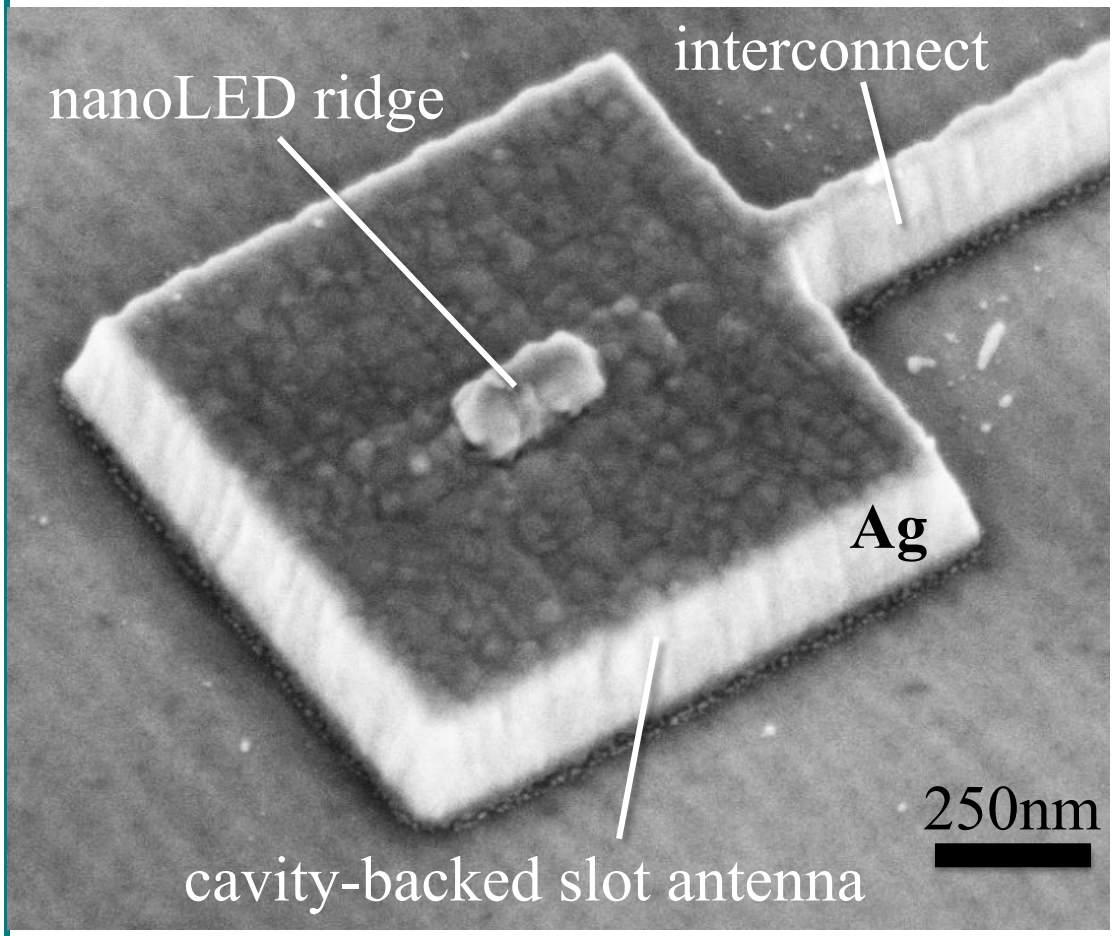
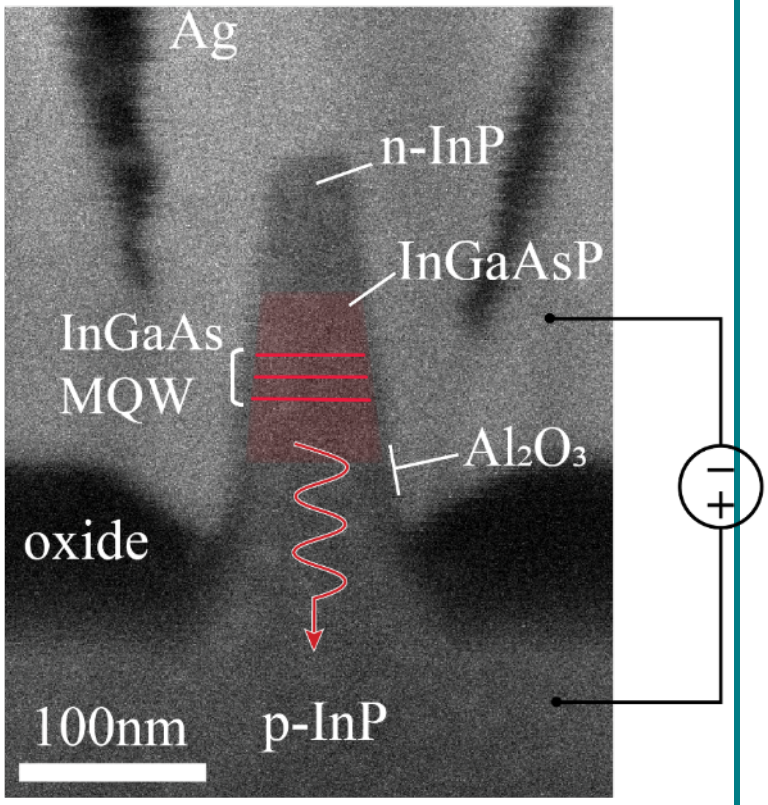
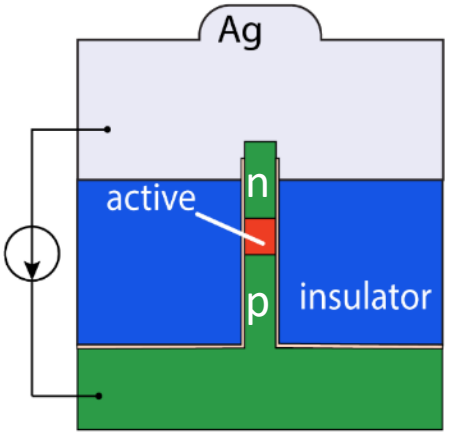
Electrically-injected III-V antenna-LED

