# Enhancing Concentrating Photovoltaic (CPV) Efficiencies with Photonics

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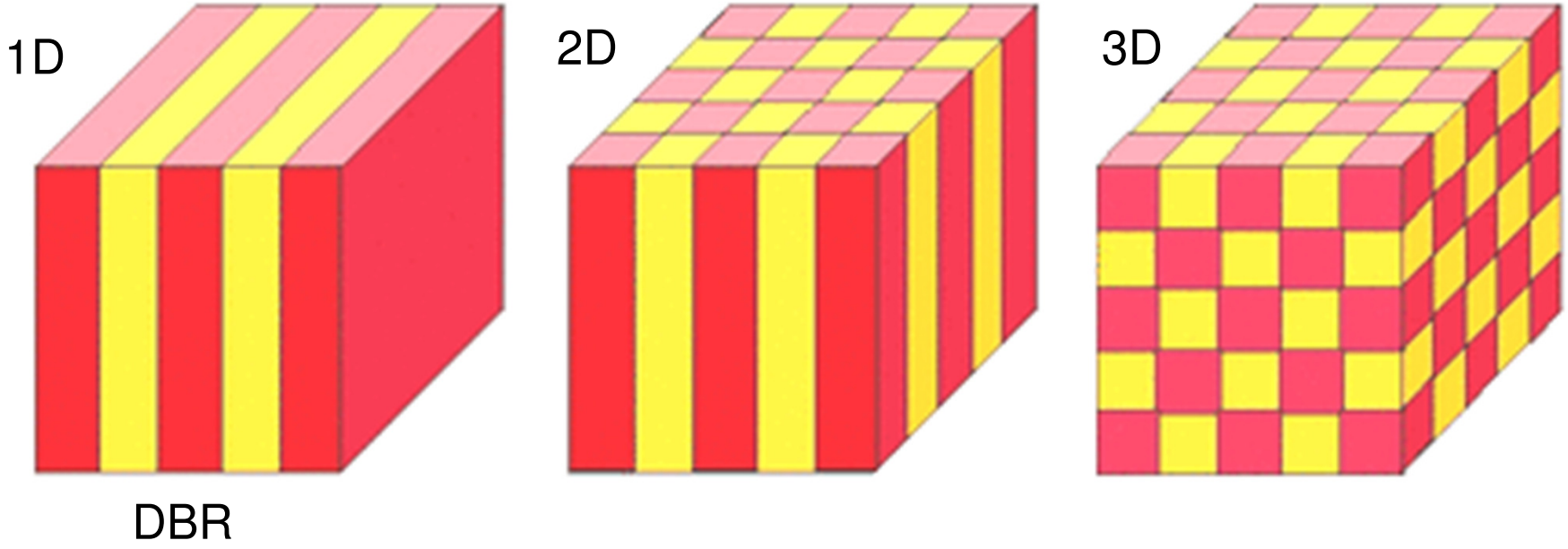
March 26, 2012

