

# GeSn Topological Photonic Crystal Laser

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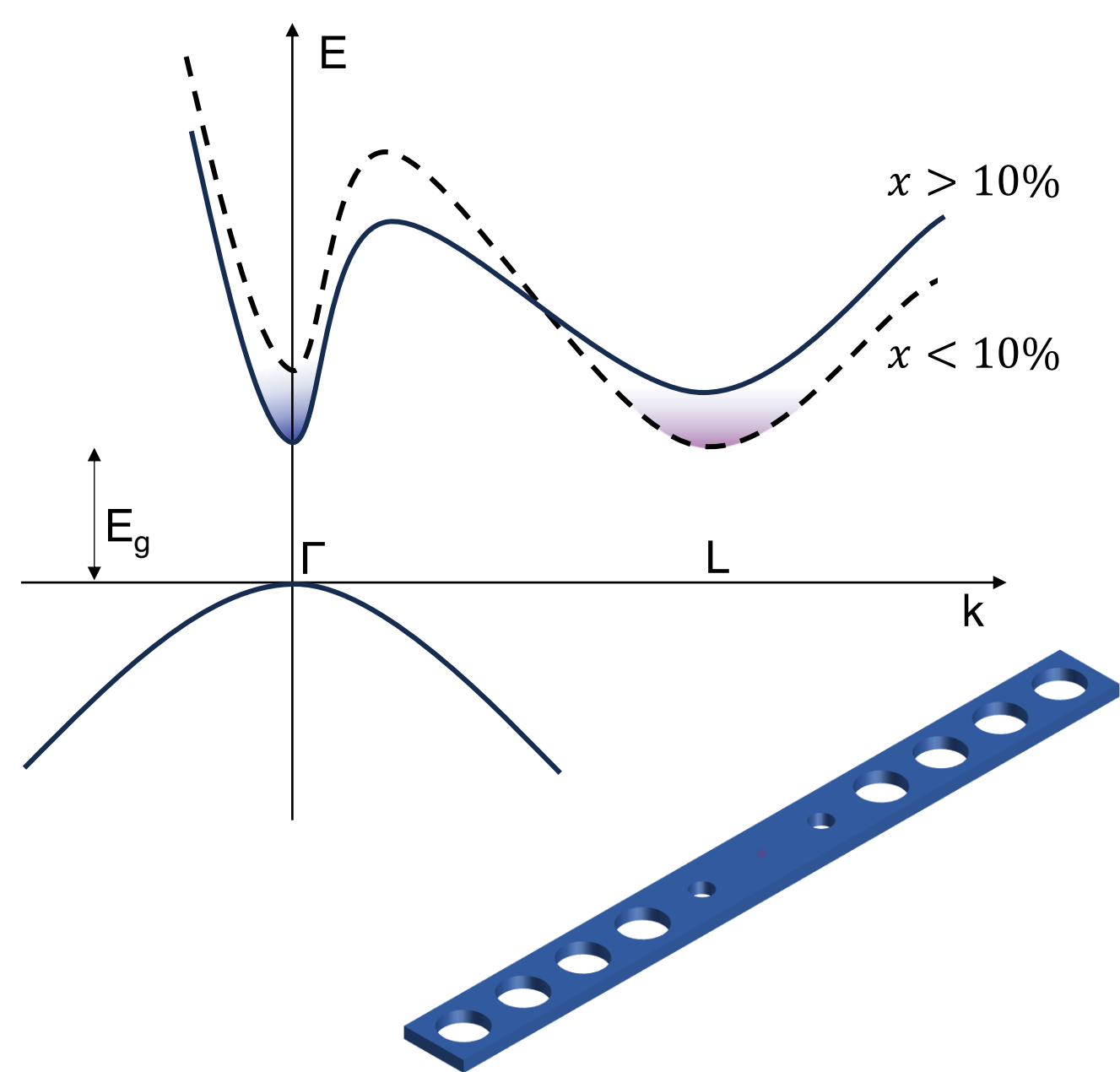
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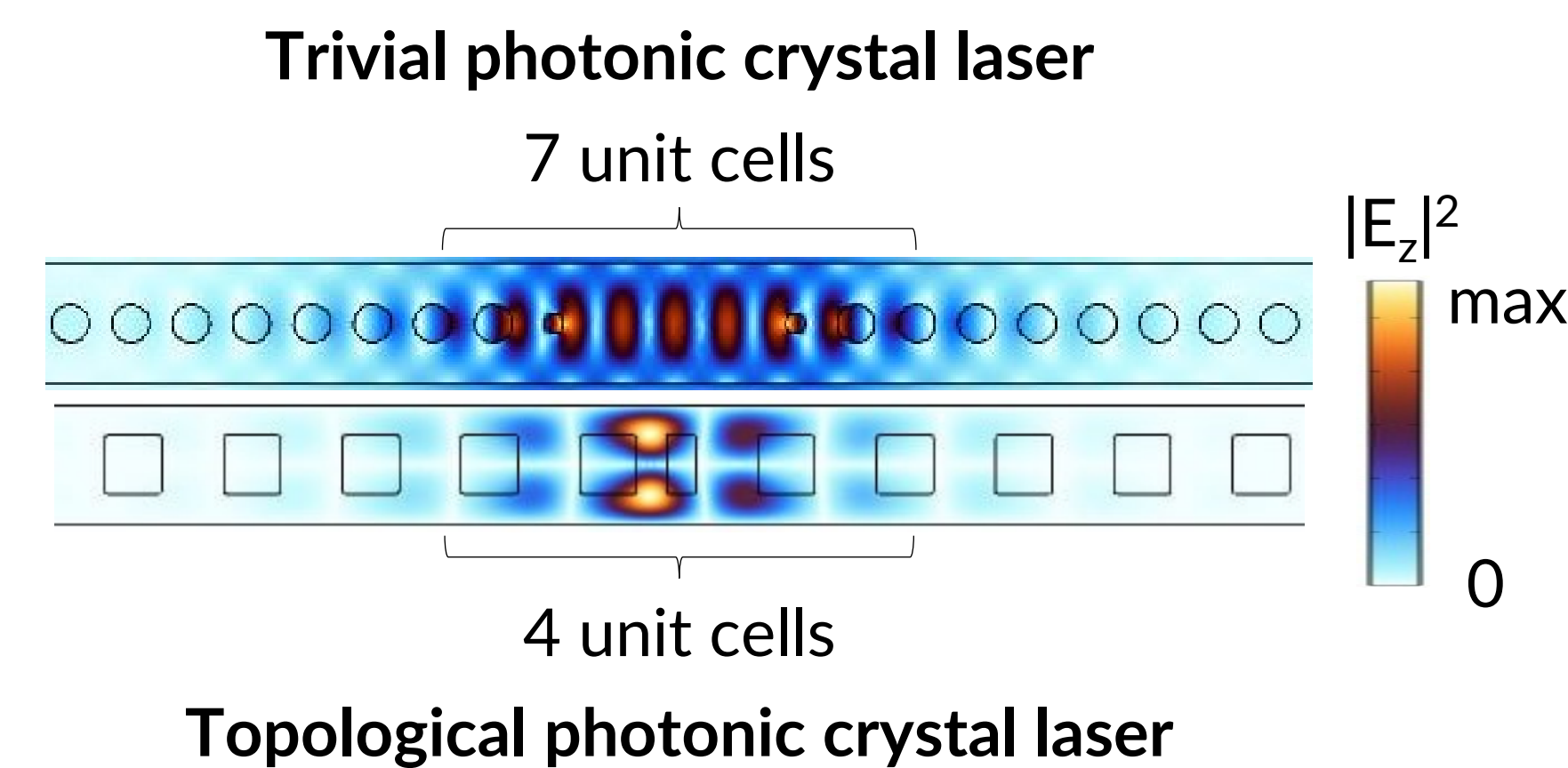
Ge<sub>1-x</sub>Sn<sub>x</sub> alloys have shown great promise as direct bandgap materials enabling the seamless integration of laser emitters into Si photonics. [1] While the performance of photonic devices has steadily improved achieving efficient low-threshold lasing, their use in the MIR with group-IV material systems remains challenging. Topological photonics offers a promising but largely unexplored solution, enabling symmetry-protected modes and robust light confinement, particularly where traditional cavities struggle with confinement and defect management. This approach has yet to be applied to CMOS-compatible laser platforms.

