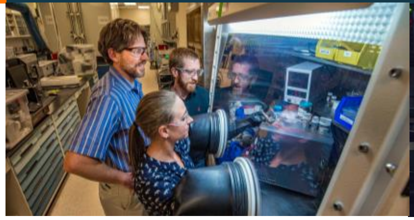
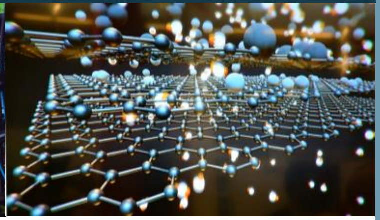
SAND2022-6802C

Sandia National Laboratories

Sub-ps Steering of Ultrafast Incoherent Emission from III-V Metasurfaces





Prasad P. Iyer, Nicholas J Karl, Sadhvikas Addamane, Sylvain Gennaro, Michael Sinclair, Igal Brener

CLEO 2022 - Symposium on Crossroads of Metaphotonics : Computational Imaging and Reconfigurable Metasurfaces

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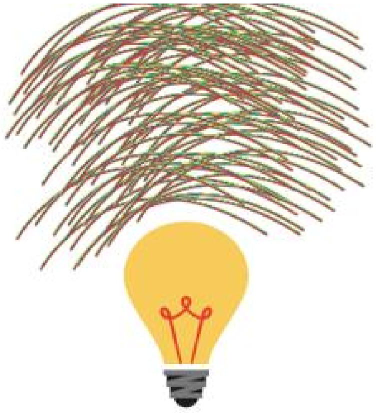
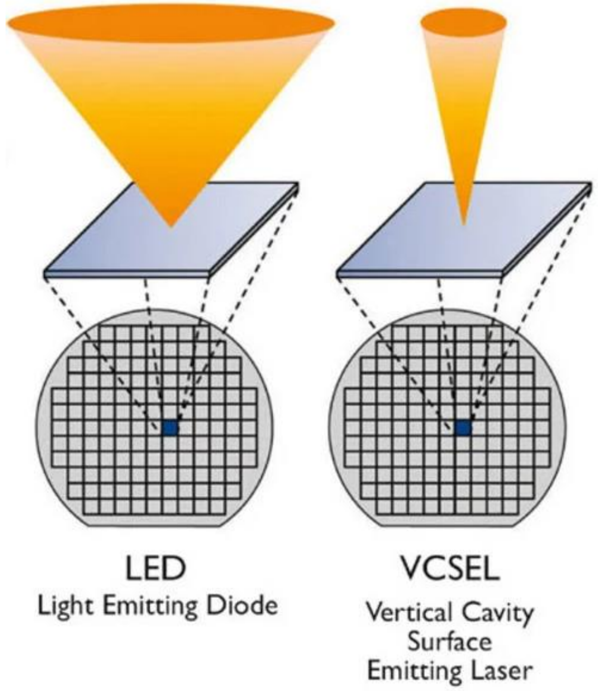
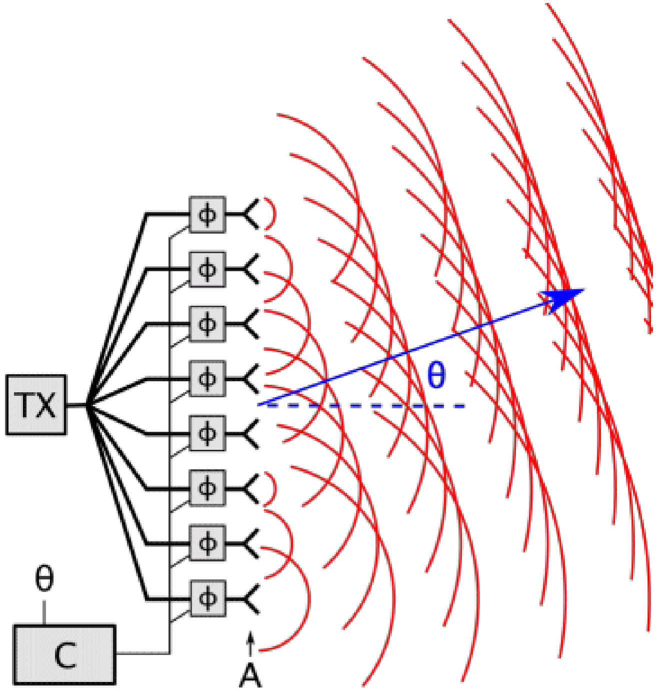
Spatiotemporal control of incoherent emission is challenging

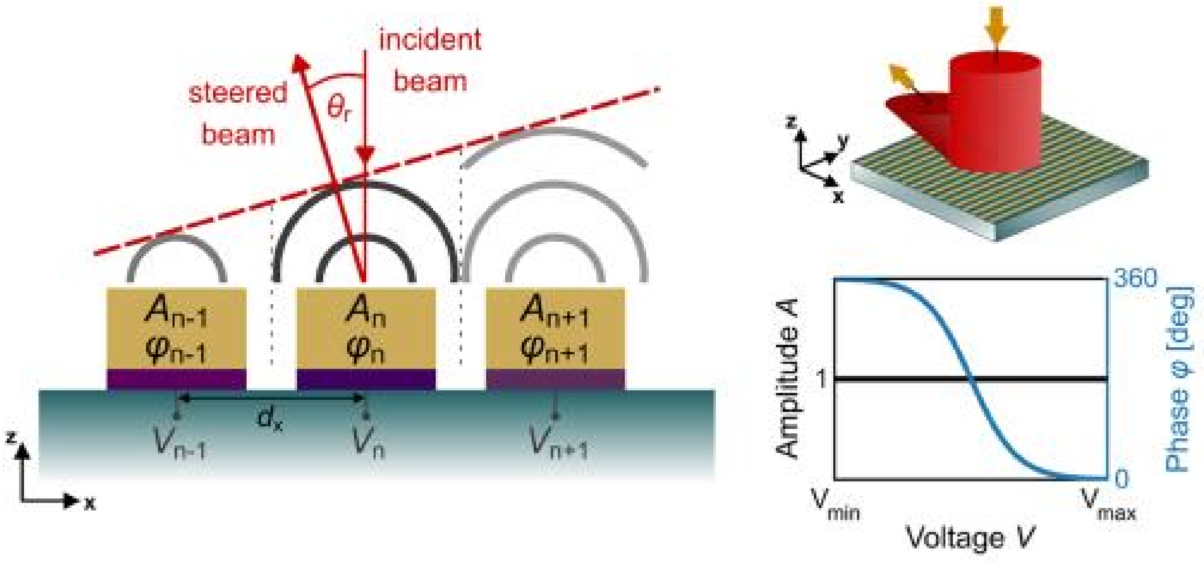
- Dynamic steering of incoherent emission is considered incompatible with traditional phased array optics.
- Dynamic emission control can lead to :
  - Holographic LED displays and illumination
  - Replacing high power lasers with LEDs for remote sensing and high speed optical communications