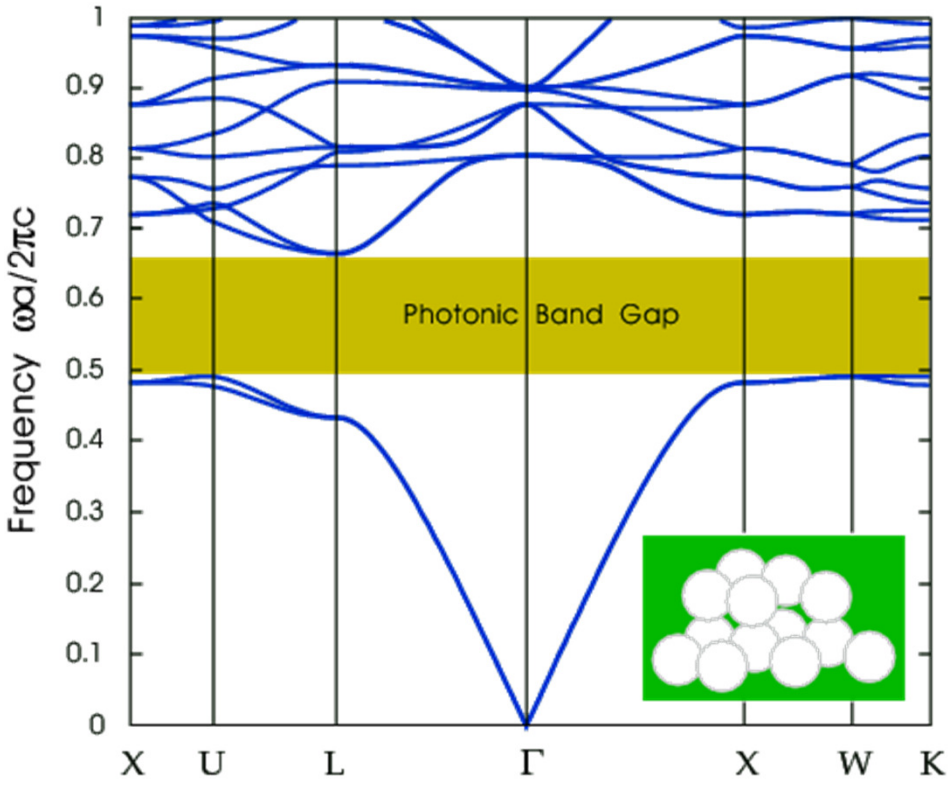
# Photonic Crystals (PhCs)




- Periodic dielectric media
- Gives rise to EM Bloch modes, characterized by band structure

# Photonic Bandgap (PBG)

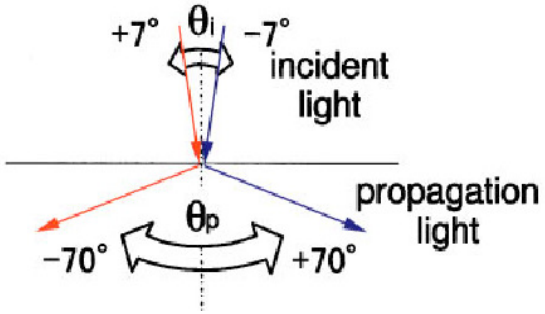
- A “gap” in the photonic band structure frequencies
- Ubiquitous for 1D structures, and some 2D and 3D structures
- Scale-invariance allows tuning over most EM frequencies