## Lasing with Ge<sub>1-x</sub>Sn<sub>x</sub> alloys



Direct bandgap in Ge<sub>1-x</sub>Sn<sub>x</sub> alloys have been already achieved by incorporating >10 at.% Sn, through precise control of growth kinetics to enhance Sn incorporation and suppress segregation. Thanks to this accomplishment it is now possible to integrate efficient group-IV emitters onto Si photonics. [1-2]

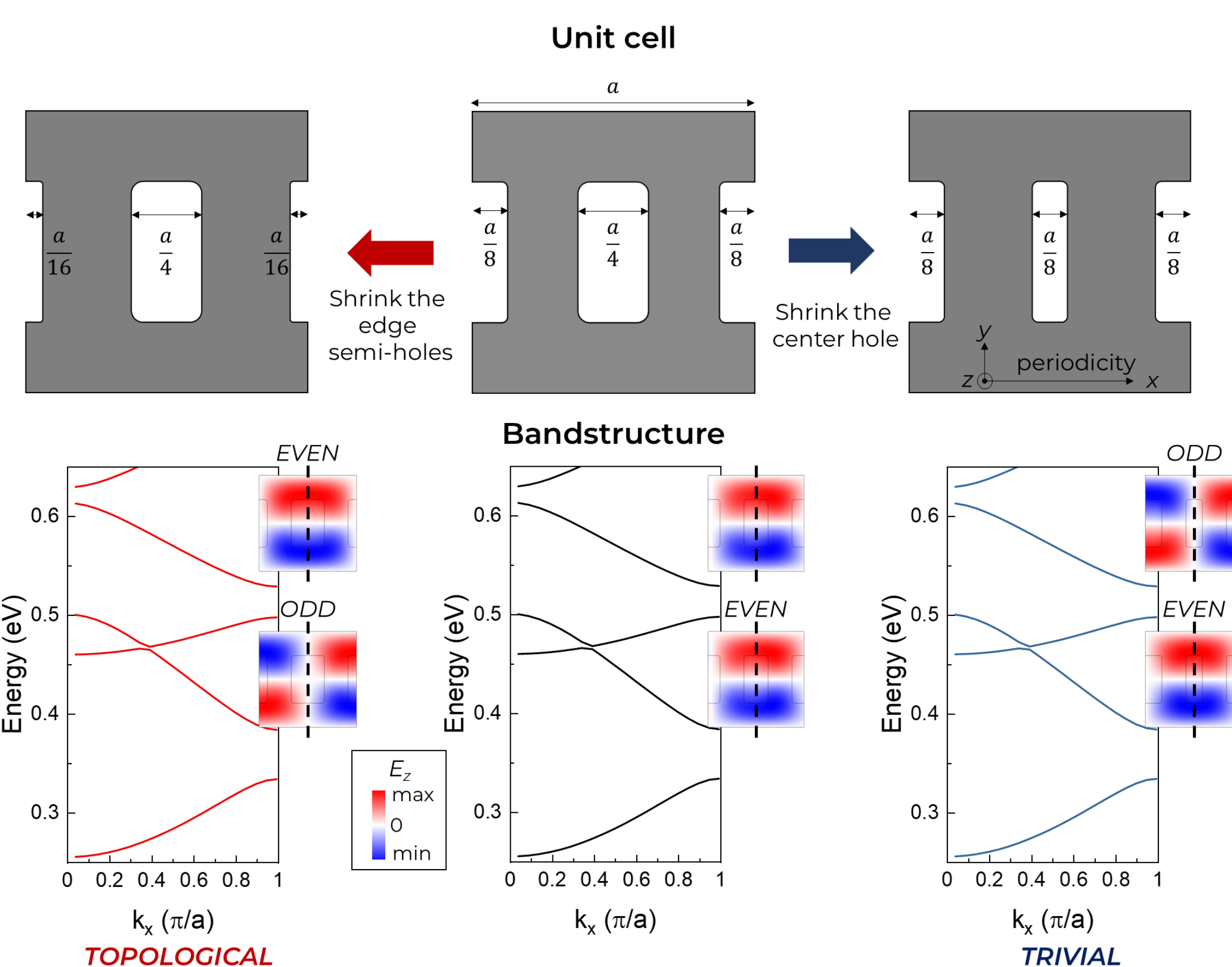
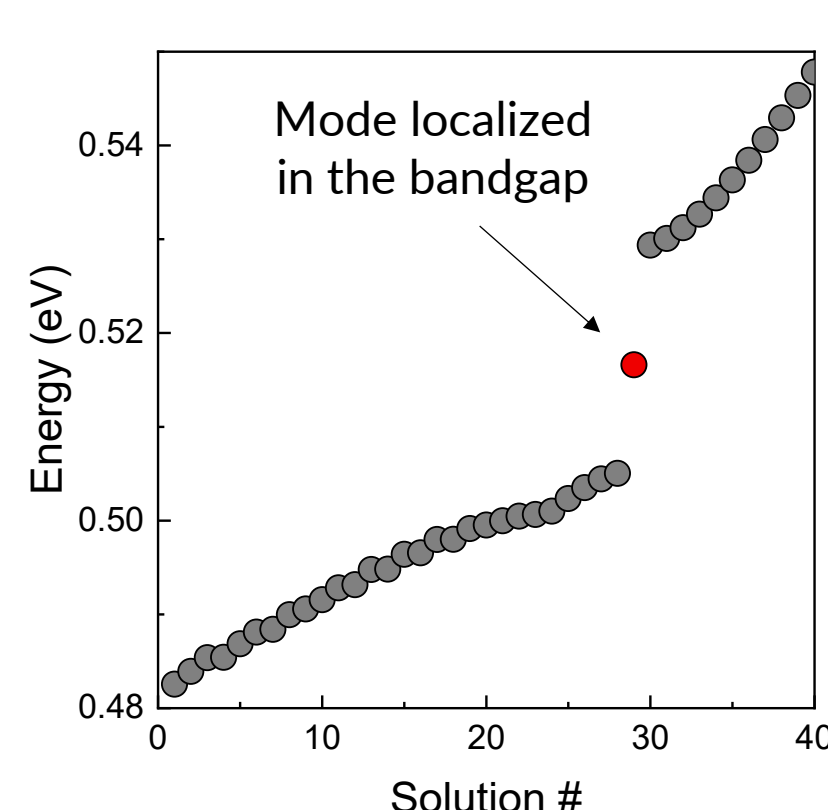
## Exploring CMOS-compatible topology