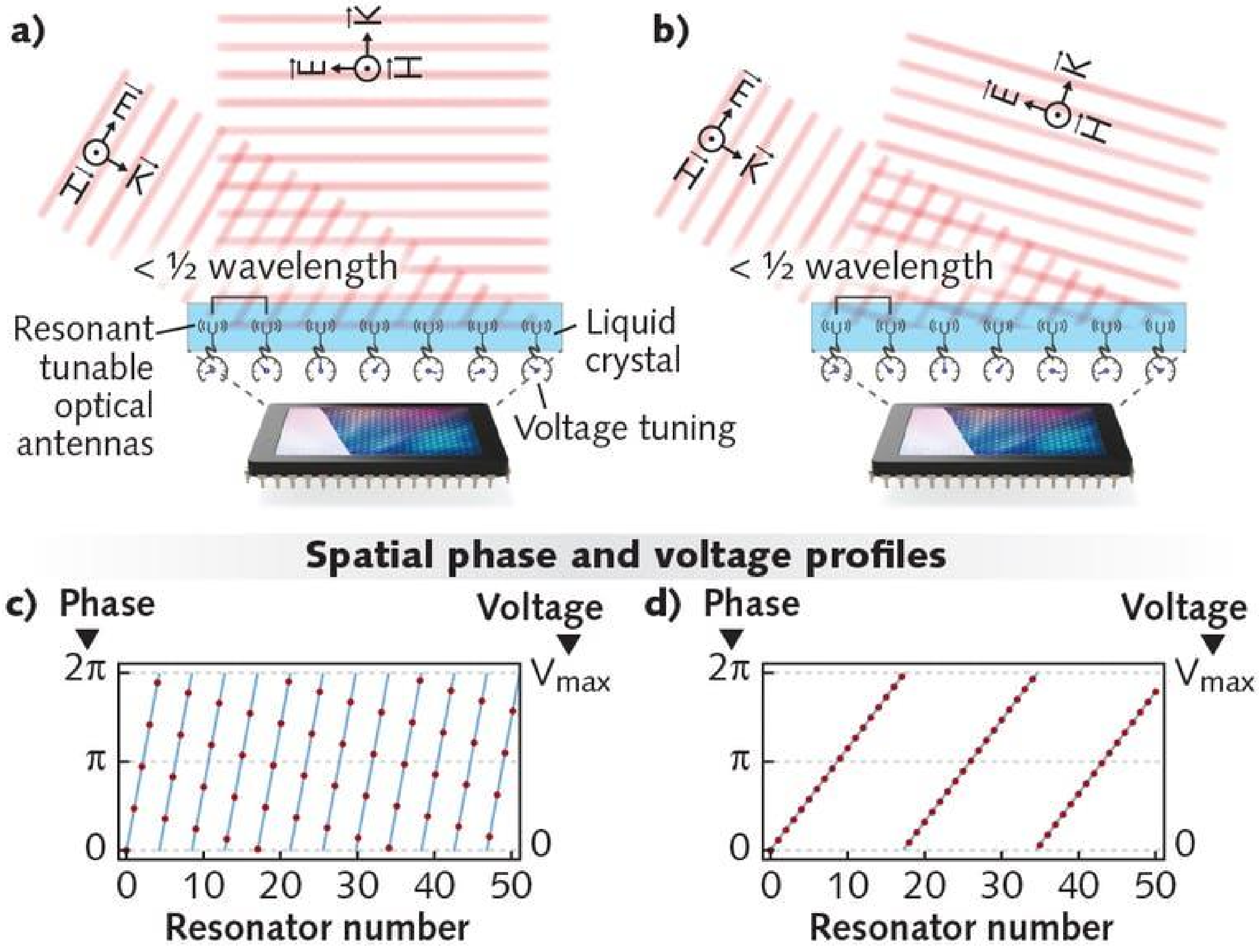




Metasurfaces typically control coherent wave fronts

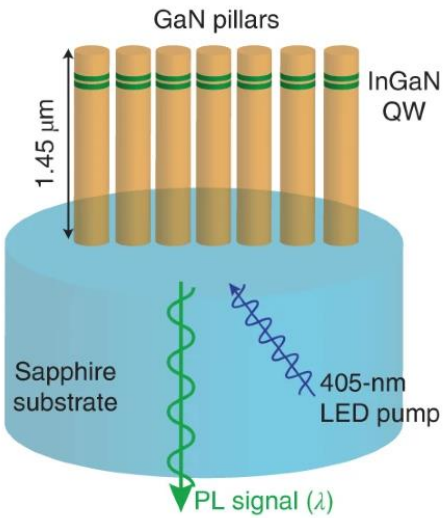


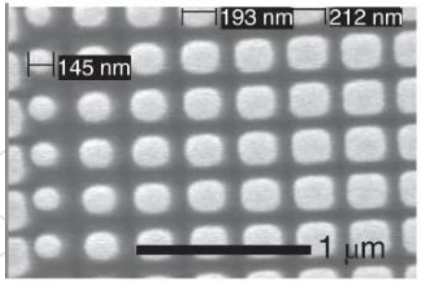
Array-Level Inverse Design of Beam Steering Active Metasurfaces – P. Thureja et.al ACS Nano 2020

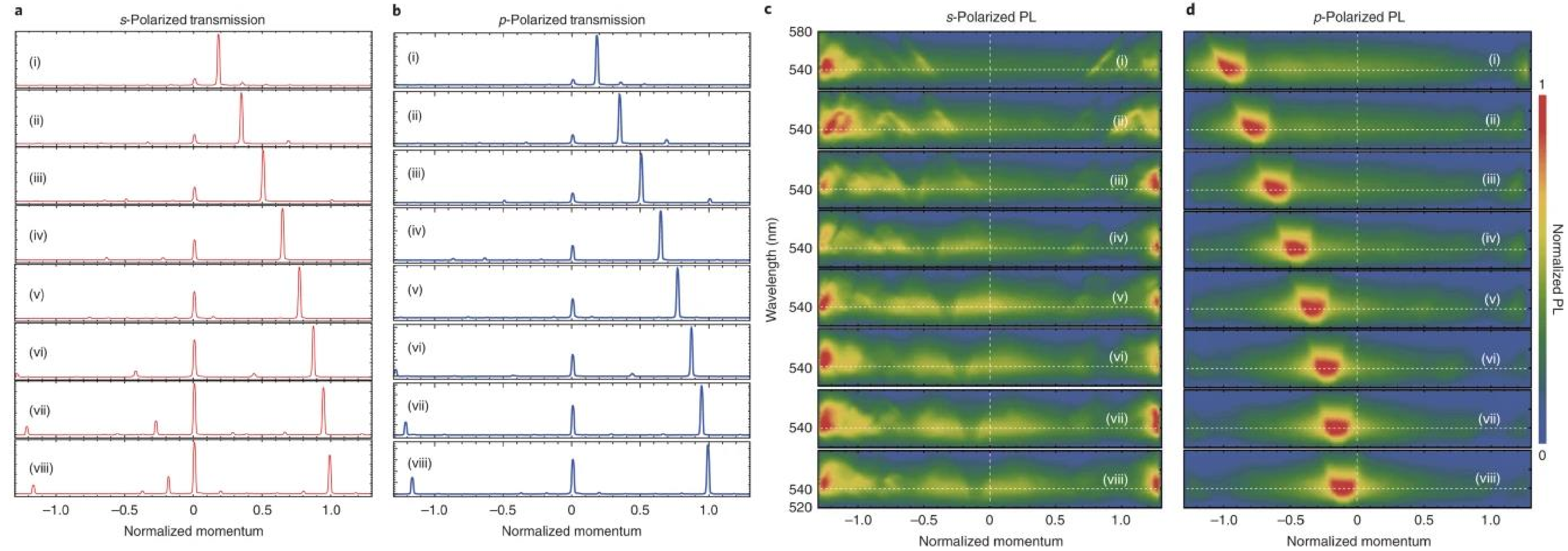


Lumotive's Liquid Crystal Metasurfaces
US Patent # : 11092675, 11005186, 10727601, 10665953