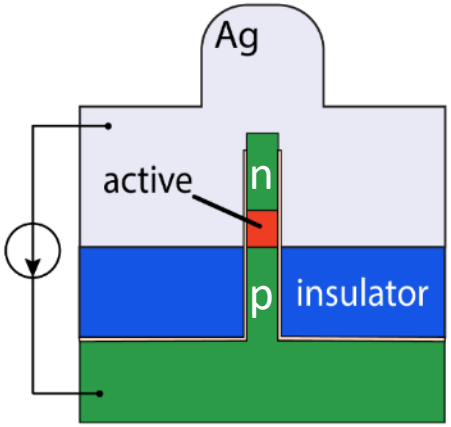




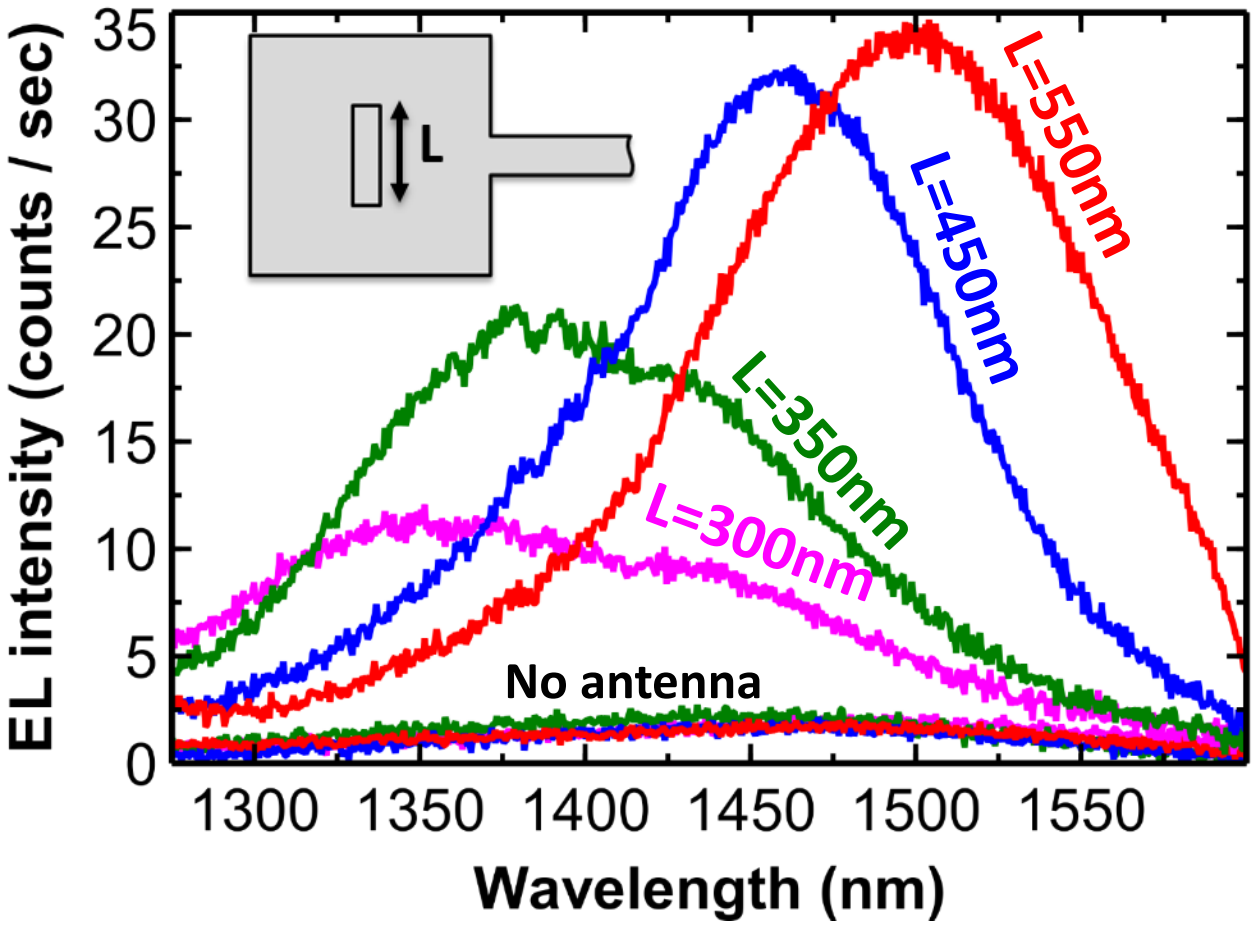
Antenna-enhanced electroluminescence



No antenna



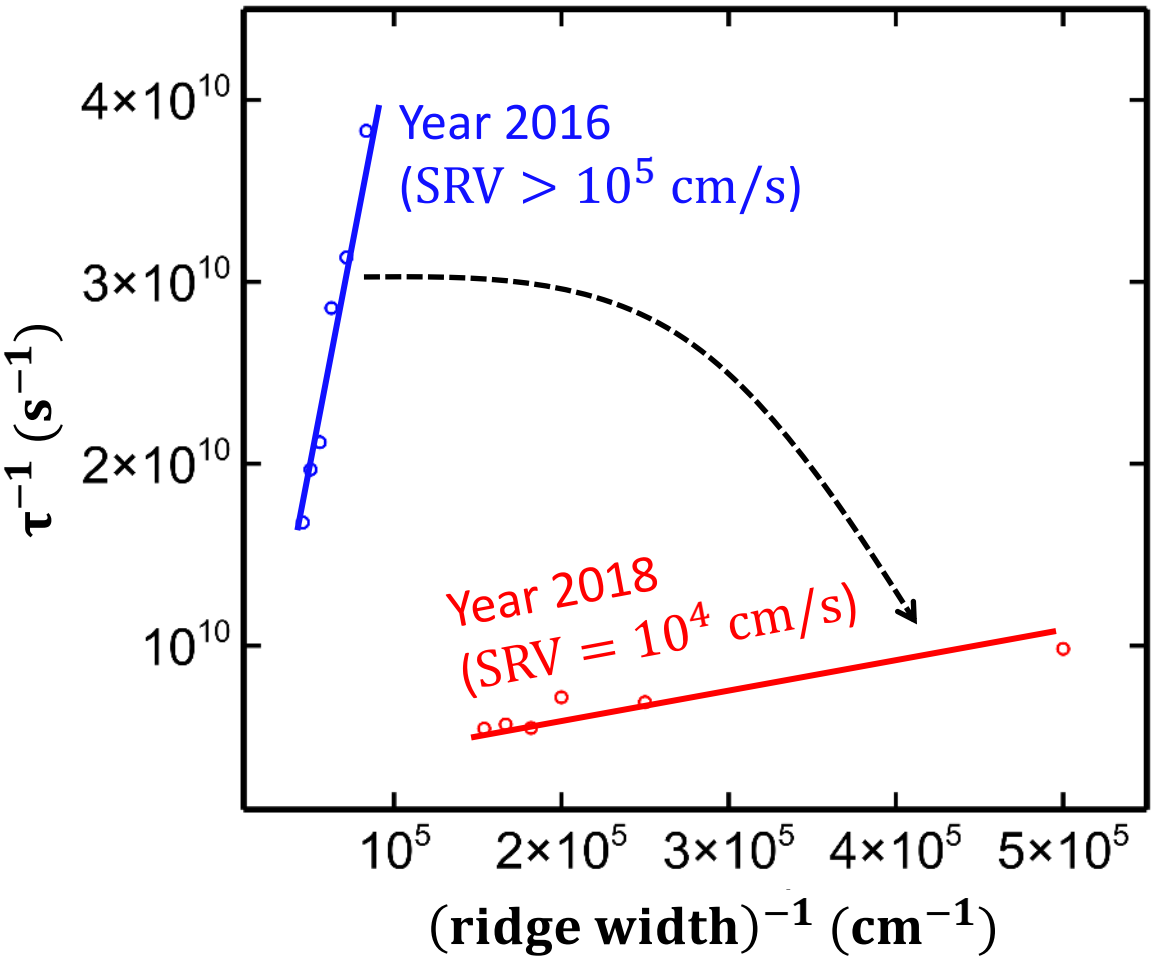
Antenna-LED



Fortuna et al. ISLC 2016

Controlling non-radiative recombination at surface

Photoluminescence decay time vs ridge width



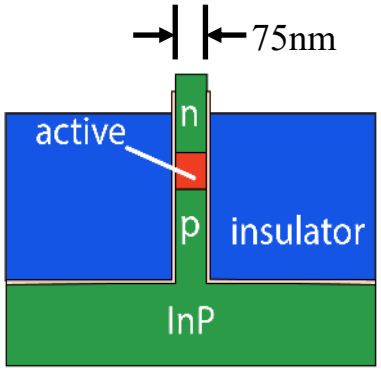
Key process steps:

1. Post–etch surface clean: Dilute TMAH followed by buffered HF leaves behind pristine surface.

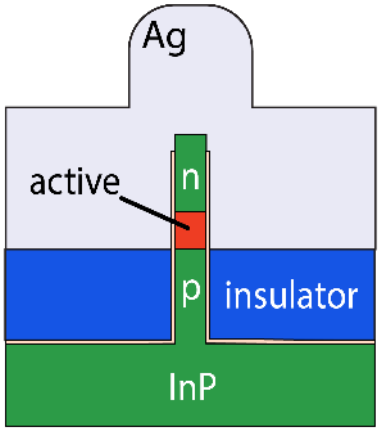
2. Surface protection: "Thick" 15nm ALD-deposited Al_2O_3 protects active region surface.