At the interface between domains of photonic crystals with distinct topological invariants, these display strongly localized states. If properly designed, topological photonic crystal (TPC) lasers can confine light into a subwavelength cavity, possibly in a tighter volume with respect to their non-topological counterparts, [3]

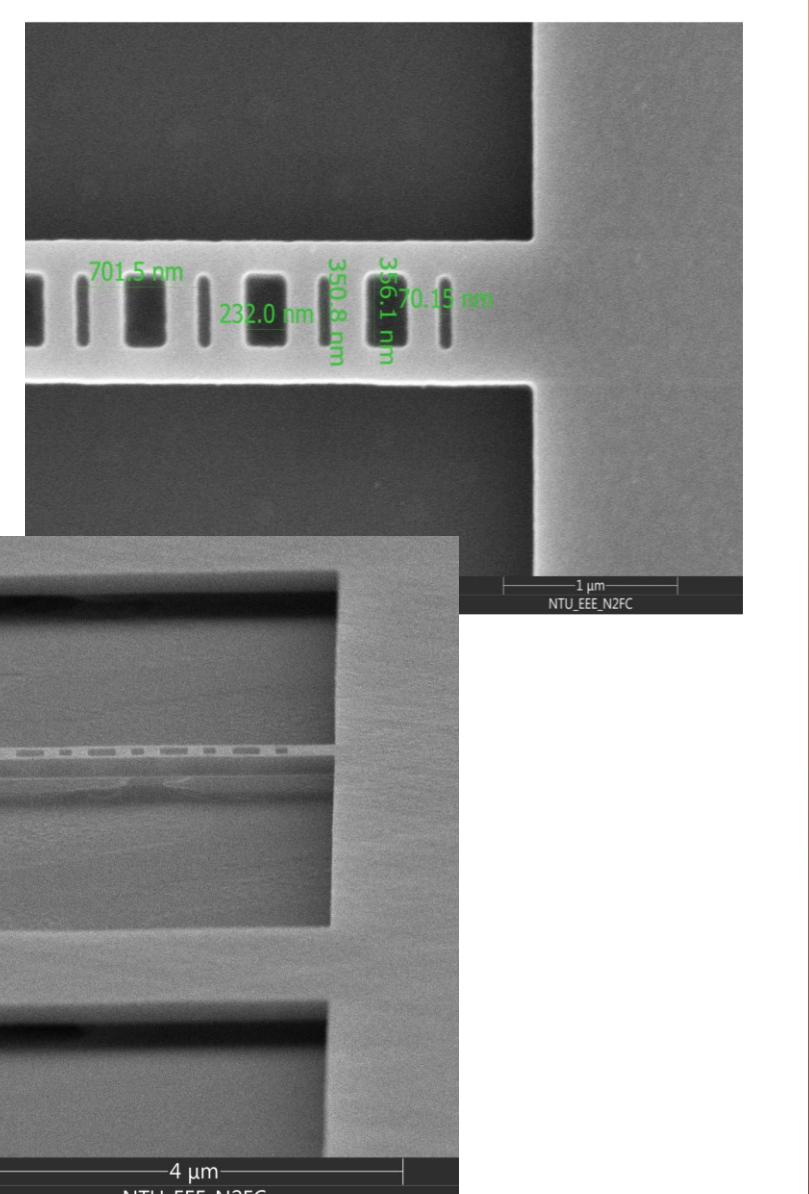
## Device design

The topological transition is characterized by the inversion of one of the system's defining degrees of freedom while preserving the same photonic bandstructure in distorted unit cells. [4] By shrinking the center and edge holes of the unit cell, we keep the symmetry in the two domains, but the electric field's parity gets inverted. When the two domains are put in contact, localized modes appear at their interface and well inside the photonic bandgap.



