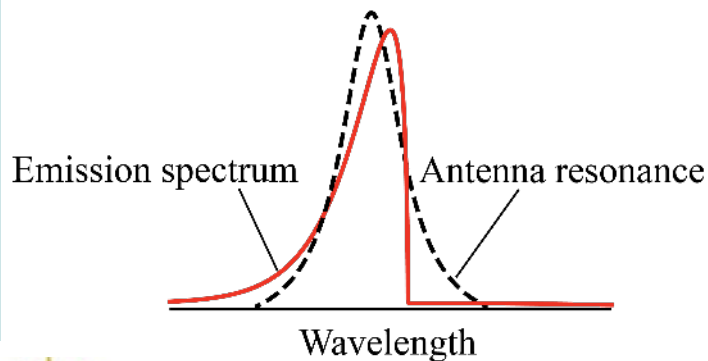


250 ps spontaneous emission lifetime

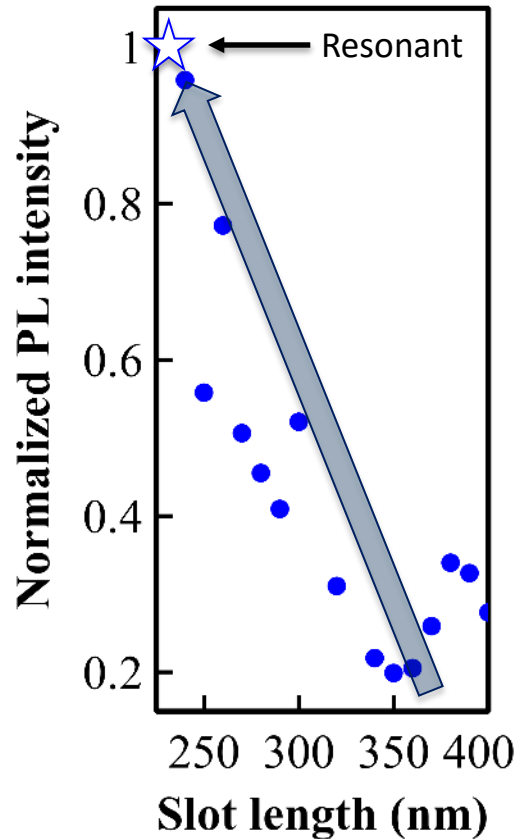
Detuned antenna
(Intensity \downarrow $\tau_{\text{rad}} \uparrow$)



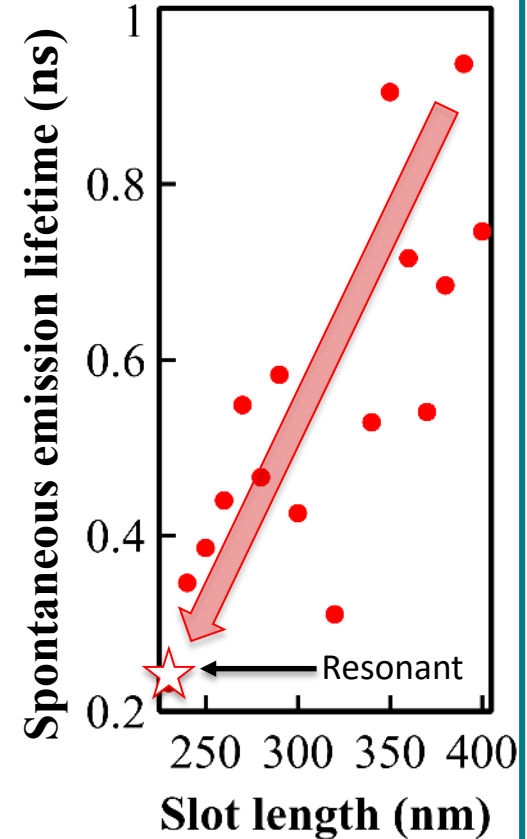
Resonant antenna
(Intensity \uparrow $\tau_{\text{rad}} \downarrow$)