3. Active region passivation Ammonium sulfide treatment followed by low-temperature (150°C) Al_2O_3 ALD.

Clear observation of antenna enhancement

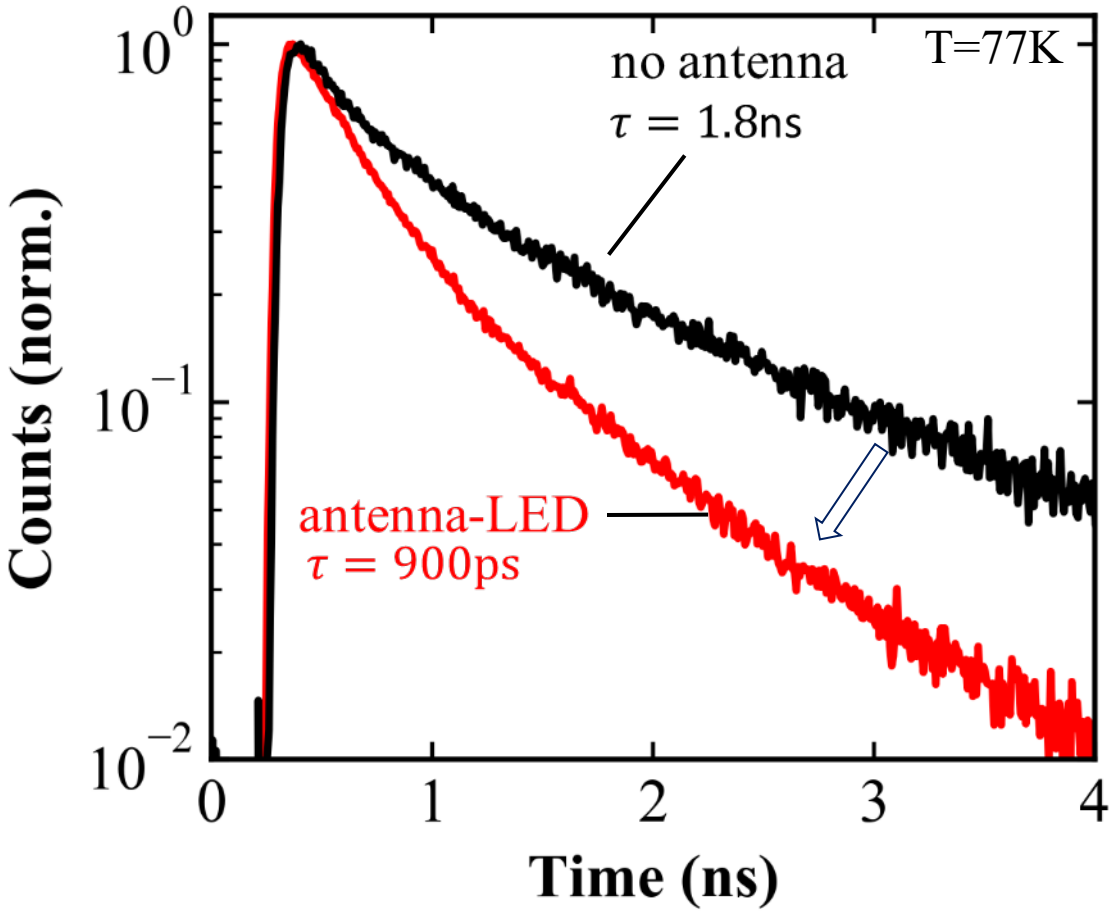


No antenna



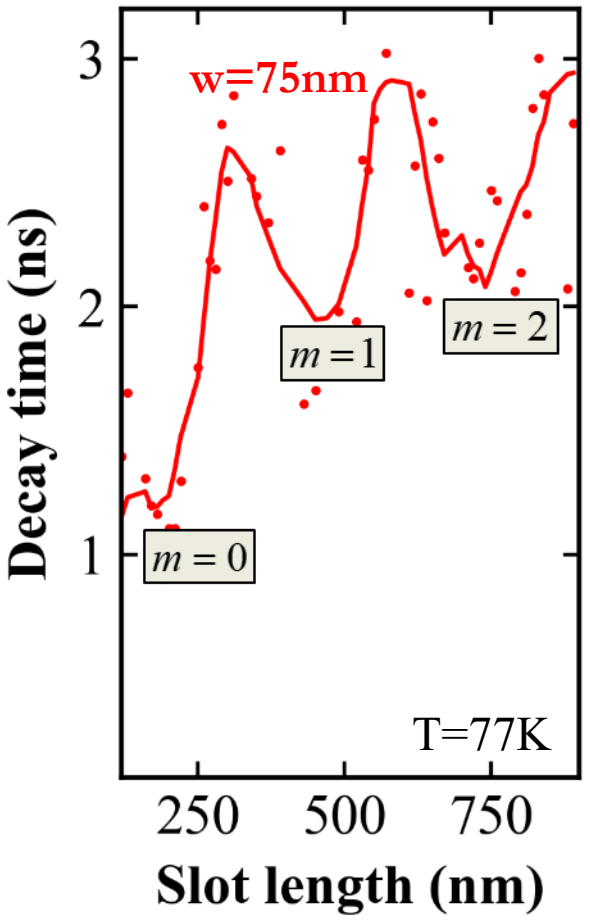
Antenna-LED

Time-resolved photoluminescence (PL)