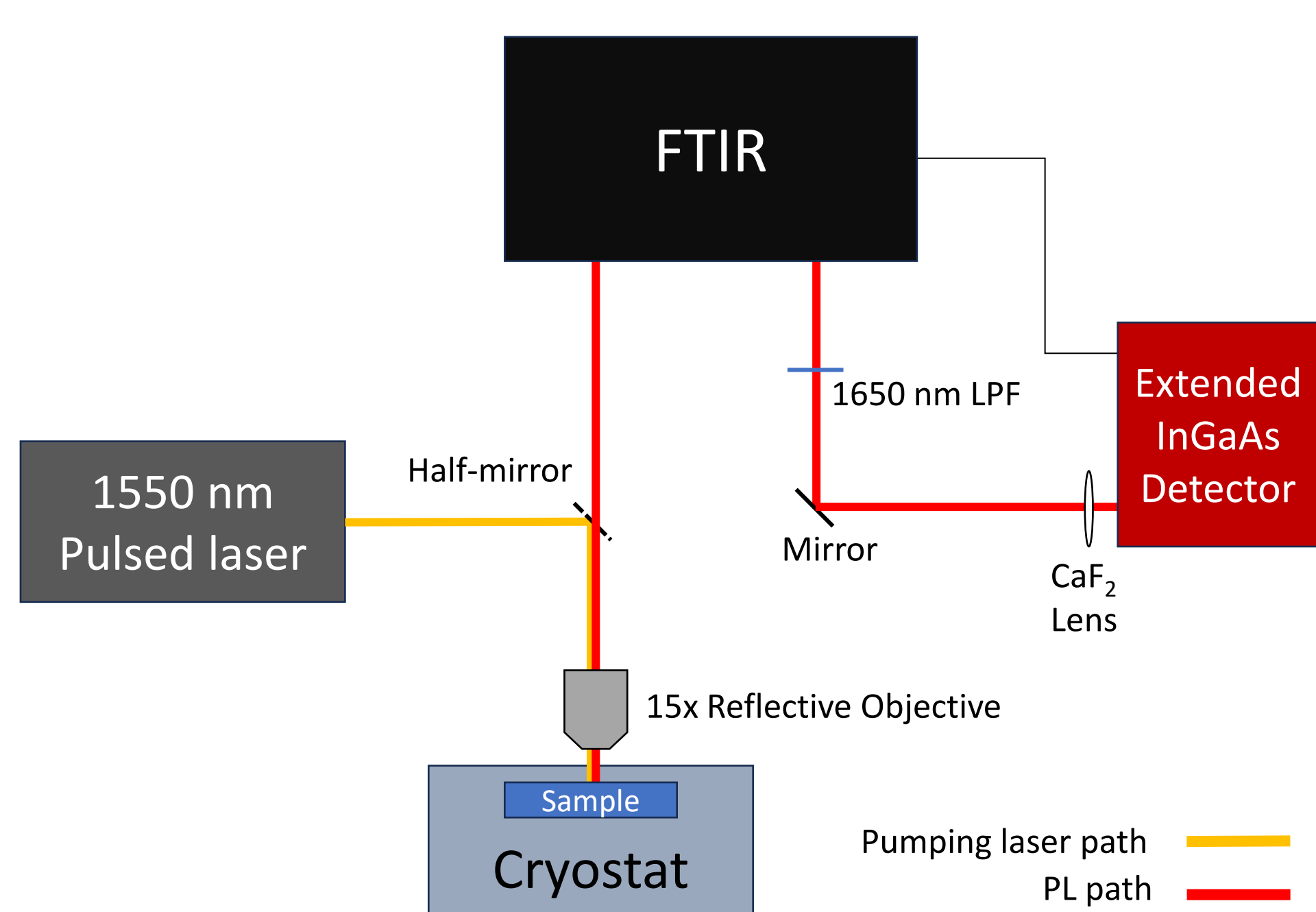
## Fabrication

- Room temperature bonding
- Grinding of Si
- CMP to remove Ge and reduce GeSn
- EBL patterning
- Alumina etching