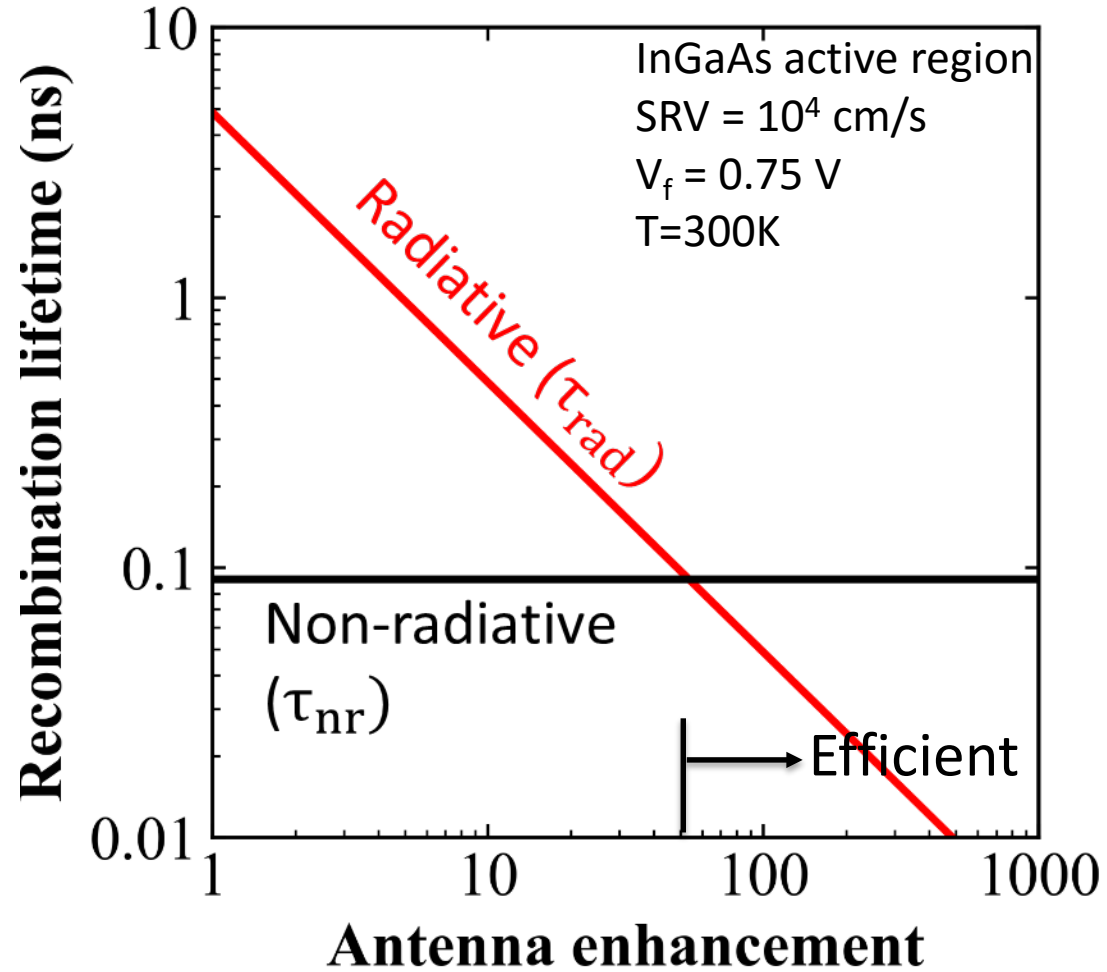
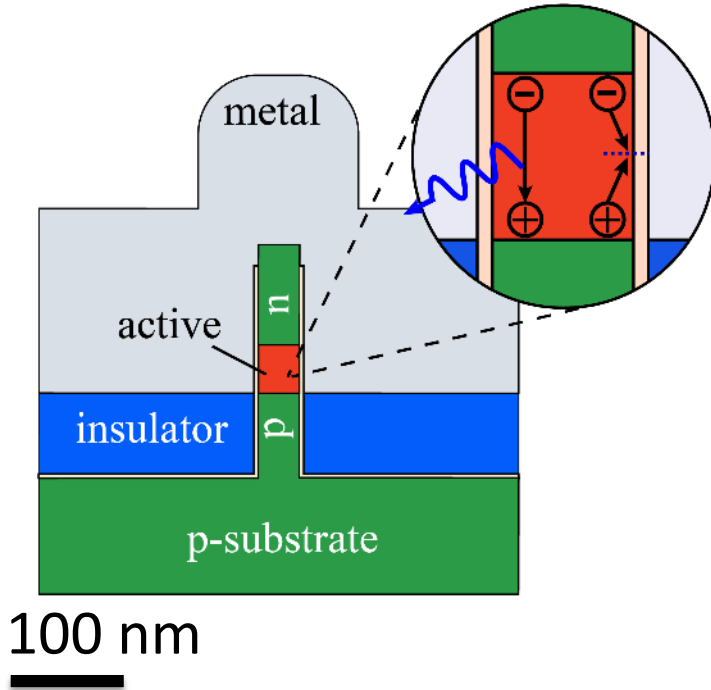
Photoluminescence