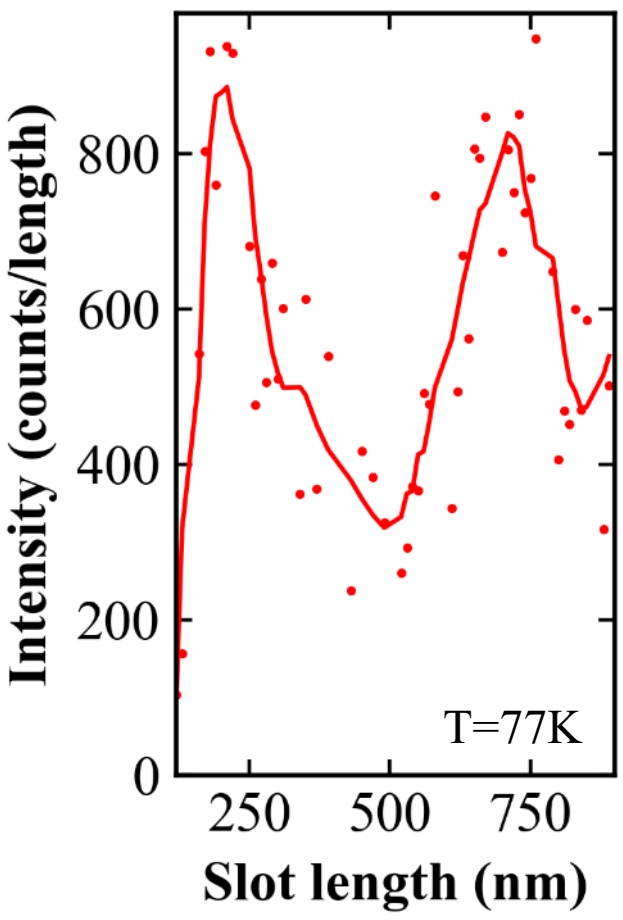


Clear observation of antenna enhancement

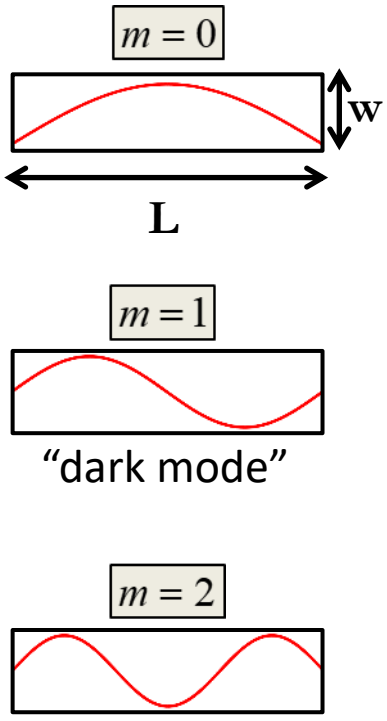
PL decay time



Intensity



Electric-field within slot

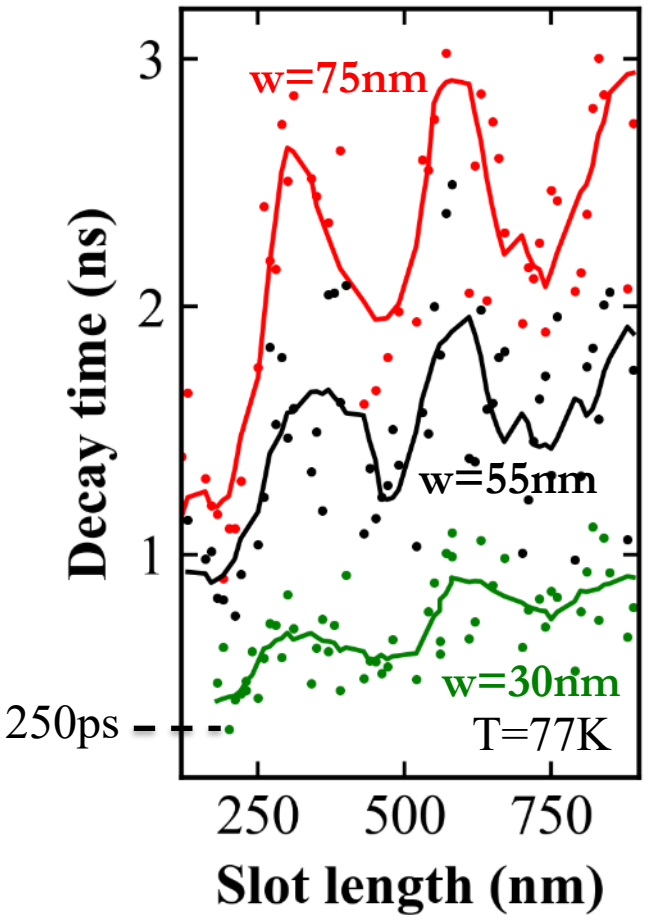


- Note: Intrinsic decay time $\tau_{rad,0} = 3.8ns$

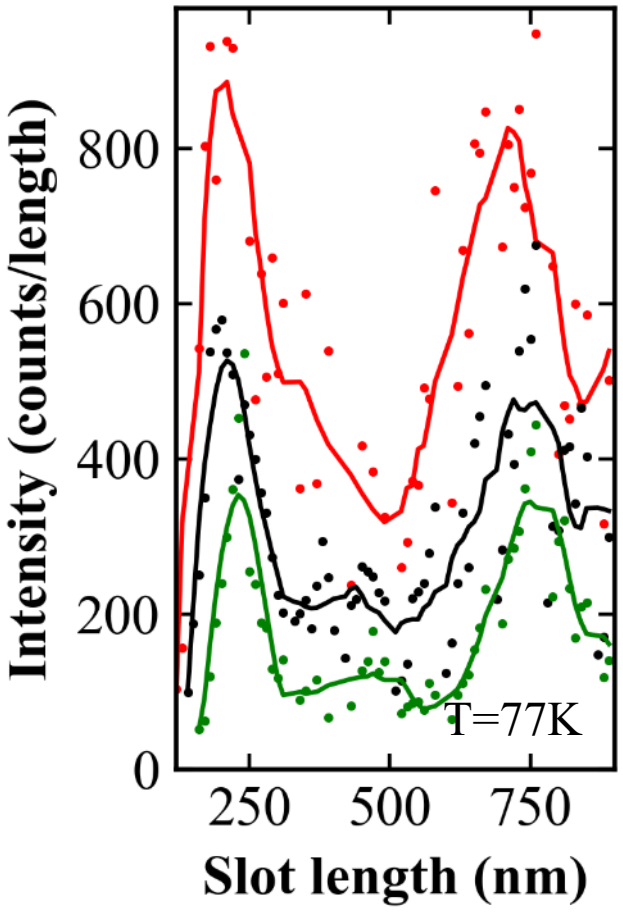
S.A. Fortuna, C. Heidelberger, E.A. Fitzgerald, E. Yablonovitch, M.C. Wu. ISLC. 2018.