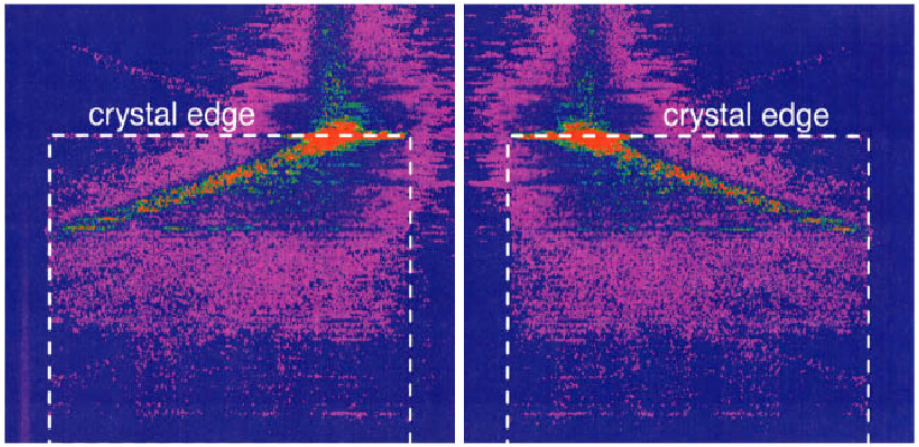



PBG for diamond structure

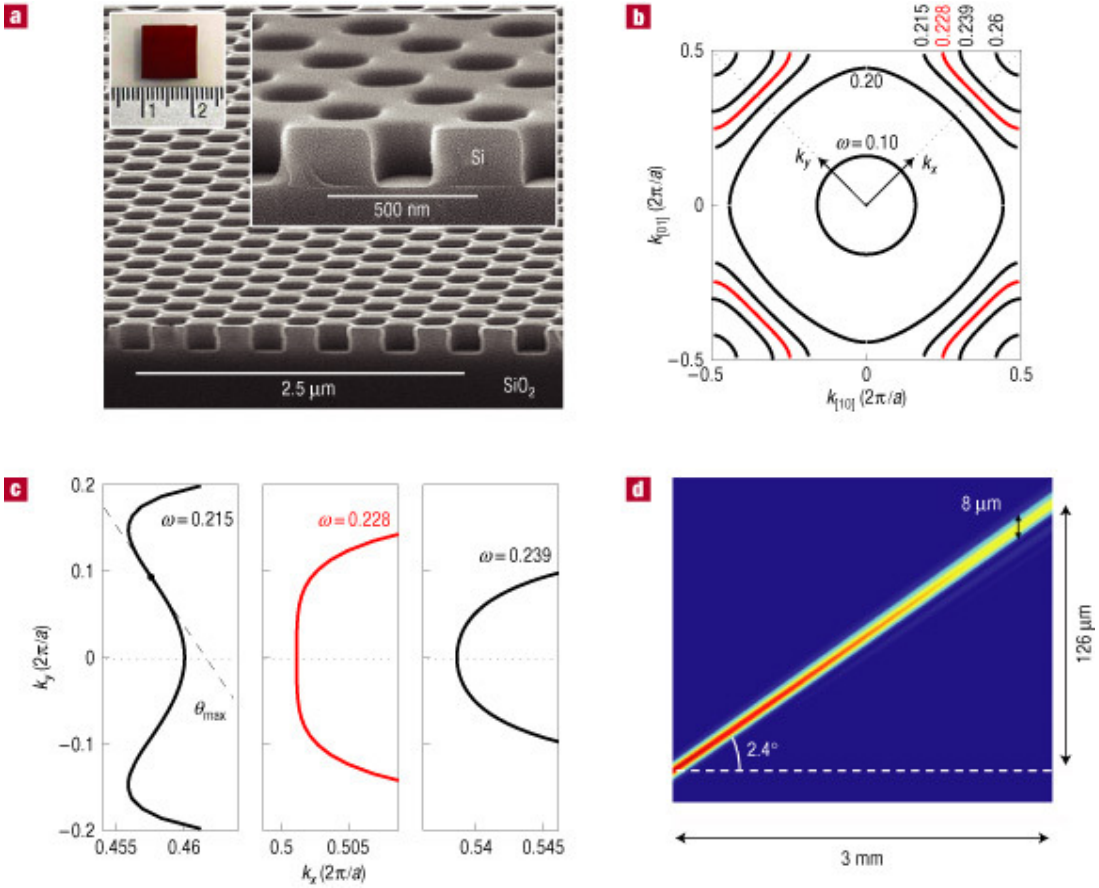
Joannopoulos *et al.*, *Photonic Crystals* (2008)

# Low Loss Spectral Splitting I: Superprisms+Supercollimation



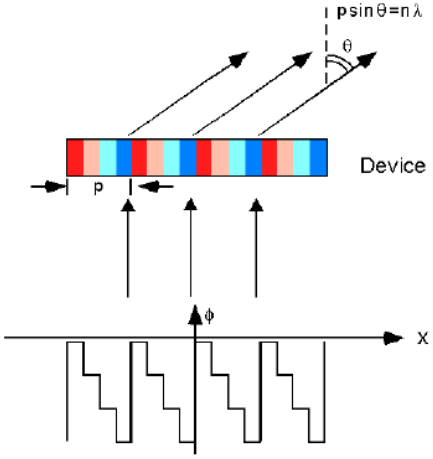



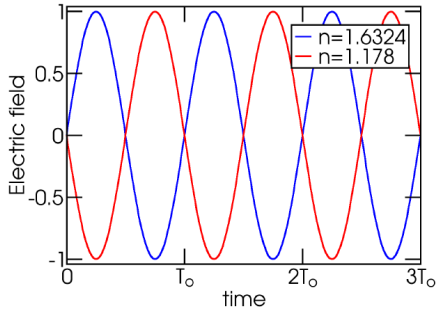

Kosaka, *PRB* **58**, R10096 (1998).