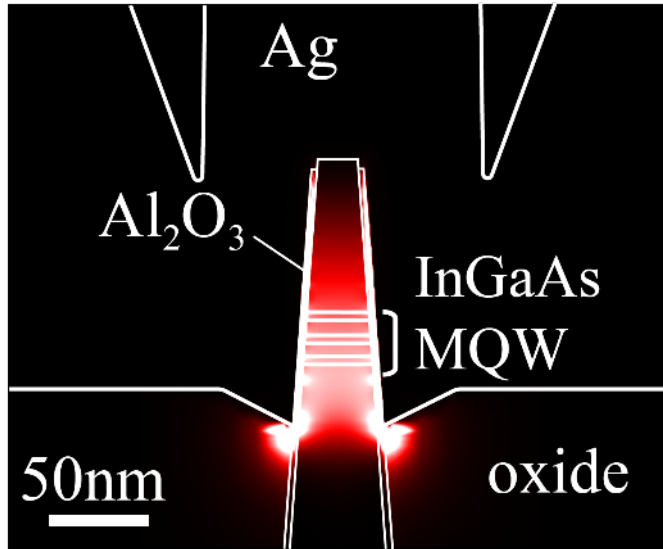
Sp. Em. lifetime



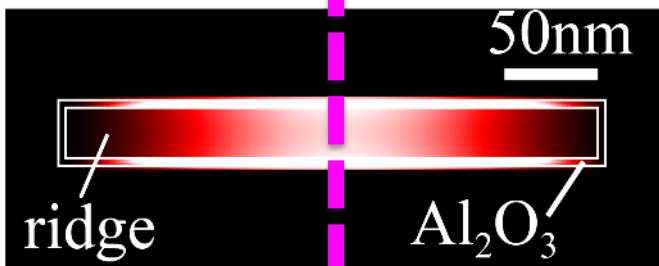
Toward high efficiency at room temp.



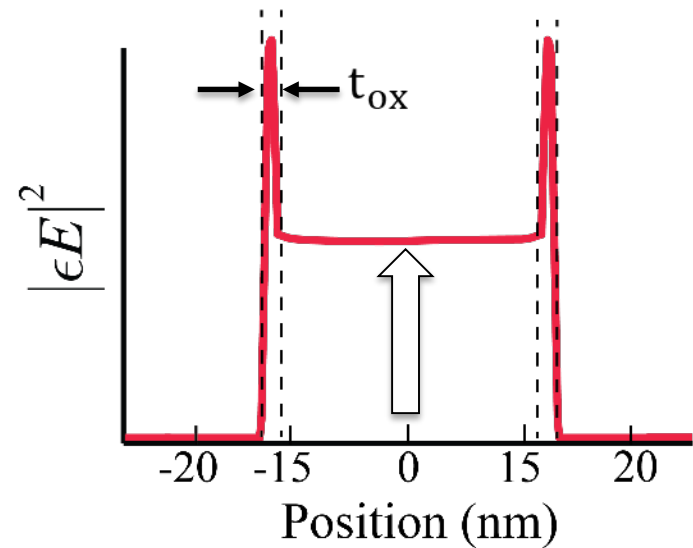
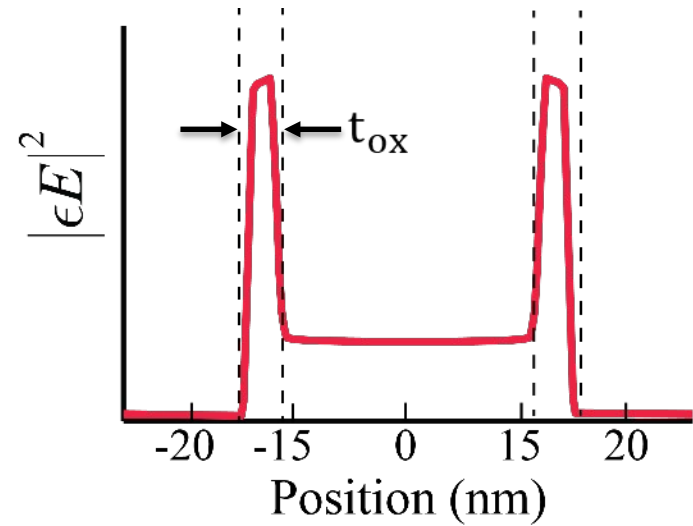
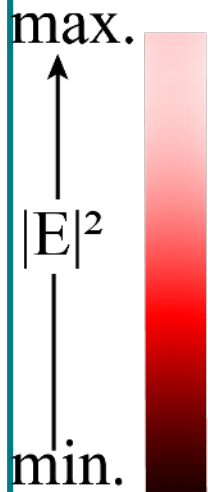
Reducing τ_{rad} with device scaling