Clear observation of antenna enhancement

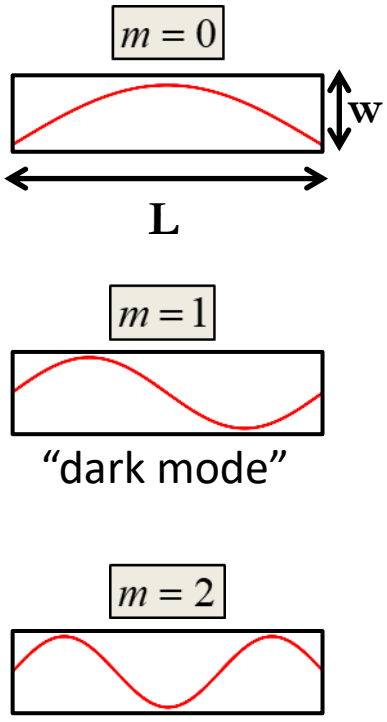
PL decay time



Intensity



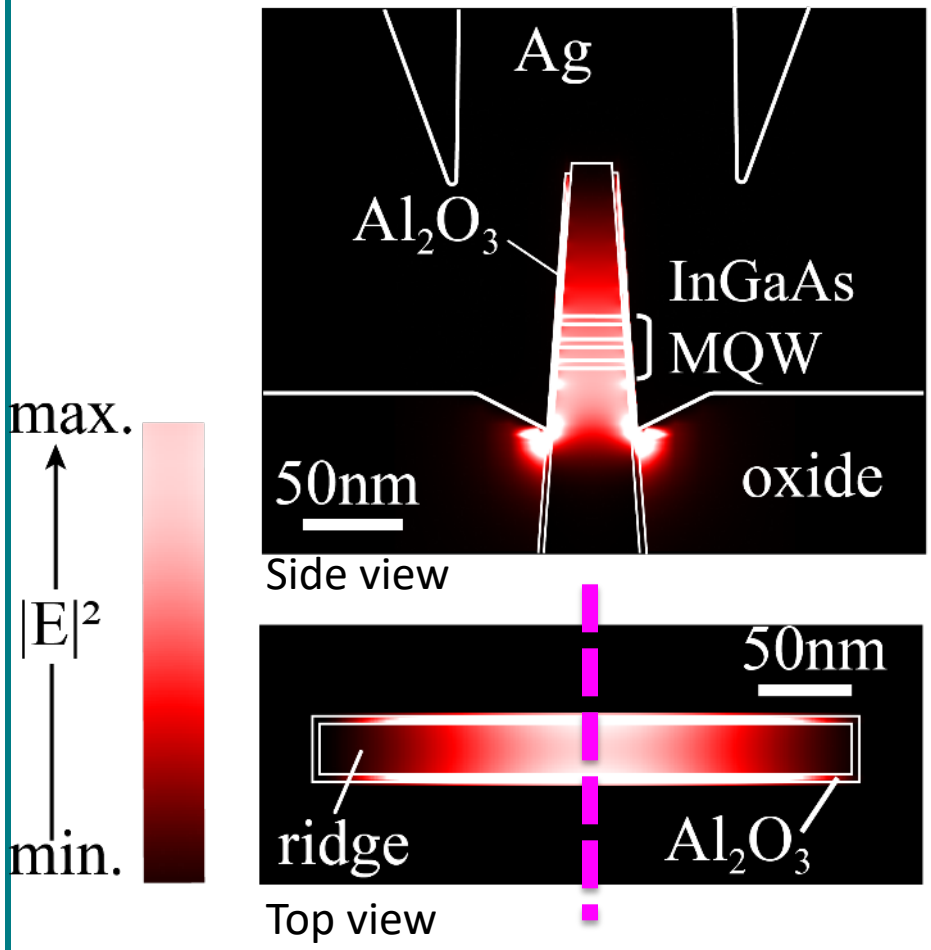
Electric-field within slot

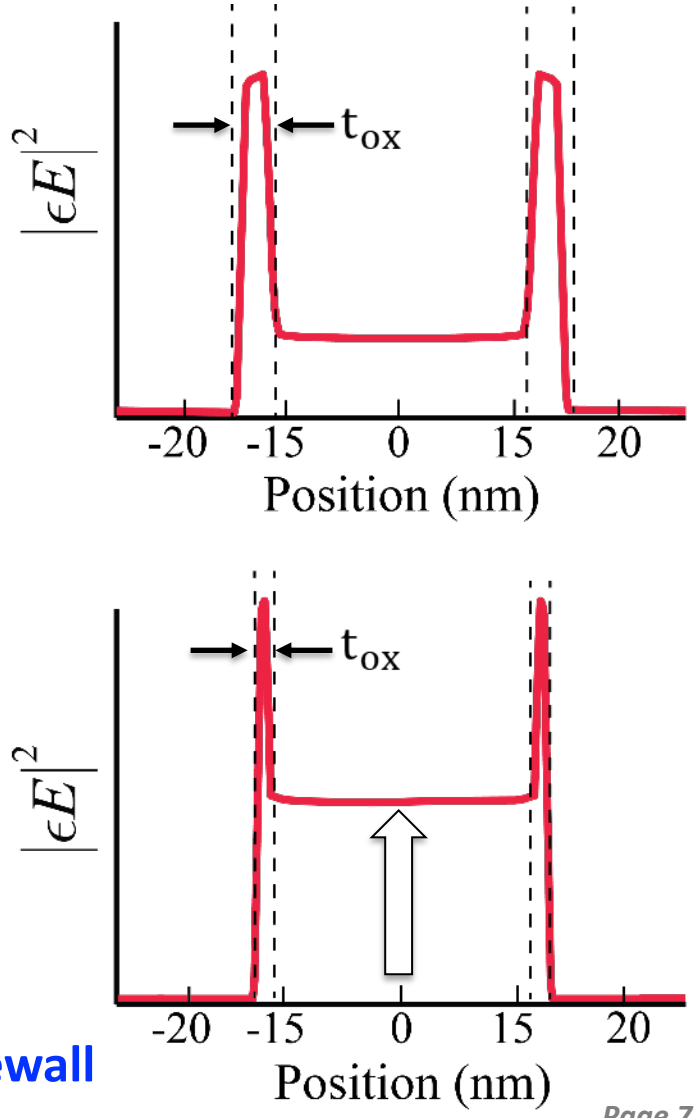


- Note: Intrinsic decay time $\tau_{rad,0} = 3.5ns$

S.A. Fortuna, C. Heidelberger, E.A. Fitzgerald, E. Yablonovitch, M.C. Wu. ISLC. 2018.