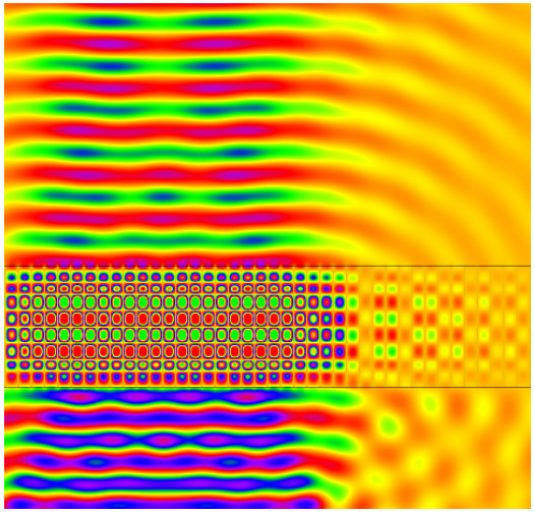

P. Rakich *et al.*, *Nature* (2006)

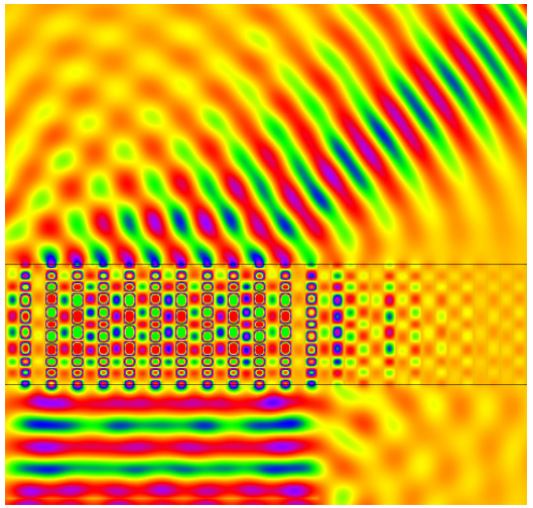
# Low Loss Spectral Splitting II: Resonant Beam Steering