Static Metasurfaces can direct photoluminescence





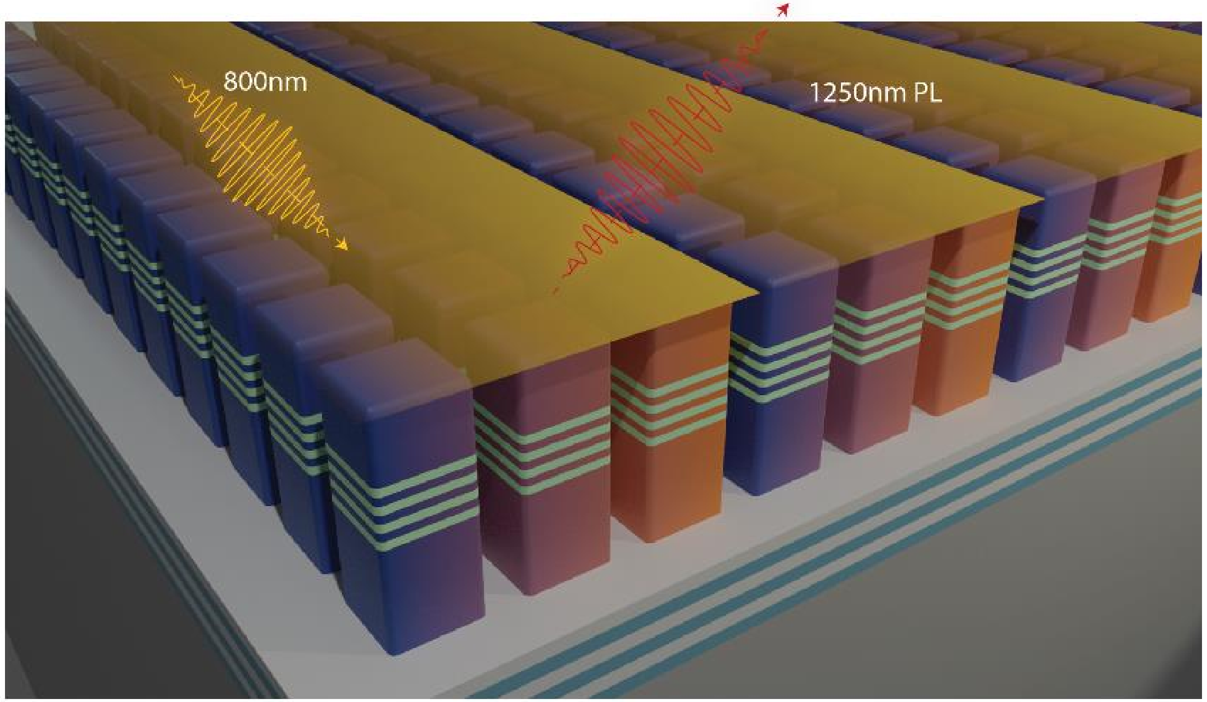


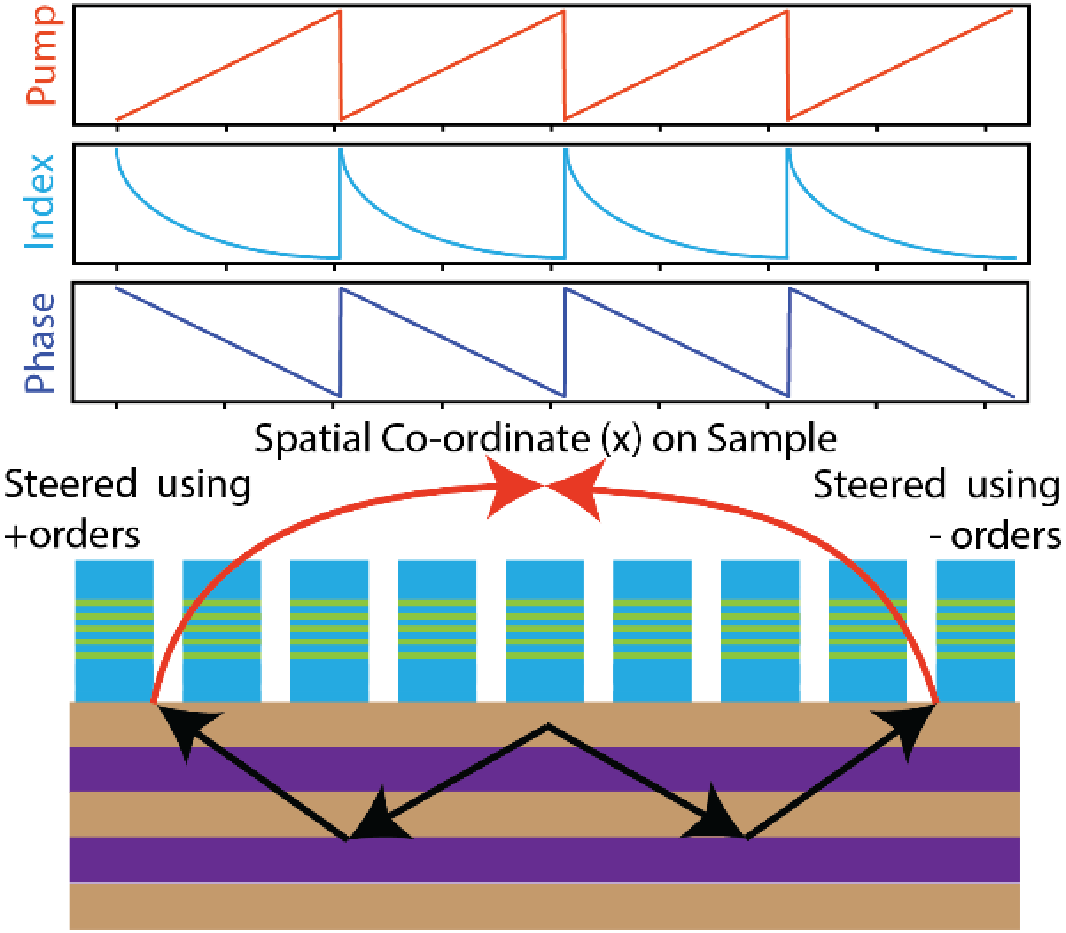
Photoluminescence (PL) can be collimated using Metasurface design principles : $\theta_{PL} \cong \frac{\pi}{2} - \theta_T$

"Unidirectional luminescence from InGaN/GaN quantum-well metasurfaces".