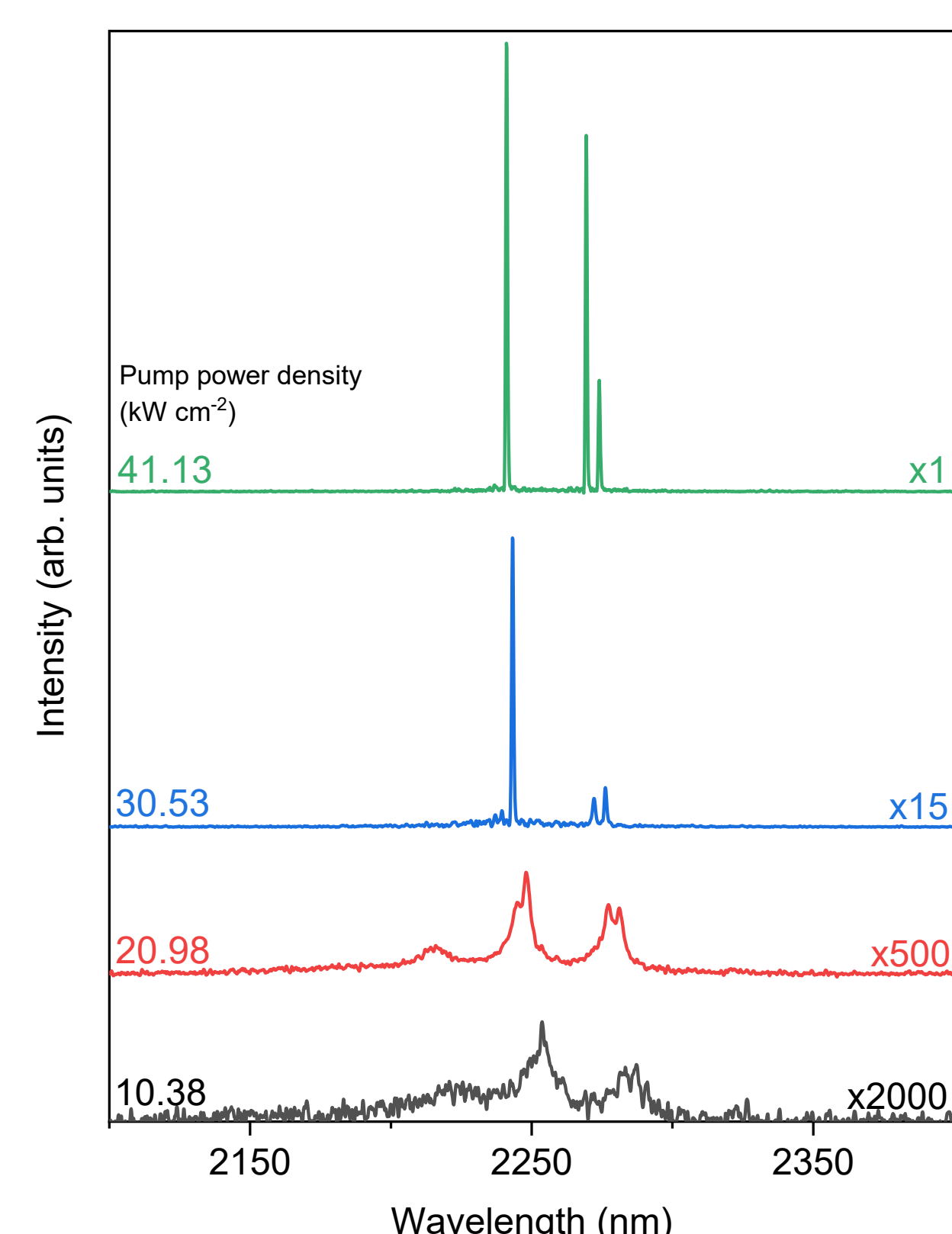


## Preliminary performance evaluation

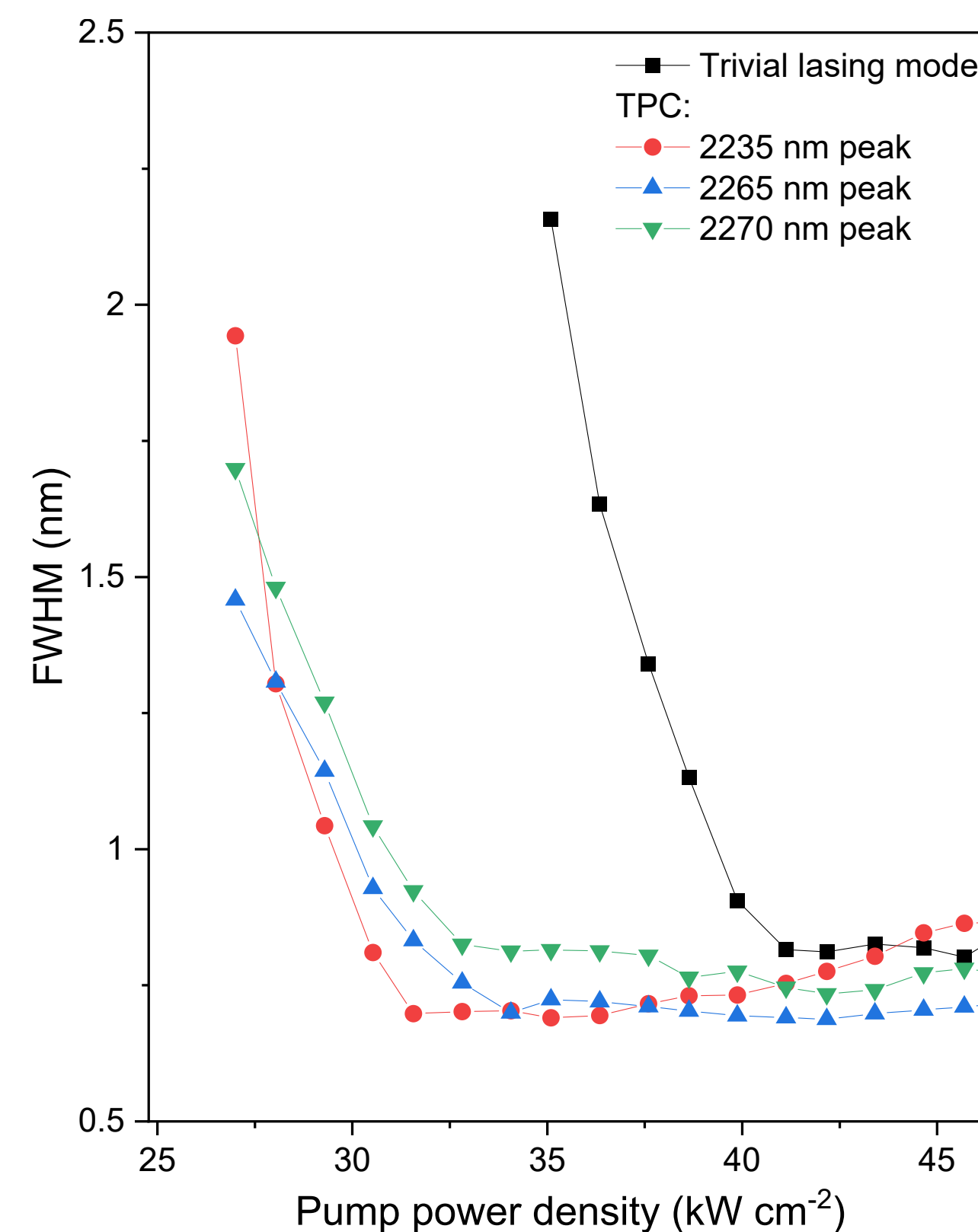
### MIR measurement setup scheme



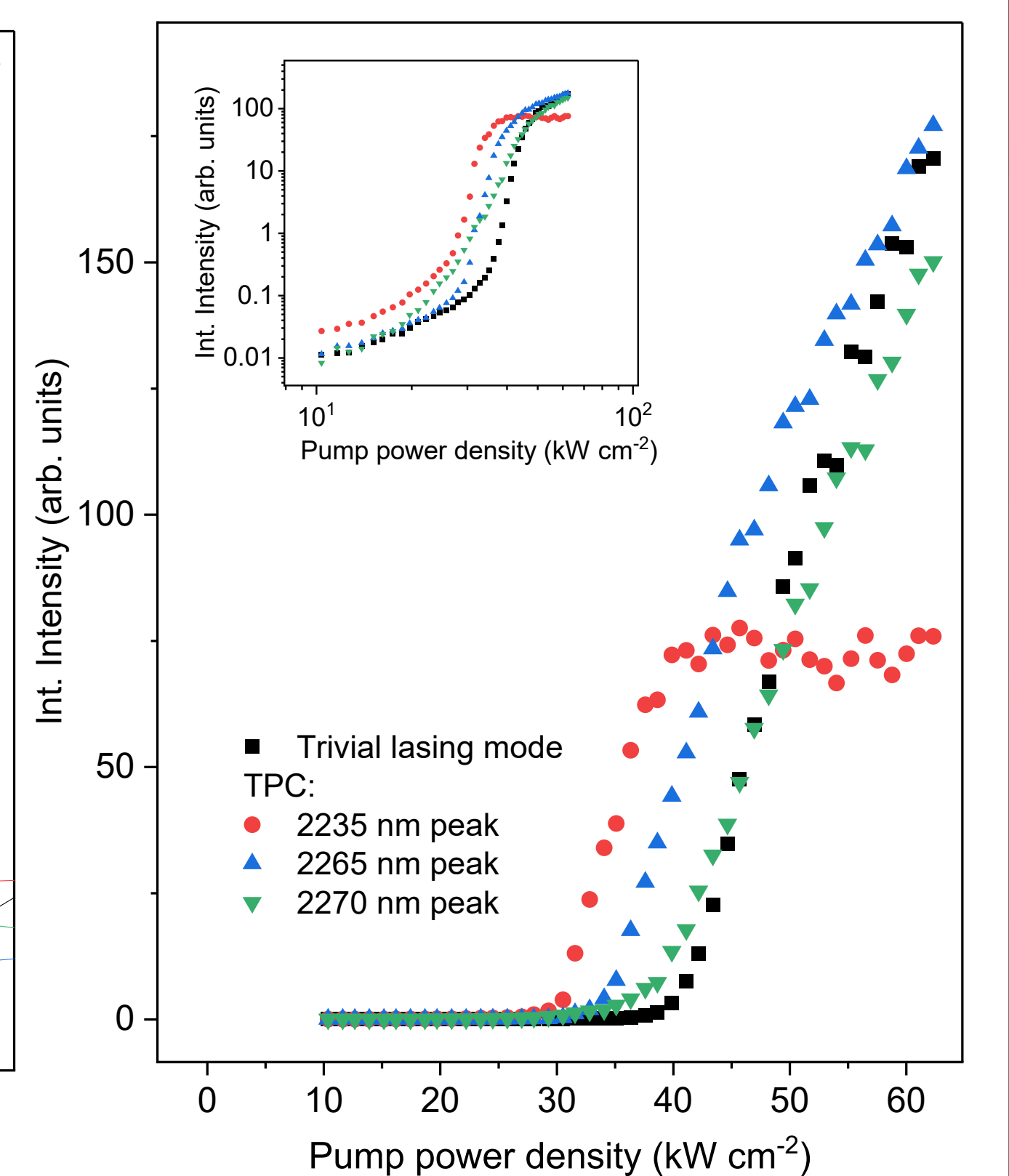
### PL spectra at different pump power densities @9K



### FWHM at different pump power densities @9K



### L-L curves @9K



## References

- [1] H.-J. Joo, et al. *Applied Physics Letters* 119, 201101 (2021).
- [2] O. Moutanabbir, et al. *Applied Physics Letters* 118, 11 (2021).
- [3] T. Ozawa, et al. *Reviews of Modern Physics*, 91(1), 015006 (2019).
- [4] P. St-Jean, et al. *Nature Photonics* 11, 651-656 (2017).

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