$$\cot\phi = \sum_i \frac{2}{\Gamma_i}(\omega - \omega_i)$$

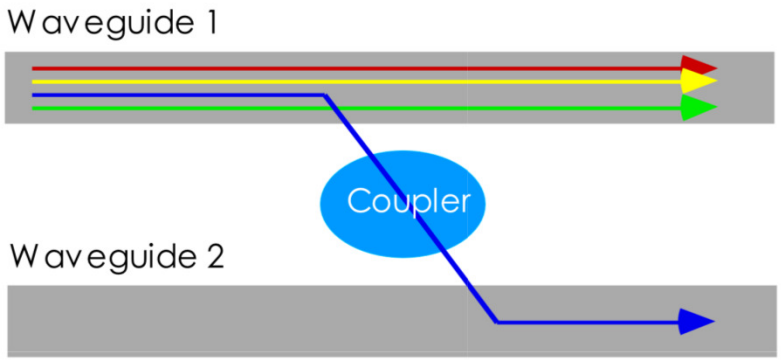




1st target frequency  2nd target frequency

P. Bermel, Ph.D. Thesis, MIT Physics (2007)

# Low-Loss Spectral Splitting III: Channel-Drop Filters



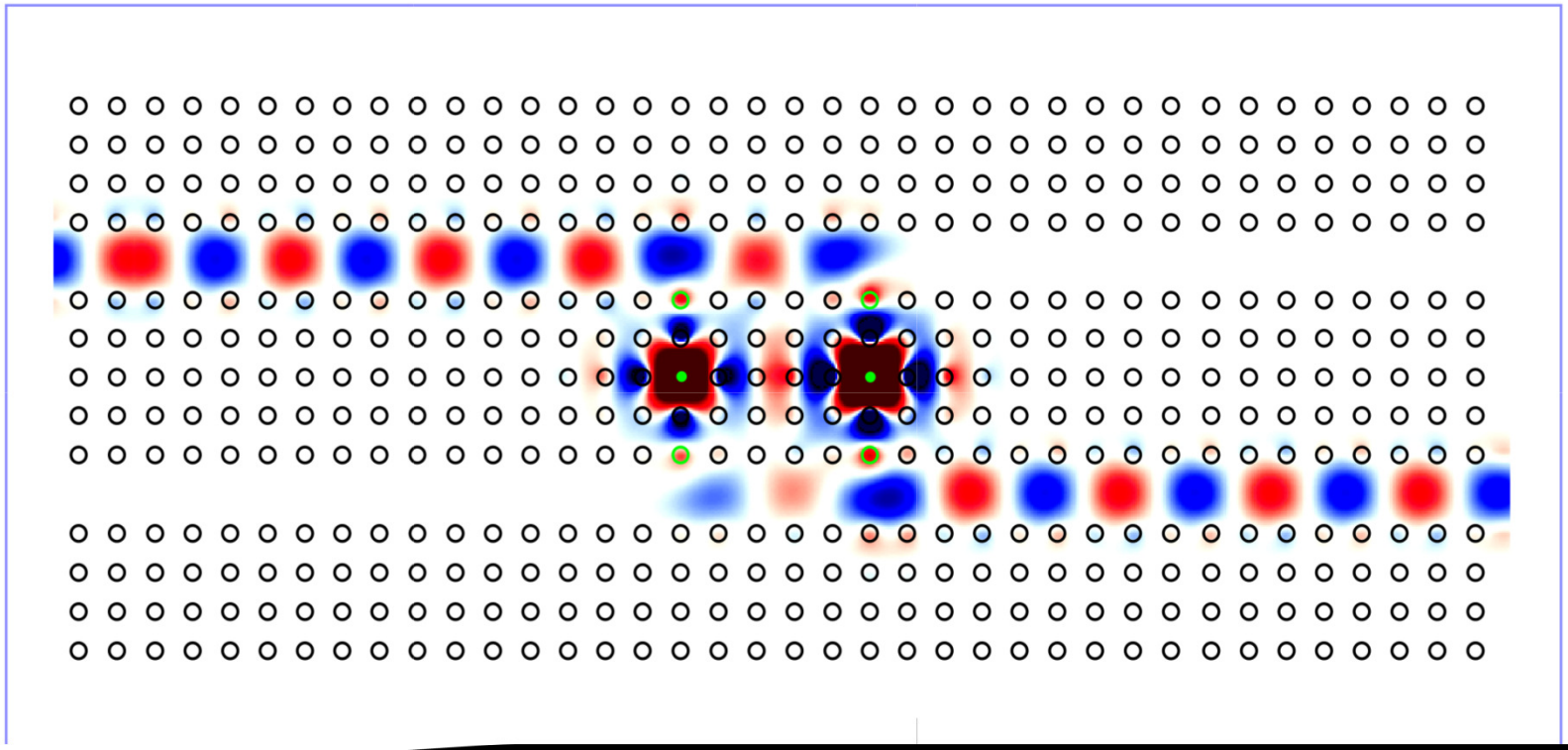