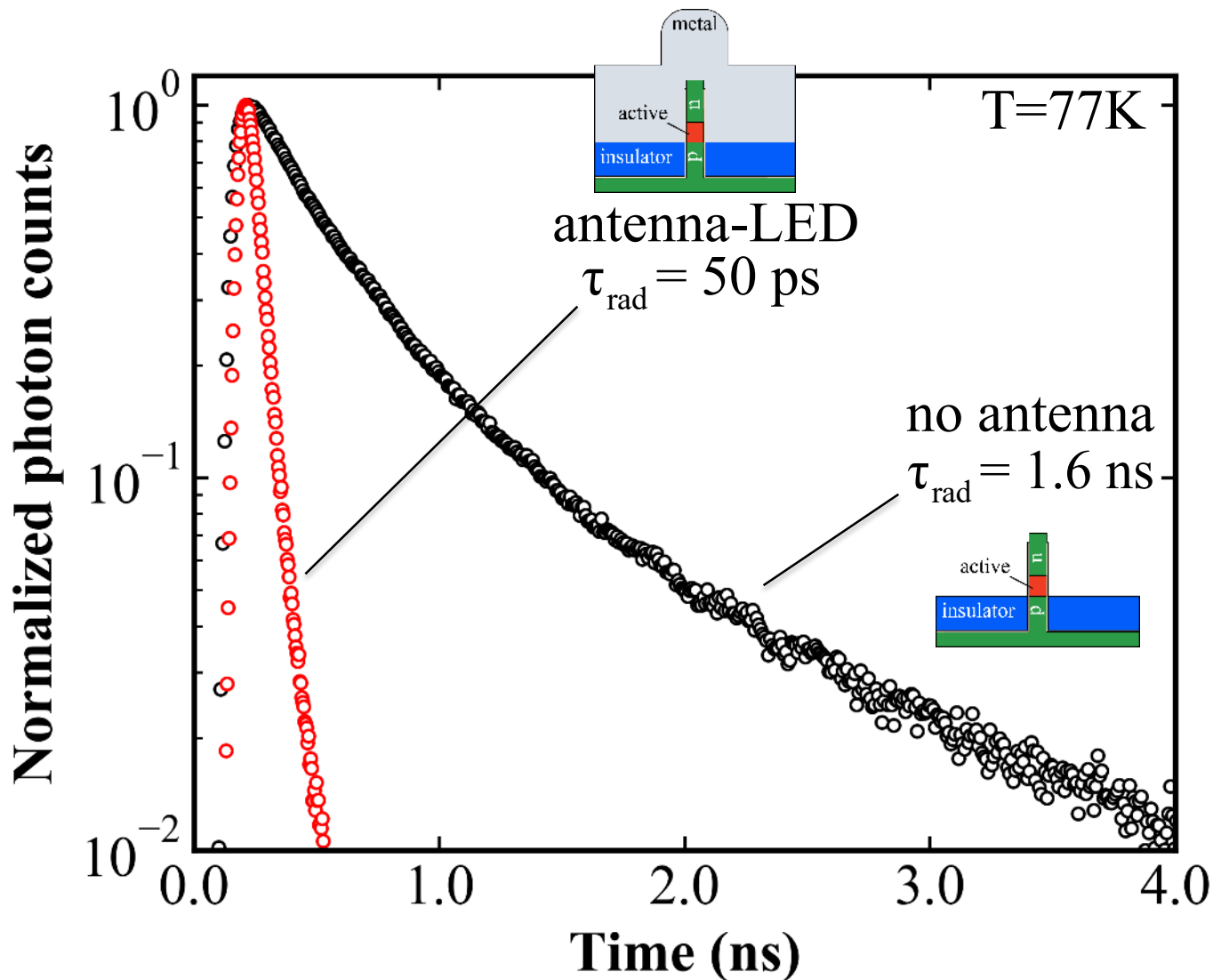
Side view



Top view

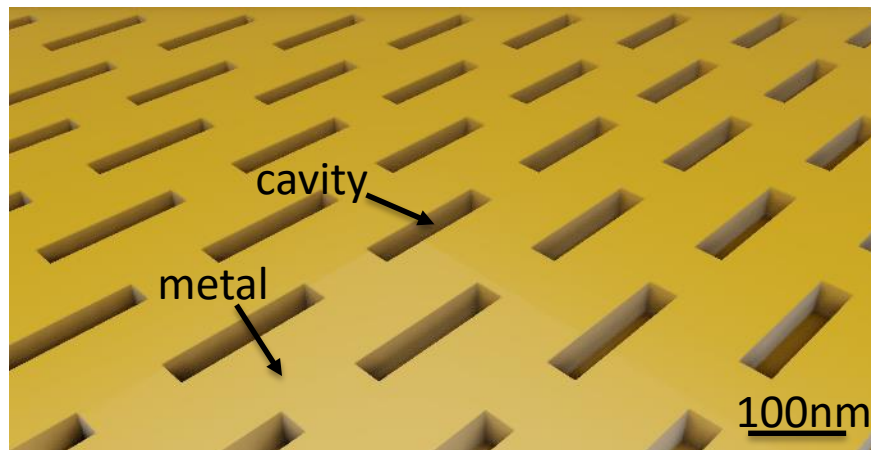


50 picosecond spontaneous emission lifetime

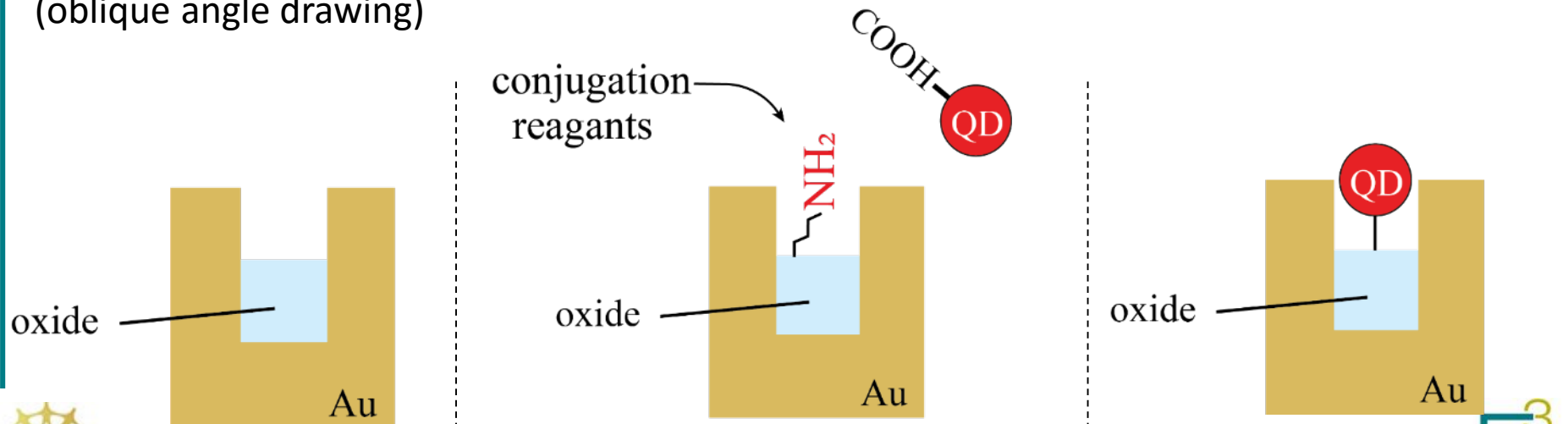
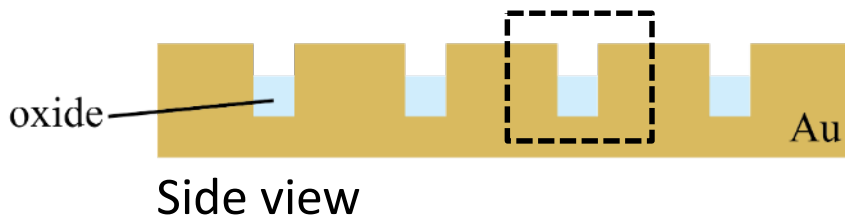


New device concept: quantum dot antenna LED

(collaboration with Michael Bartl)



Array of cavity-backed slot antennas
(oblique angle drawing)