Prasad P. Iyer et.al Nature Photonics *14, 543-548. 2020*

Structured optical pumping for steering PL from metasurfaces

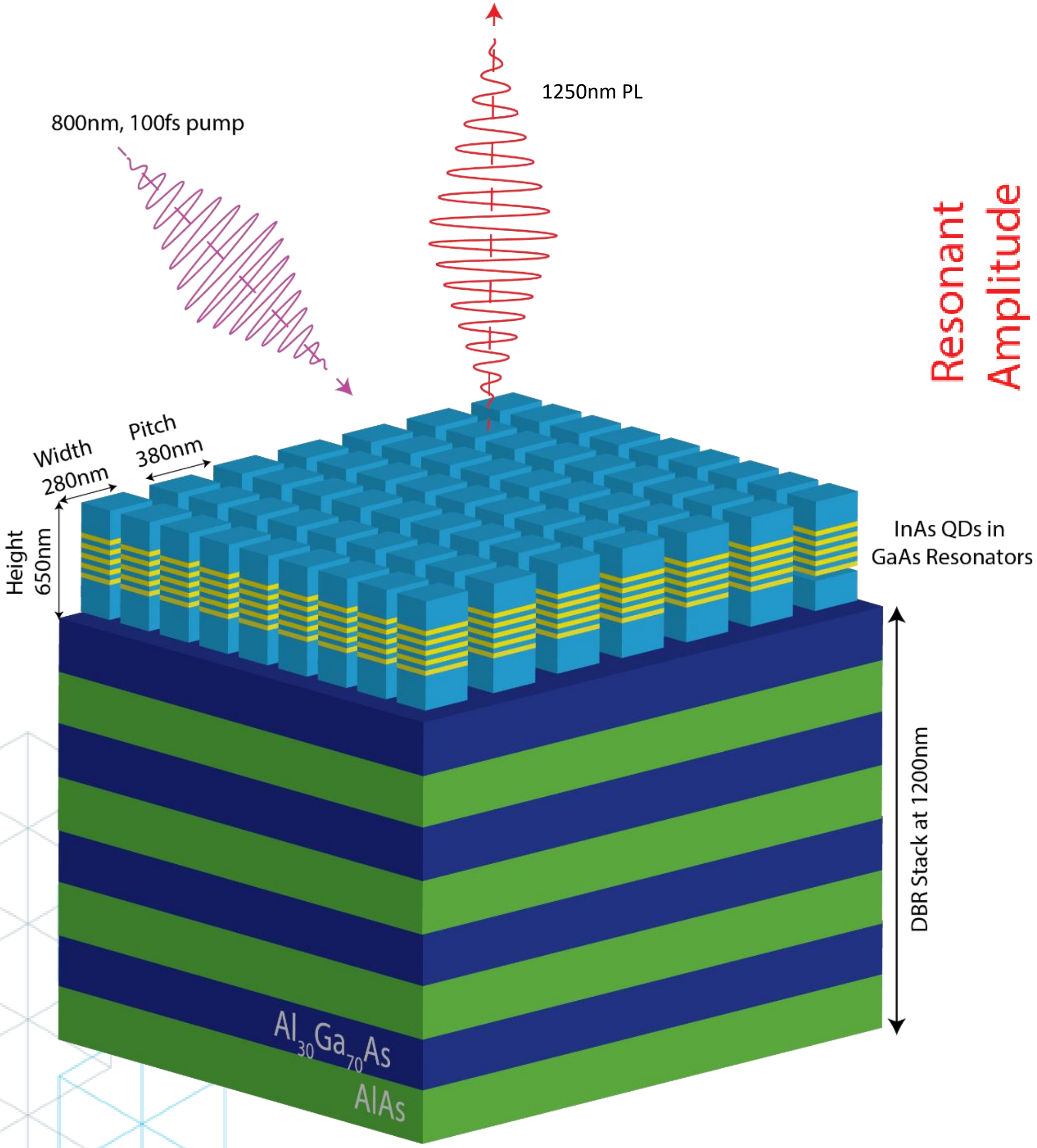




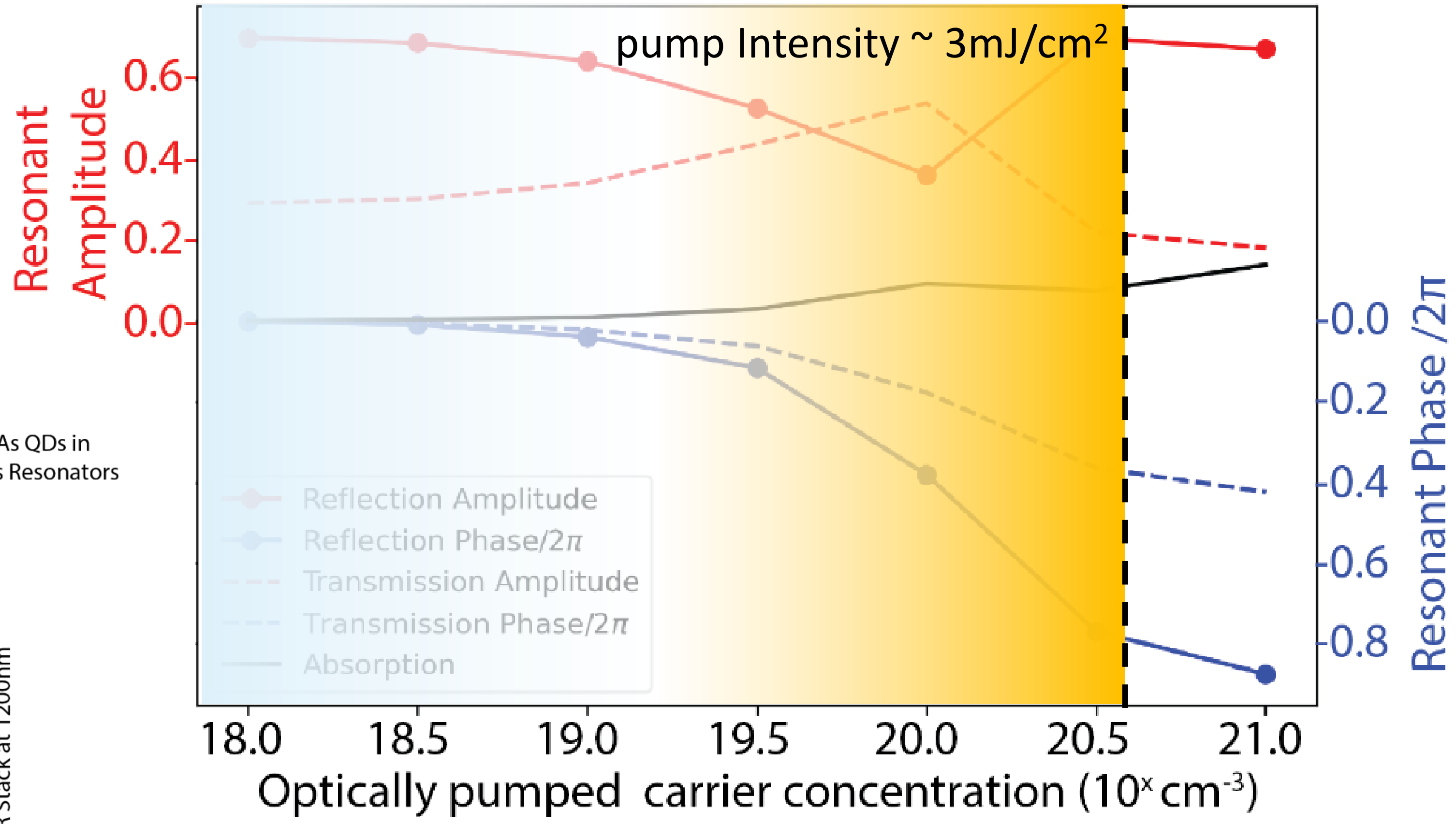
- We demonstrate that structured materials in combination with structured pumping can dynamically control photoluminescence

Dynamic beam steering with all-dielectric electro-optic III–V multiple-quantum-well metasurfaces - P.C. Wu et al. Nature Communications 2019

Designing metasurfaces for active PL steering



Simulated unit cell properties under optical pumping



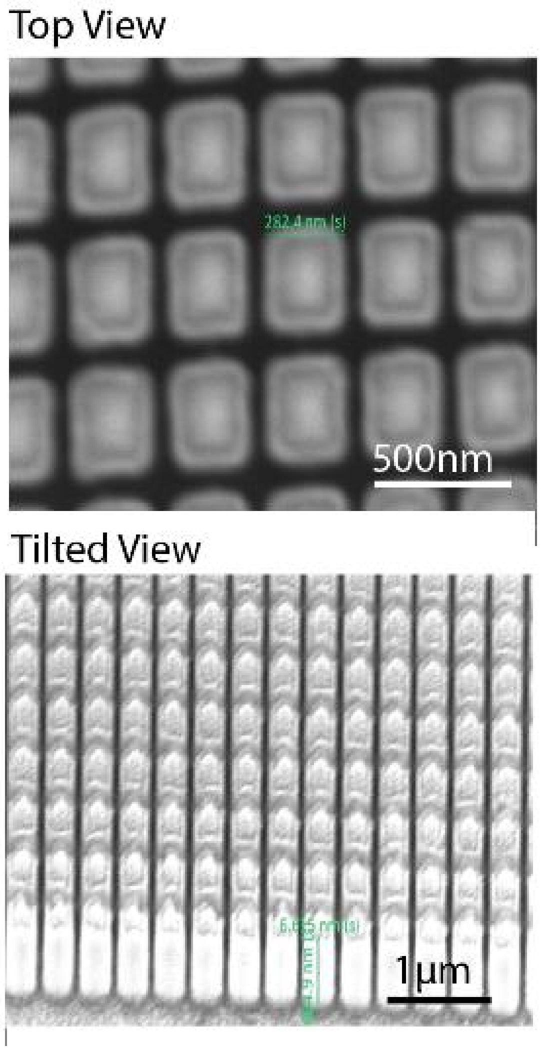
Dynamic 2π phase coverage in the resonators from free carriers excited by the 800nm pump