*Criteria for Perfect Channel-dropping*

*Two resonant modes with even and odd symmetry*

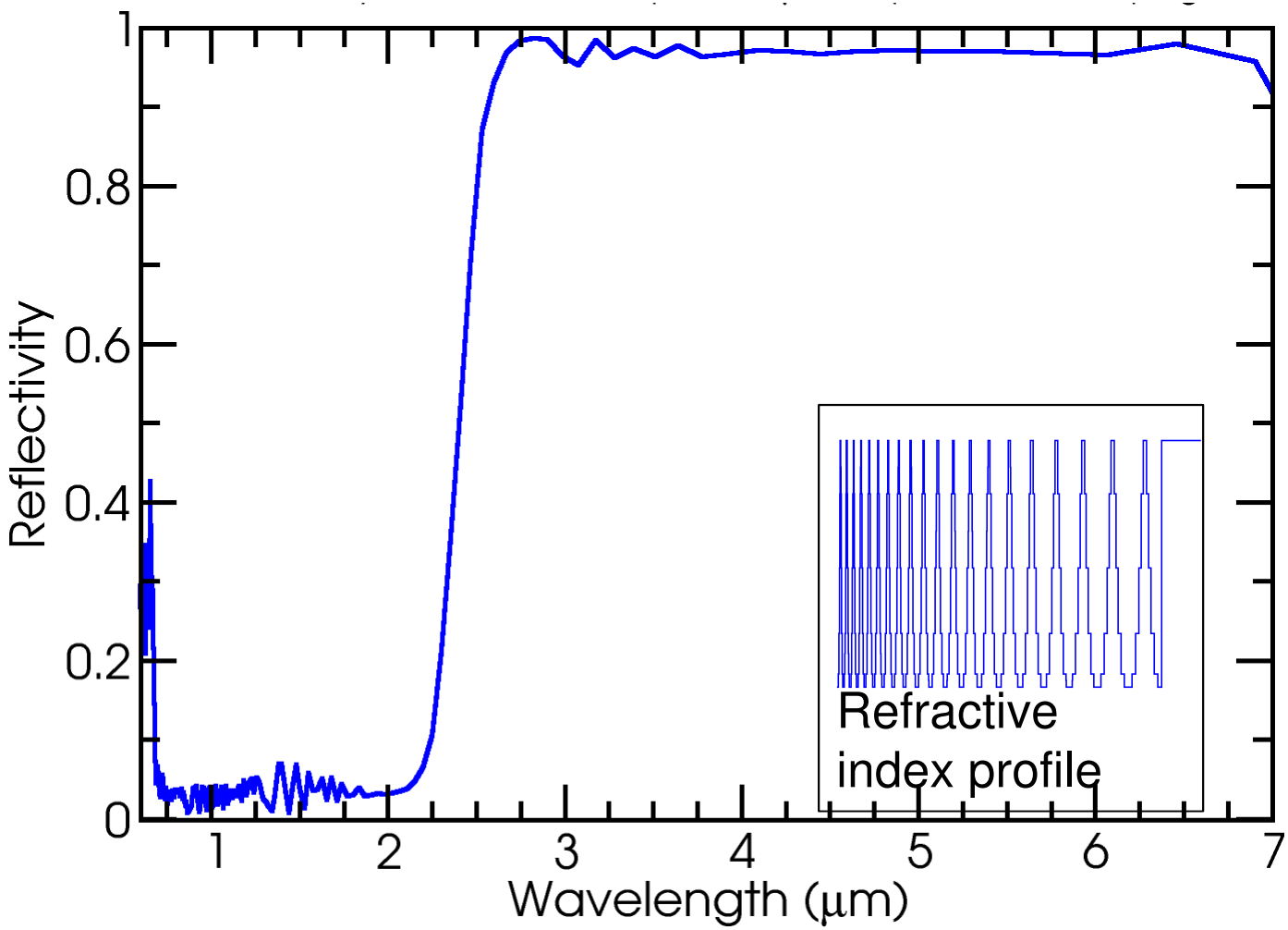
*Modes must be degenerate*

*Modes must have equal decay rates*

[ S. Fan *et al.*, *Phys. Rev. Lett.* **80**, 960 (1998) ]