11/1/2018

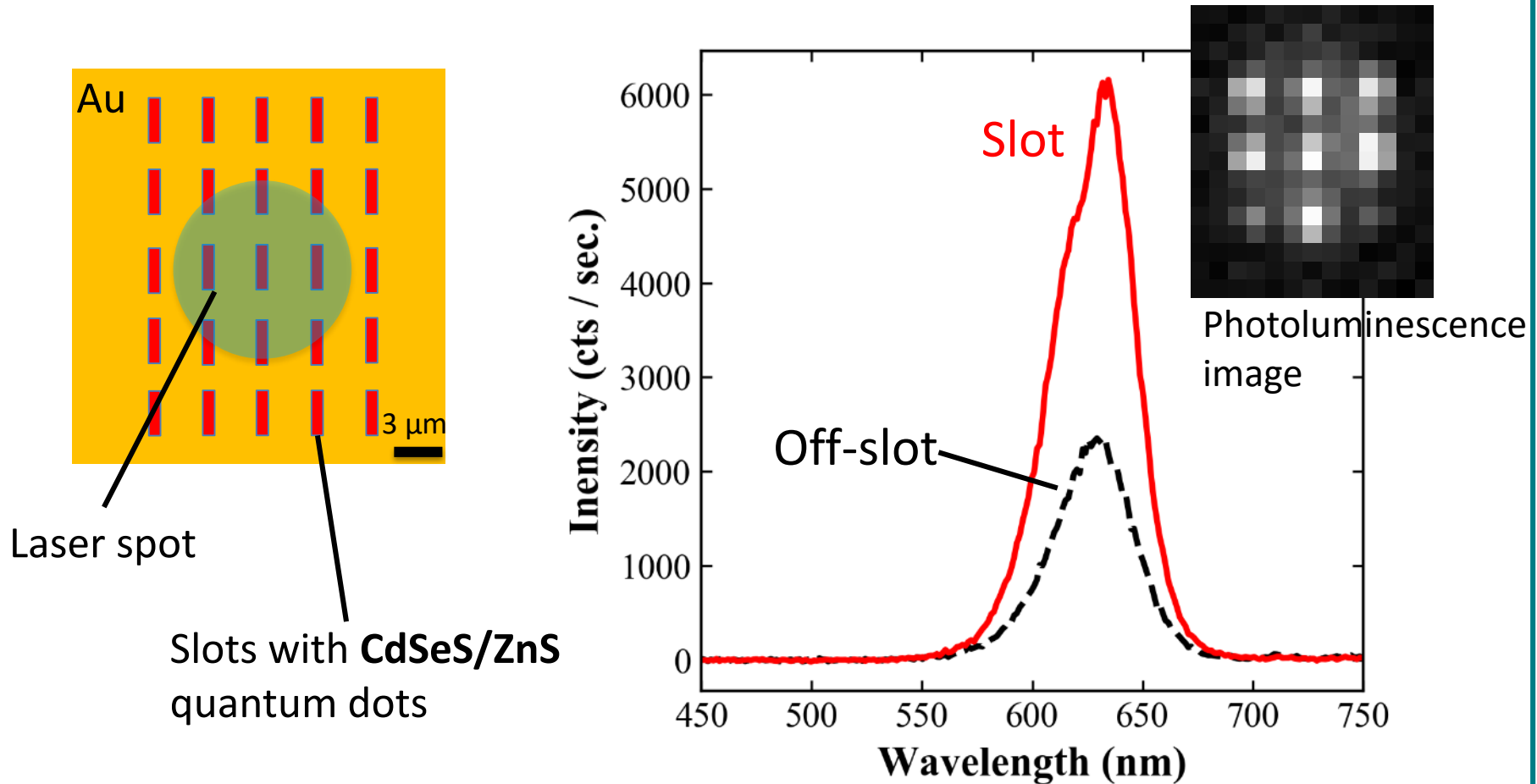
A Science & Technology Center

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Electronics Science



First demonstration: Integration of slot antenna with colloidal quantum dots



Summary

- **Demonstrated time-resolved light emission of an antenna-coupled nanoscale III-V light emitting diode.**
- **6X reduction of spontaneous emission lifetime from 1.6 ns to 250 ps at T=77K with corresponding increase in light emission intensity.**
- **Optimized antenna mode gives further 30X reduction of spontaneous emission lifetime to 50 ps.**
- **Toward high efficiency and high speed at room temperature: continued device scaling and optimized active layer design.**
- **Introduced quantum dot antenna-LED**