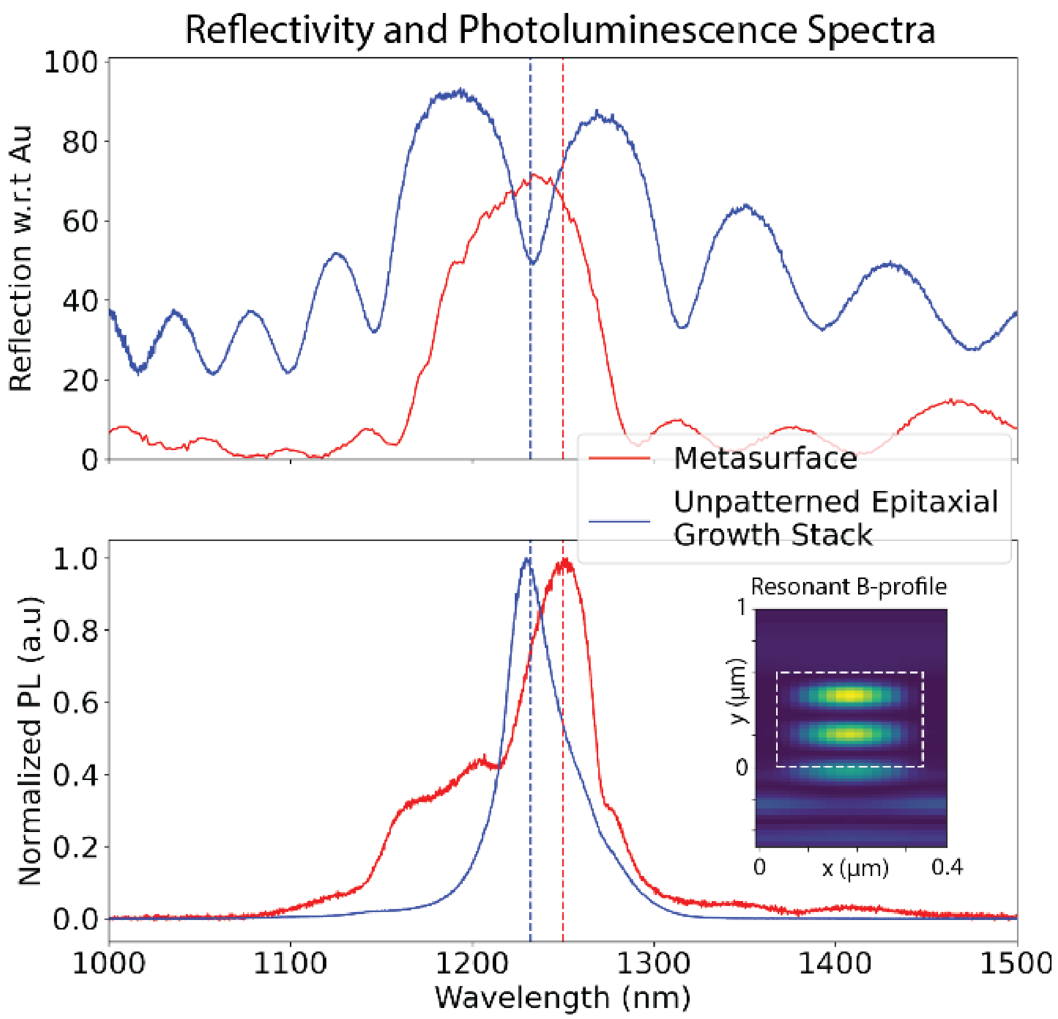
Submission under Review

Dielectric metasurfaces reduces the PL emission linewidth

- The resonators on DBR enable us to achieve reconfigurable 2π phase coverage in reflection

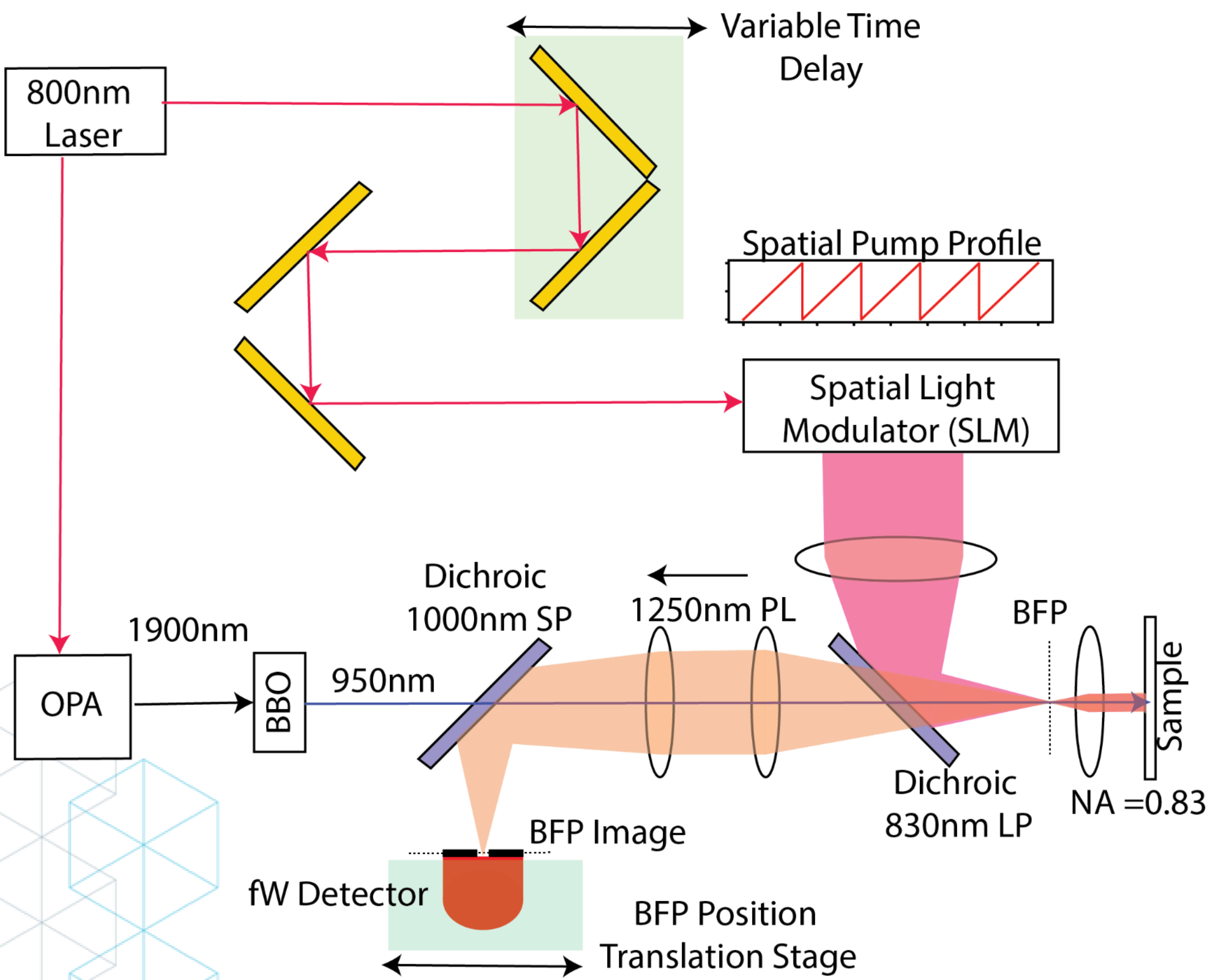
- Low loss dielectric resonators enhance the Q-factor (25.6) of PL emission bandwidth