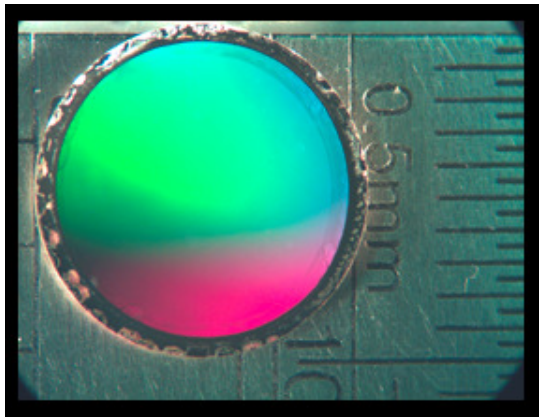


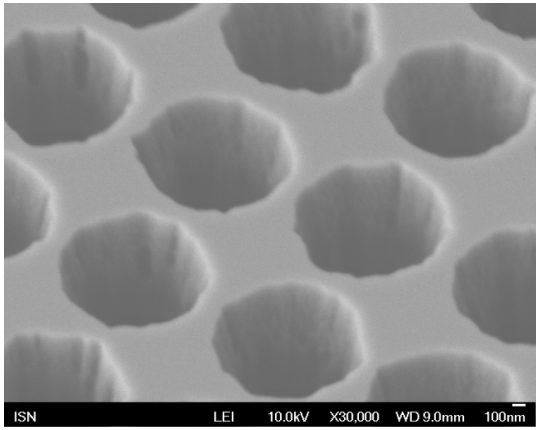
# Photon Recycling with Rugate Filters



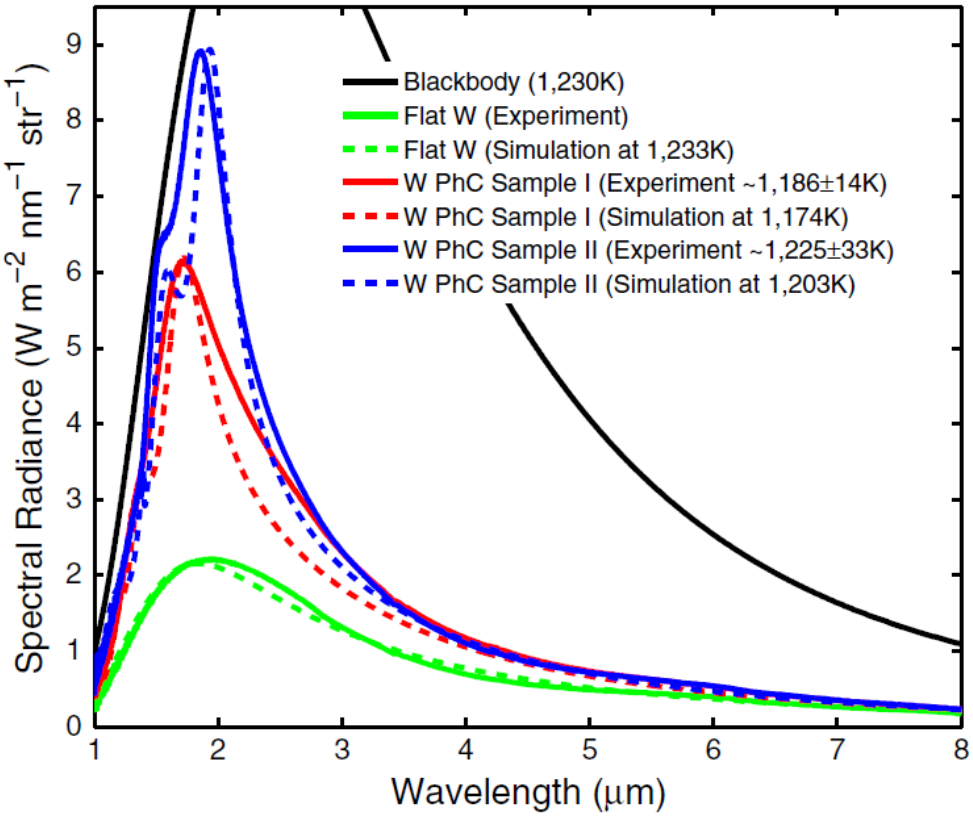