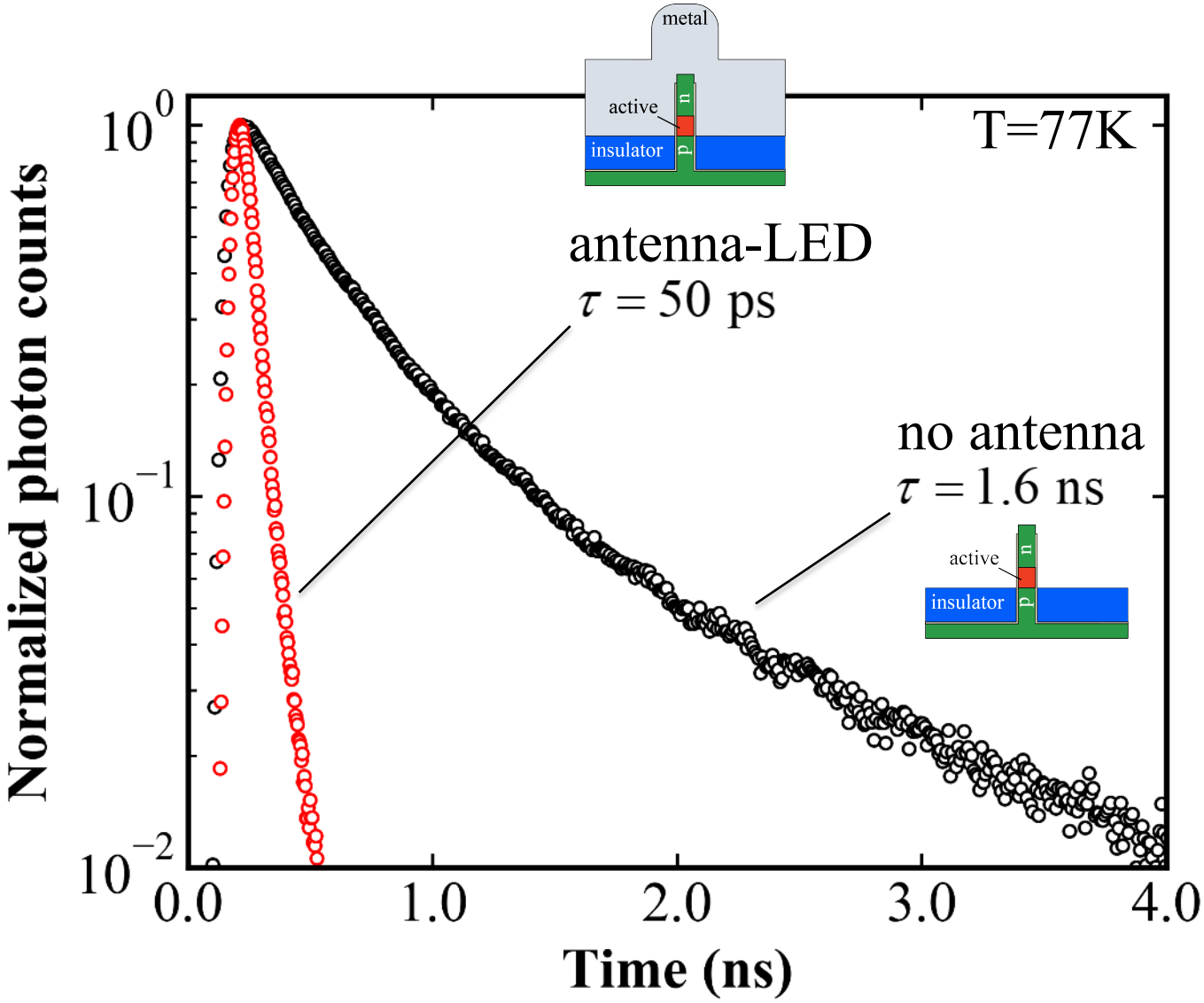
Further Enhancement with Device Scaling





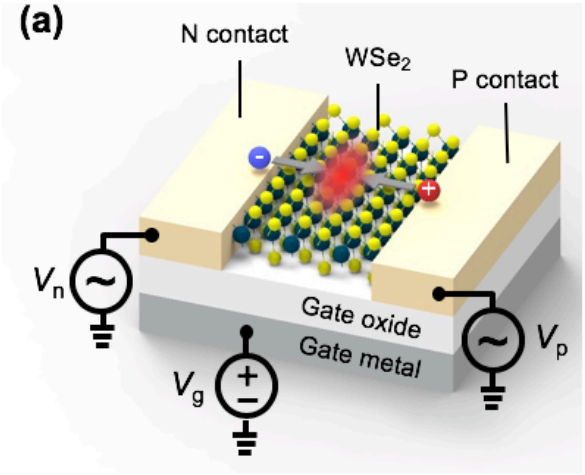
Oxide thickness on sidewall reduced from 3 nm to 1 nm

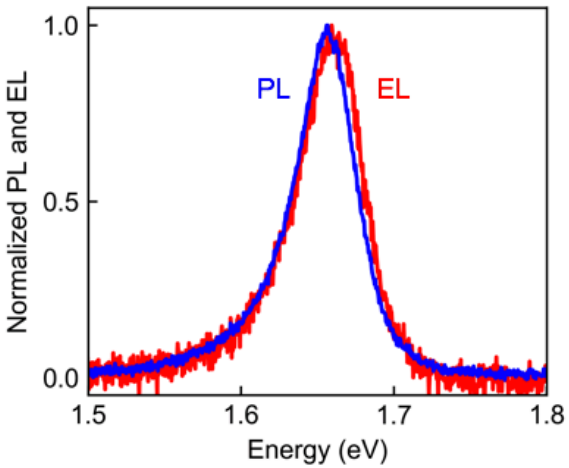
50 picosecond spontaneous emission lifetime
Aggressively-scaled 1nm oxide thickness

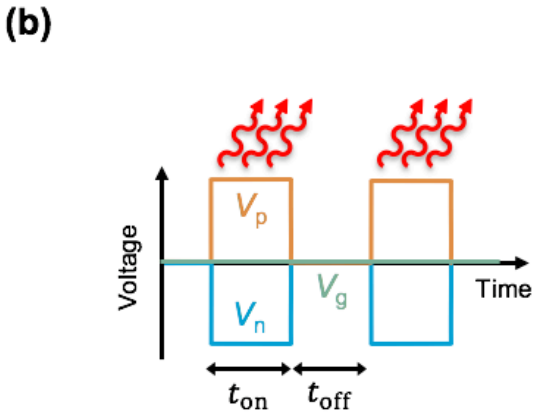


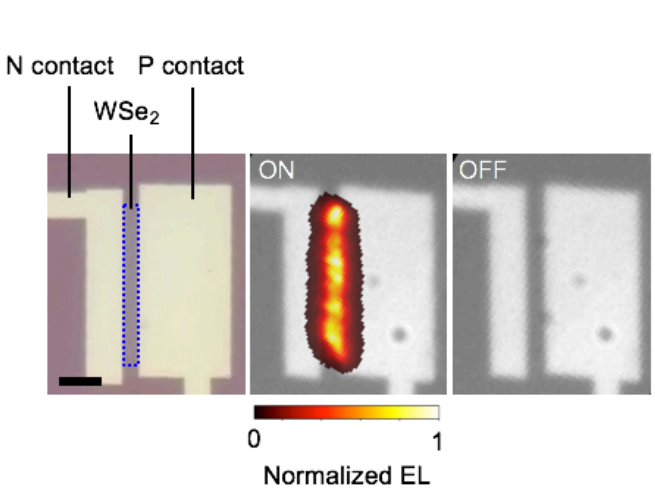
High efficiency Monolayer WSe_2 LEDs (collaboration with Javey Group)