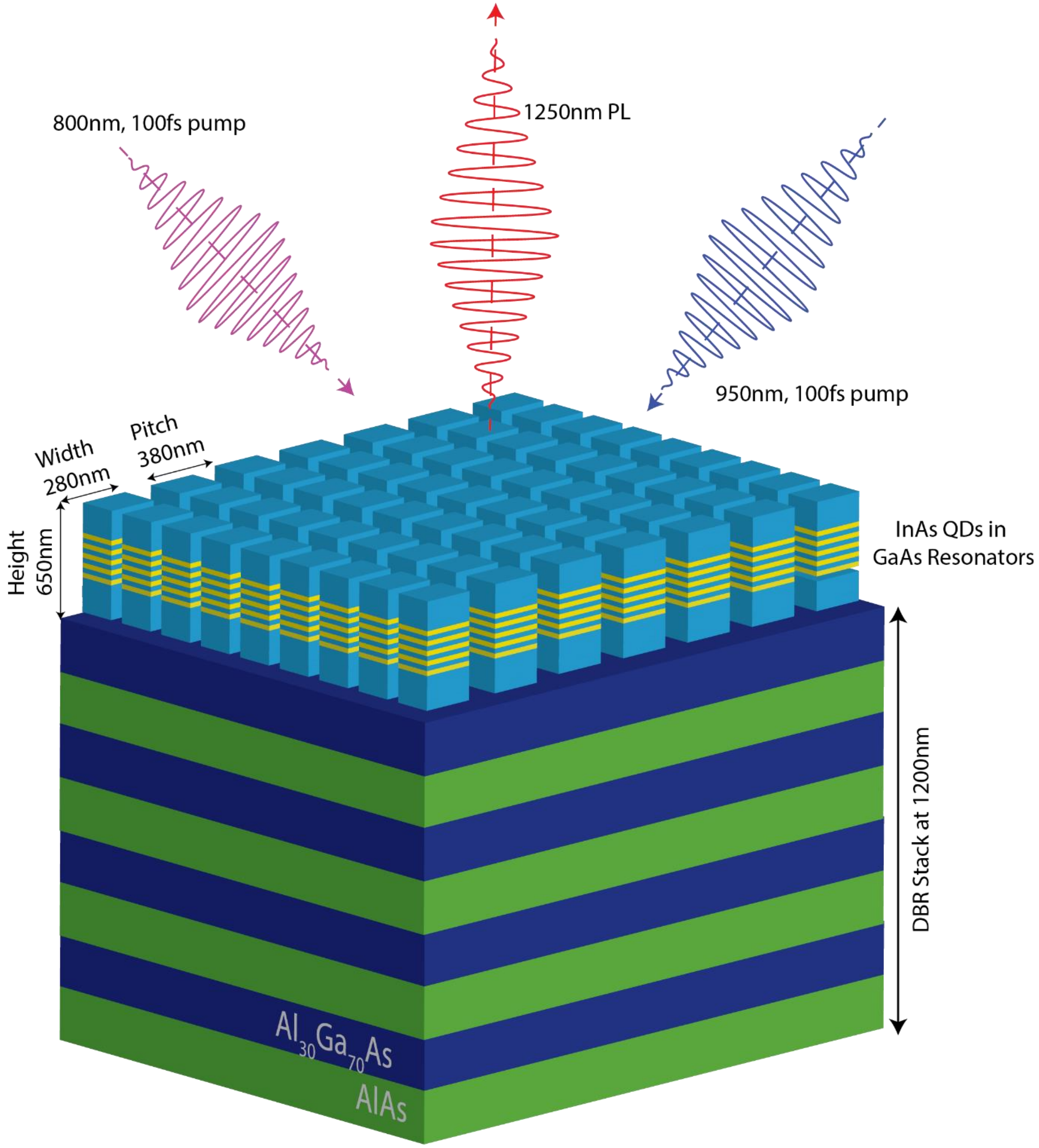




Submission under Review

Experimental Setup for 2-color pump for PL lifetime measurements

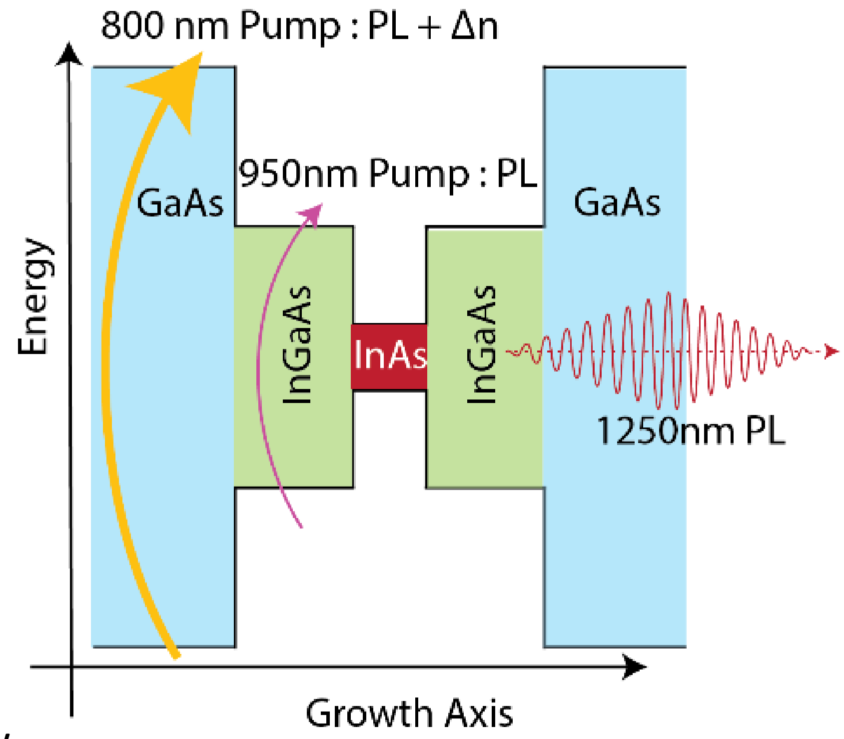


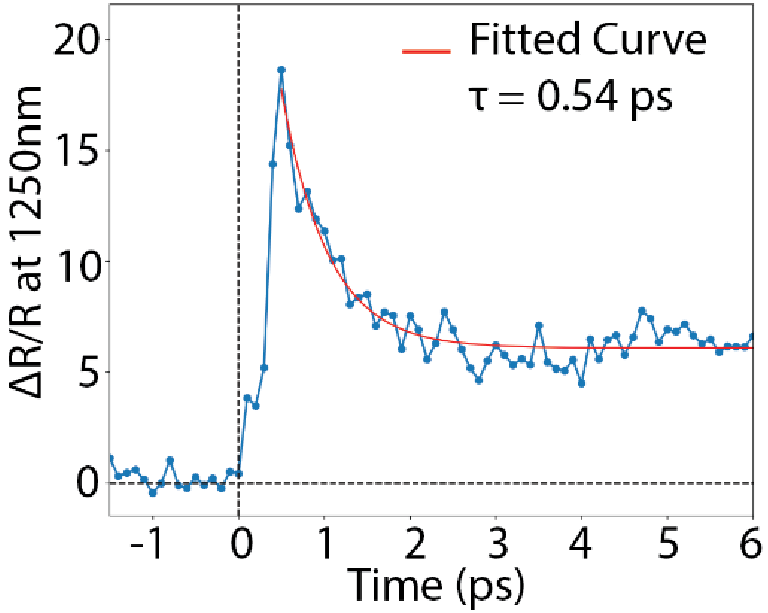


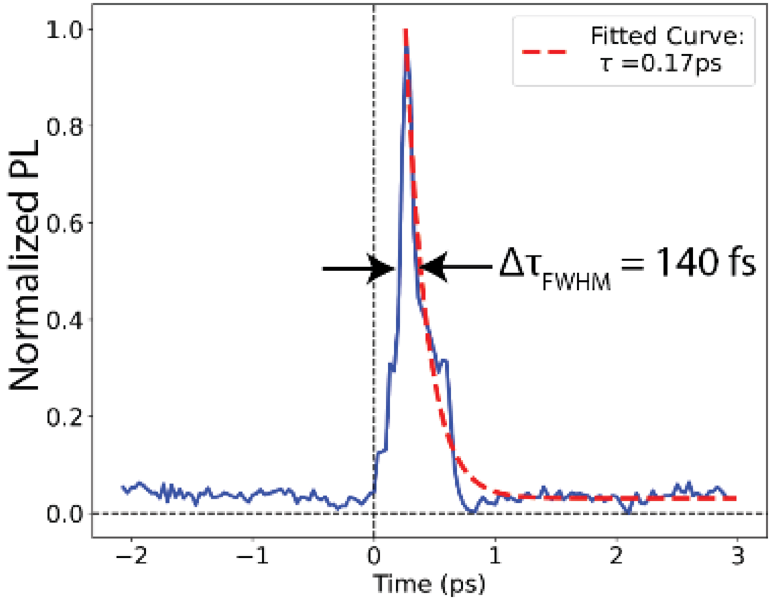
Submission under Review

Ultrafast transitions in InAs QDs creates fs-PL pulses

- The large temporal refractive gradients at 1250nm are determined by the lifetime of the electrons with $0.06m_0$ effective mass in GaAs
- The PL decay lifetime is governed by the hole thermionic activation process at high pump fluence ($2\text{-}3 mJ/cm^2$) in InAs QDs to 140fs pulses

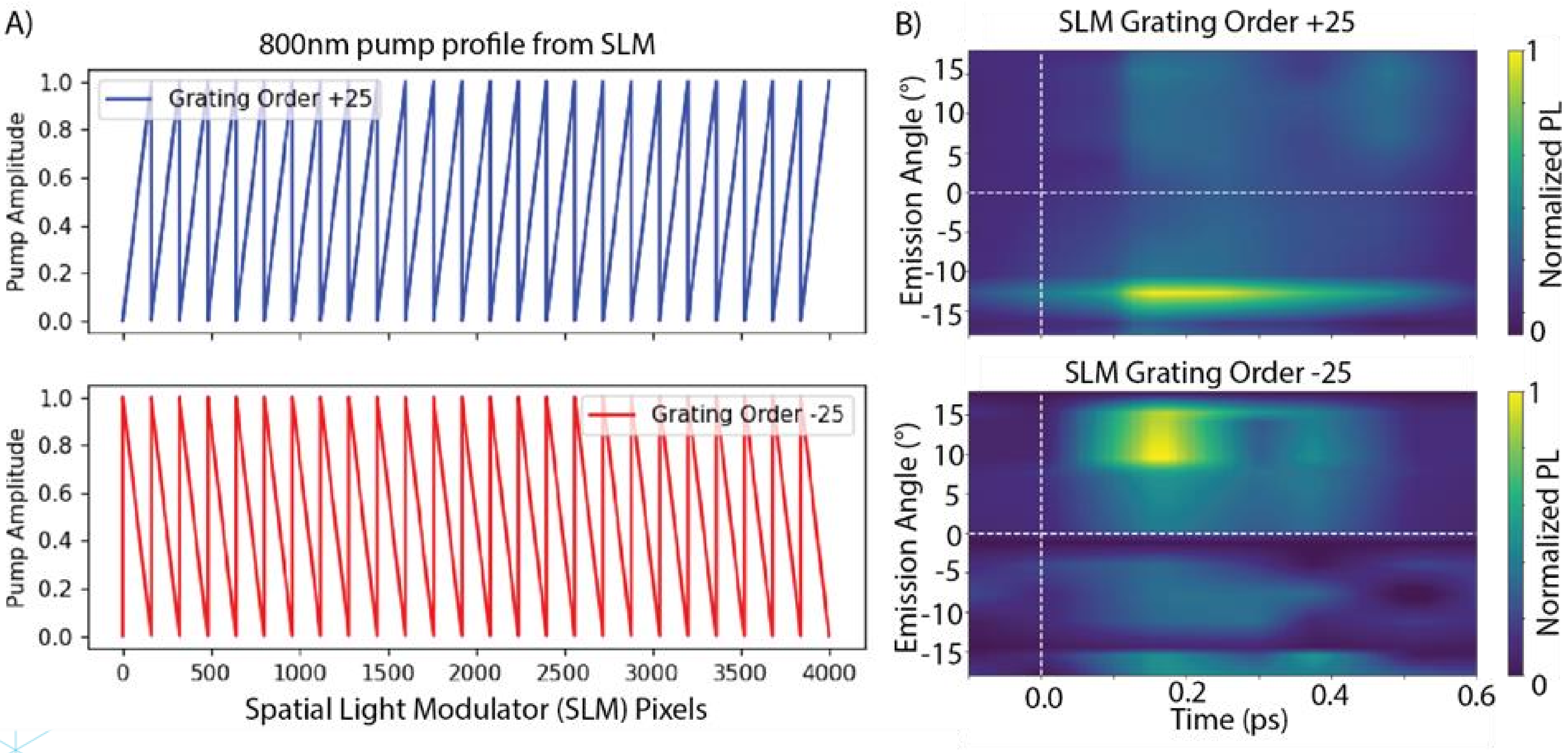






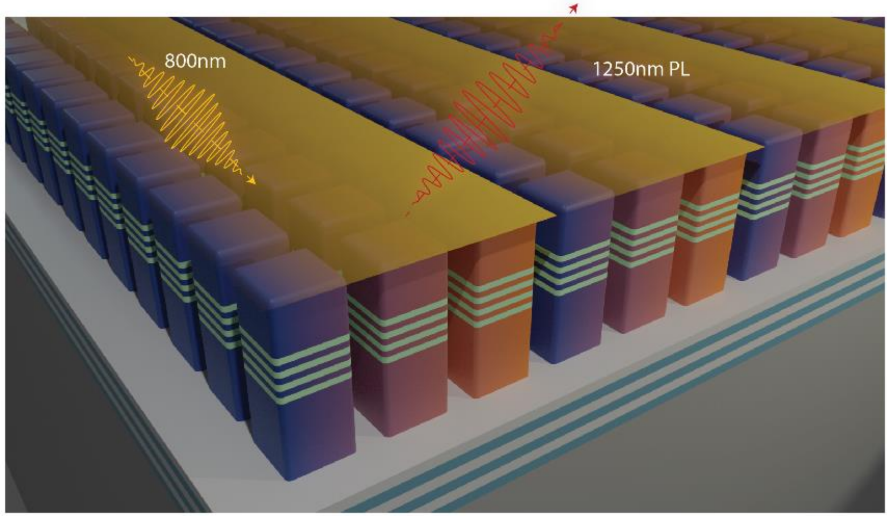
Submission under Review

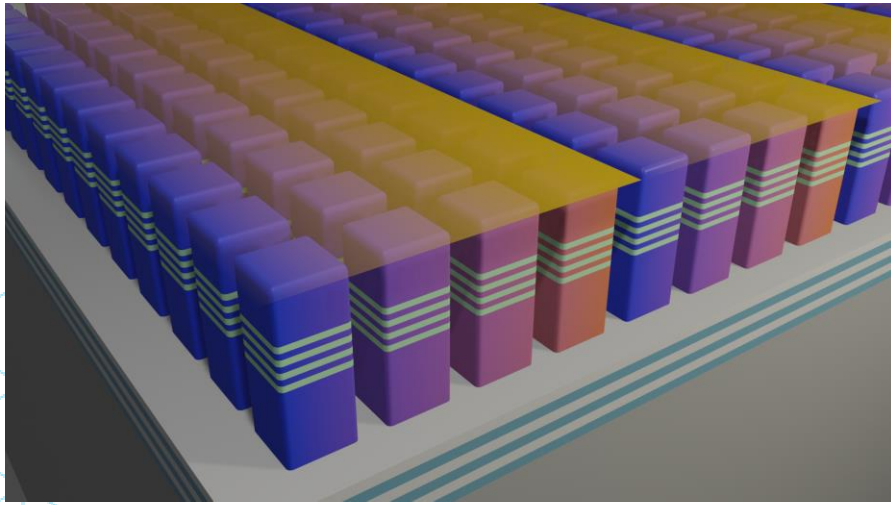
Femtosecond spatiotemporal dynamics of PL