Kevin Han



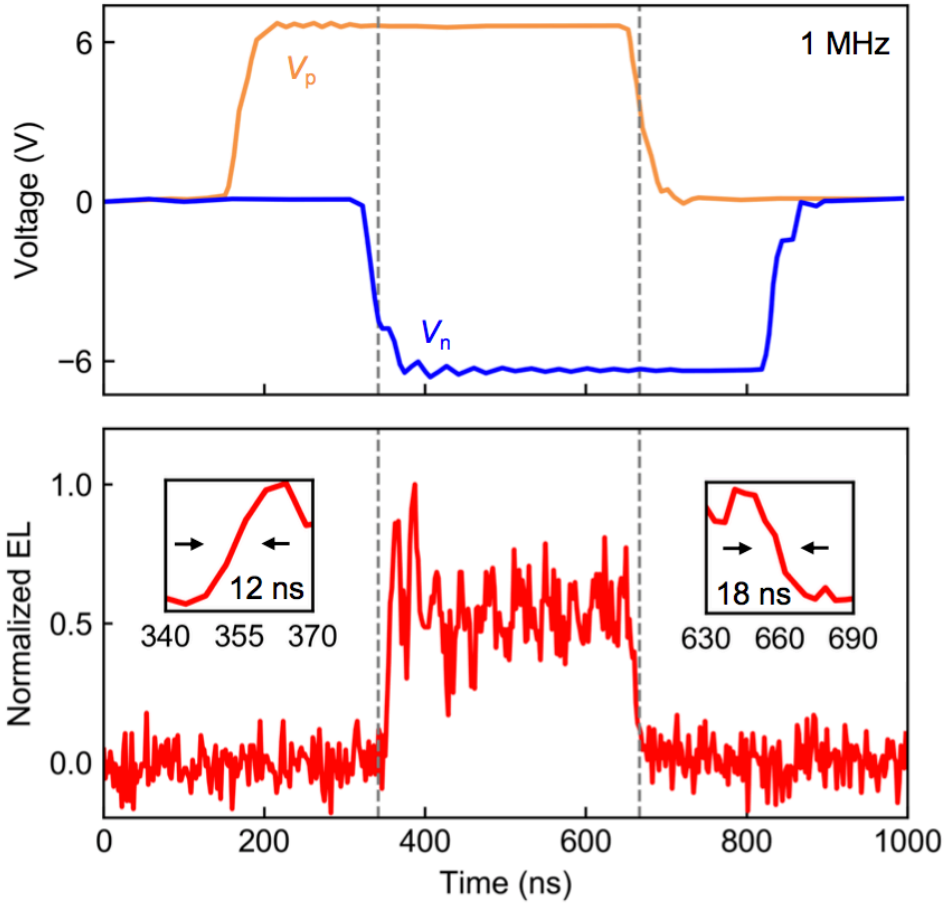






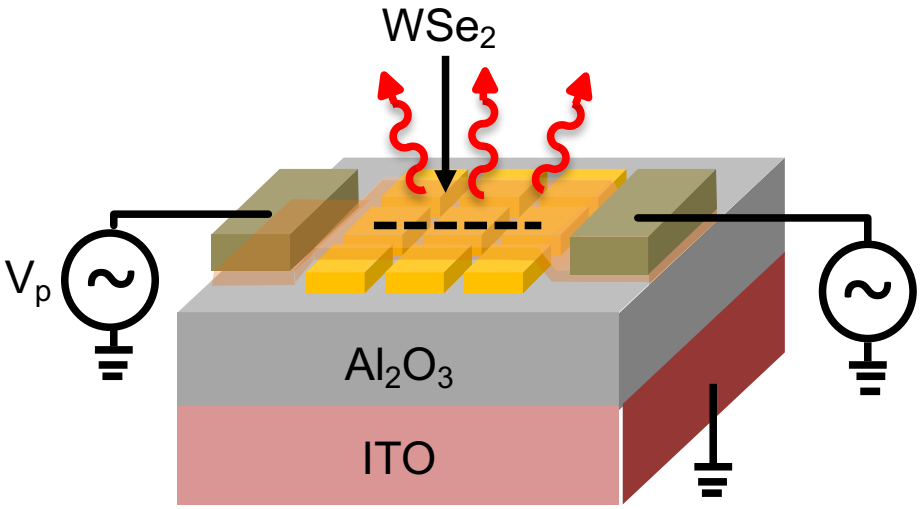
Process improvements yield EL efficiency close to PL (~1%), indicating material-limited efficiency

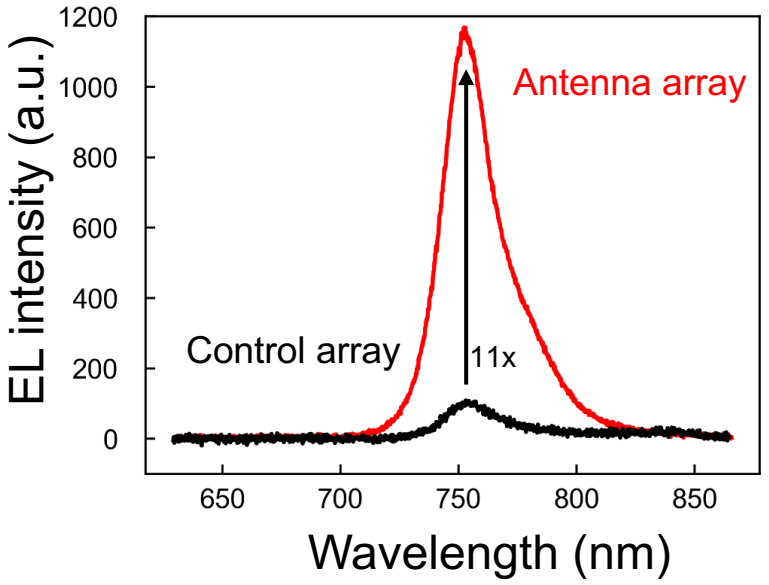
Dynamic Response of TMDC LED

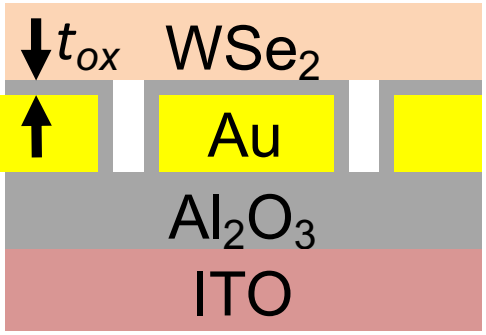


- Strong light emission when both electrons and holes are injected
- Rise/fall time ~ 12/18 ns

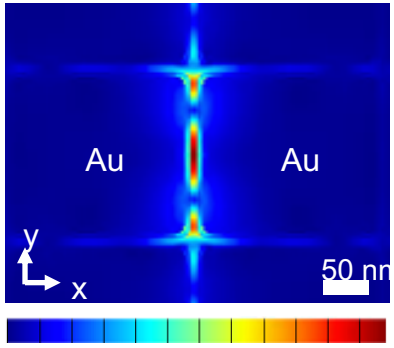
First Electrical Injection Antenna LED in Monolayer TMDC