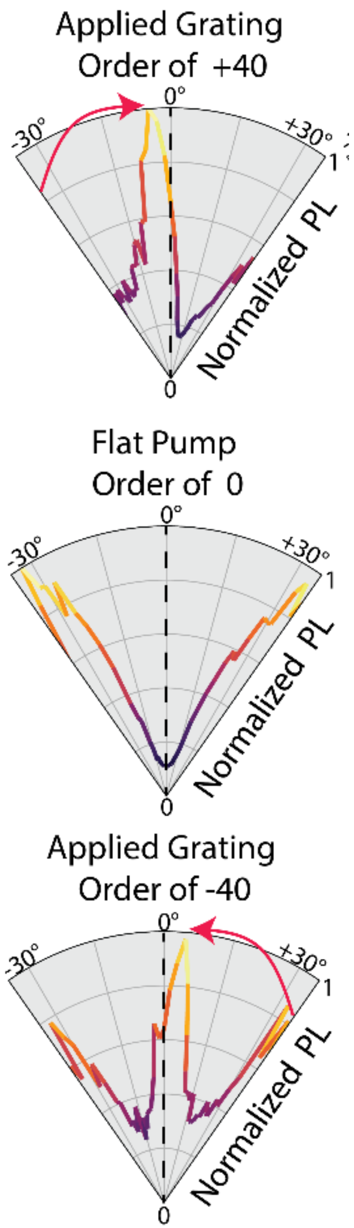


Submission under Review

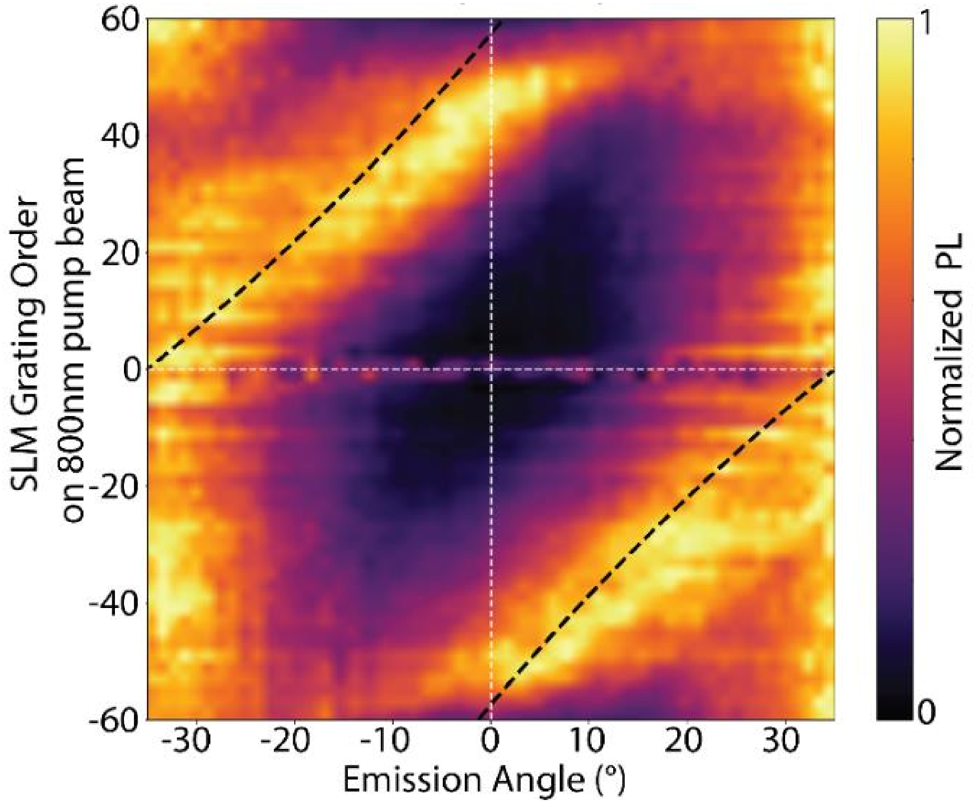
PL steering through momentum matched metasurfaces







Continuous Unidirectional Steering over 70°

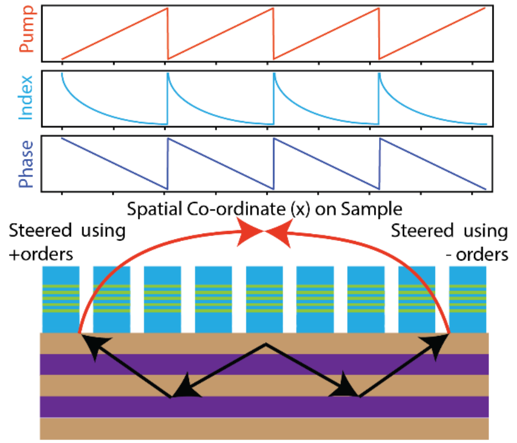


$$\overrightarrow{k_e} = \pm\overrightarrow{k_i} + \overrightarrow{k_M}$$

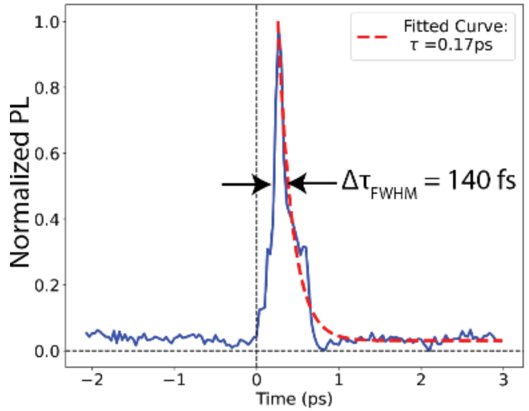
Submission under Review

Conclusion

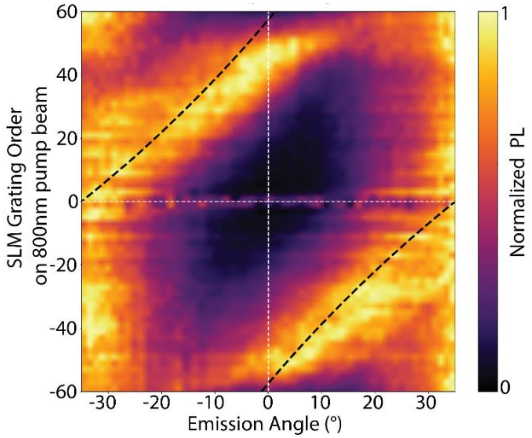
- Unidirectional dynamic PL steering with a combination of structured materials and structured optical pumping



- Ultrafast transitions in InAs QDs enables the generation of 140fs PL pulses



- Sub-ps PL pulse steering demonstrated over 70° field of view with close matching with analytical model



Acknowledgements

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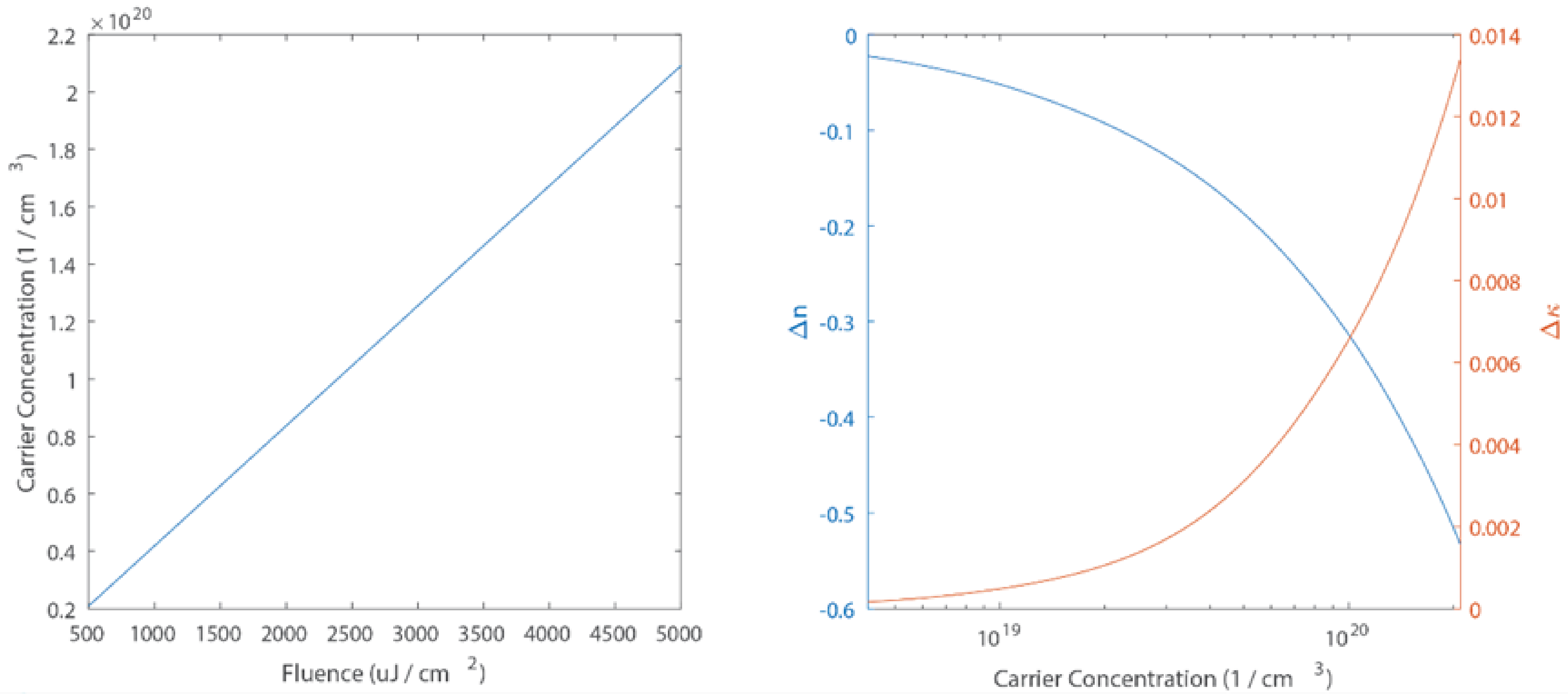
Contributing work from

Nicholas J Karl, Sadhvikas Addamane, Sylvain Gennaro, Michael Sinclair, Igal Brener, Ting S. Luk, Raktim Sarma, Oleg Mitrofanov, Jayson Briscoe, Sueli Skinner - CINT

Supplementary Information

Refractive Index change in GaAs



Lack of PL steering from unpatterned films