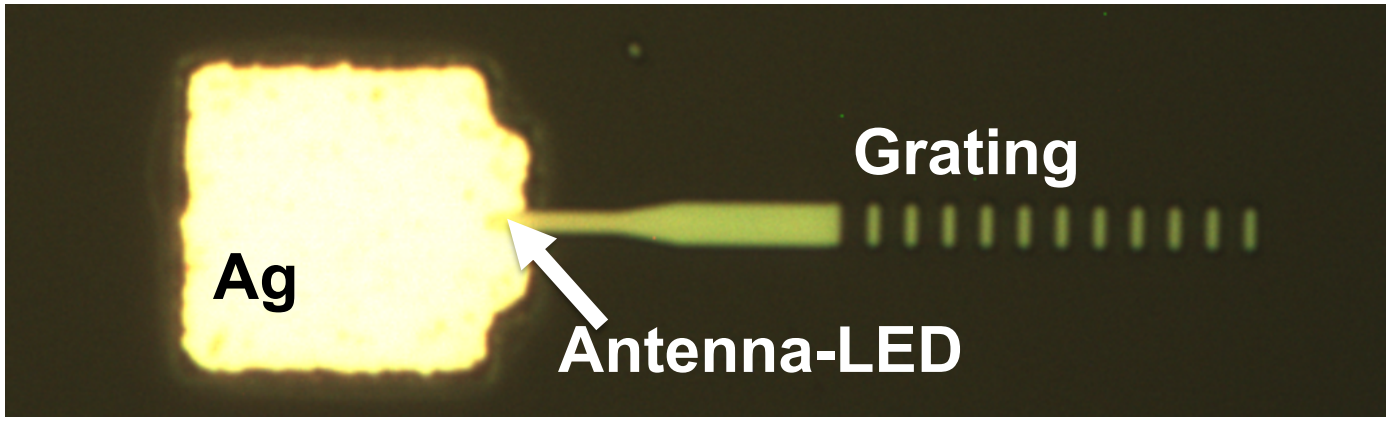
Cross Section

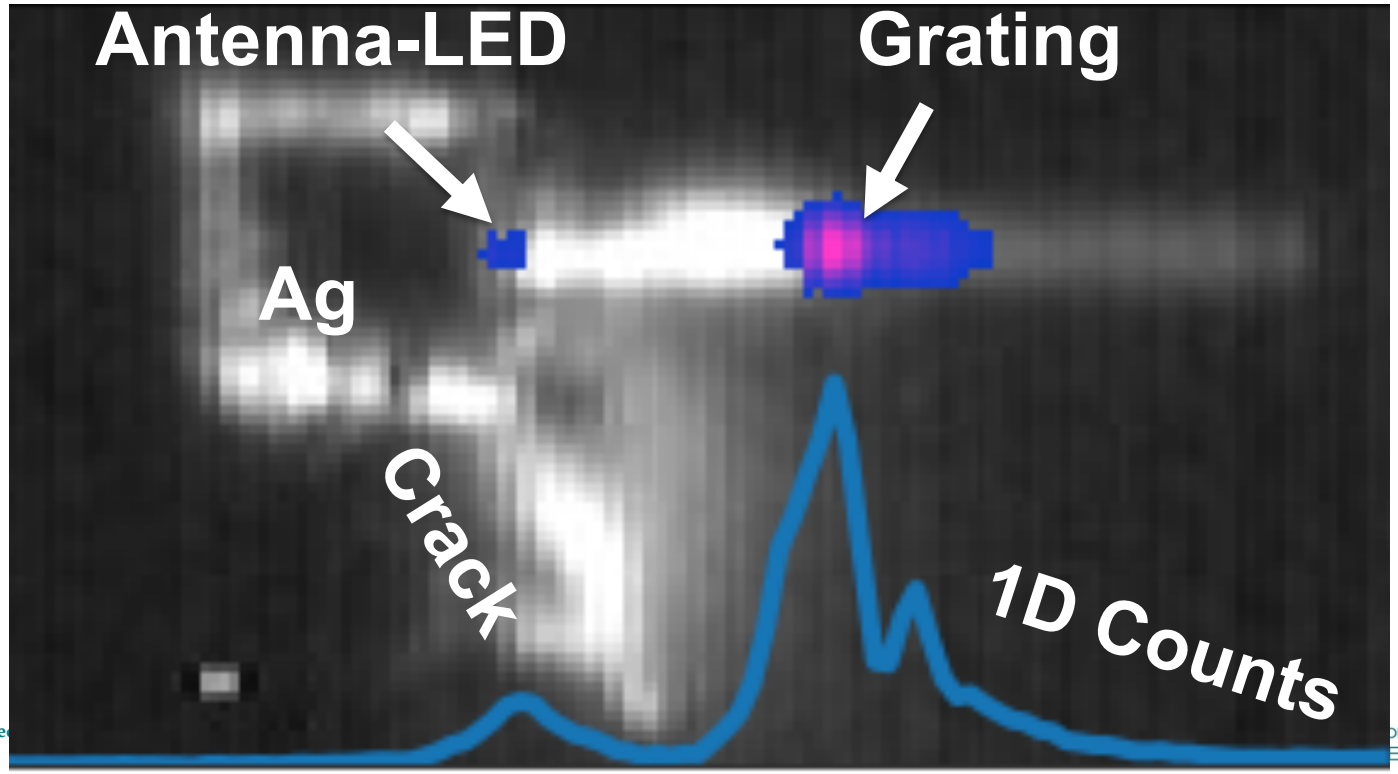


Top View E-Field

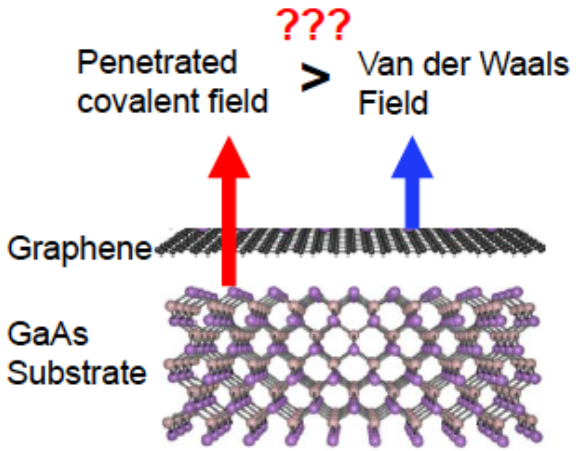
Antenna-LED with tapered coupler

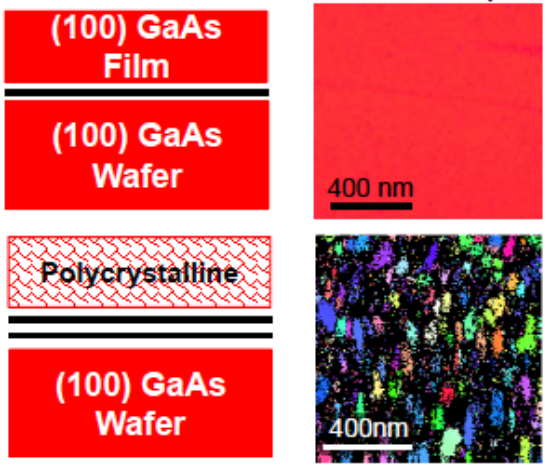
Nicolas Andrade

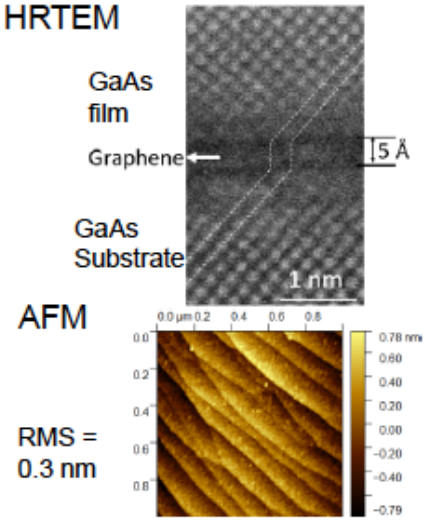




Strategy to interointegrate nano-LED on Si: Remote epitaxy

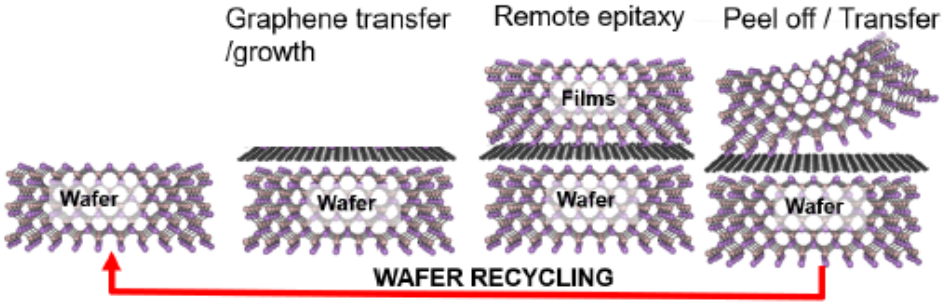


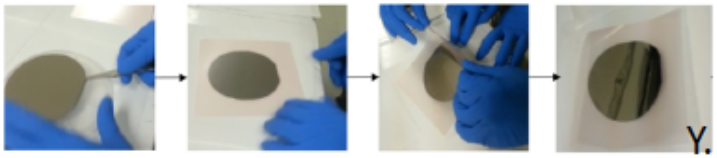




Perfect single-crystalline planar films can be grown on 2D materials

Application: 2D material-based layer transfer (2DLT)





Monolayer graphene + Wafer

= Copy Machine (Film producer)

Y. Kim et al., and J. Kim., ***Nature*** 544, 340 (2017)

Prof. Jeehwan Kim

Major Accomplishments

- First temporal measurement of III-V antenna-LED
  - 50 ps spontaneous emission lifetime measured at 77K
  - Compared with 1.6 ns without antenna
- First experimental demonstration of waveguide-coupled slot antenna LED
- Electrical injection antenna LED with monolayer WSe_2 emitter
  - Demonstrated first reliable LED operation in ambient condition
  - 11x enhancement demonstrated with optical antenna
- III-V antenna-LED with p-doped emitter (for faster response)
- Remote epitaxy for heterogeneous integration