Can generate sharp cutoff with 60 periods of silicon oxynitride

# PhC-Enhanced Radiative Absorption and Emission





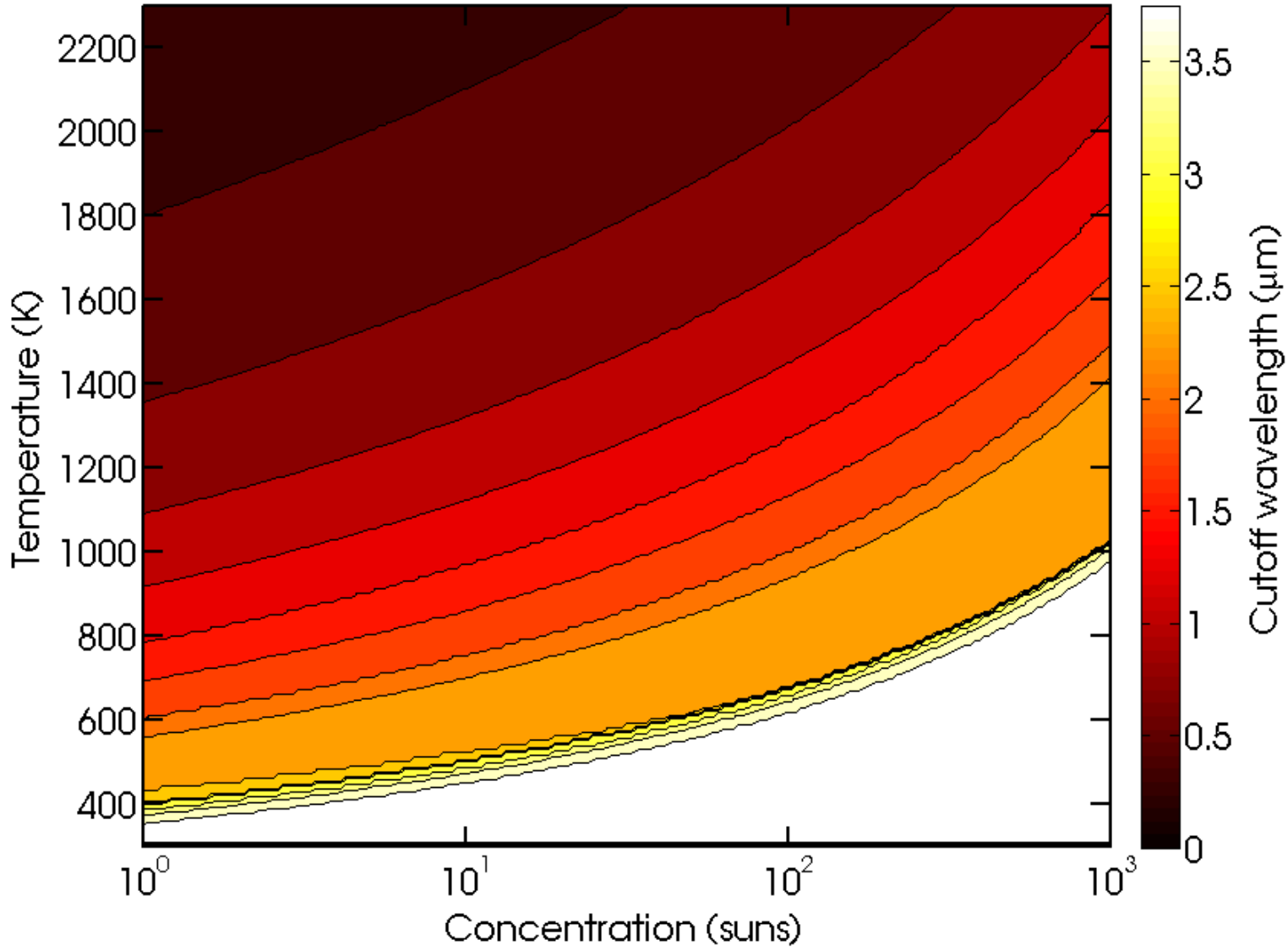

Fabricated Samples



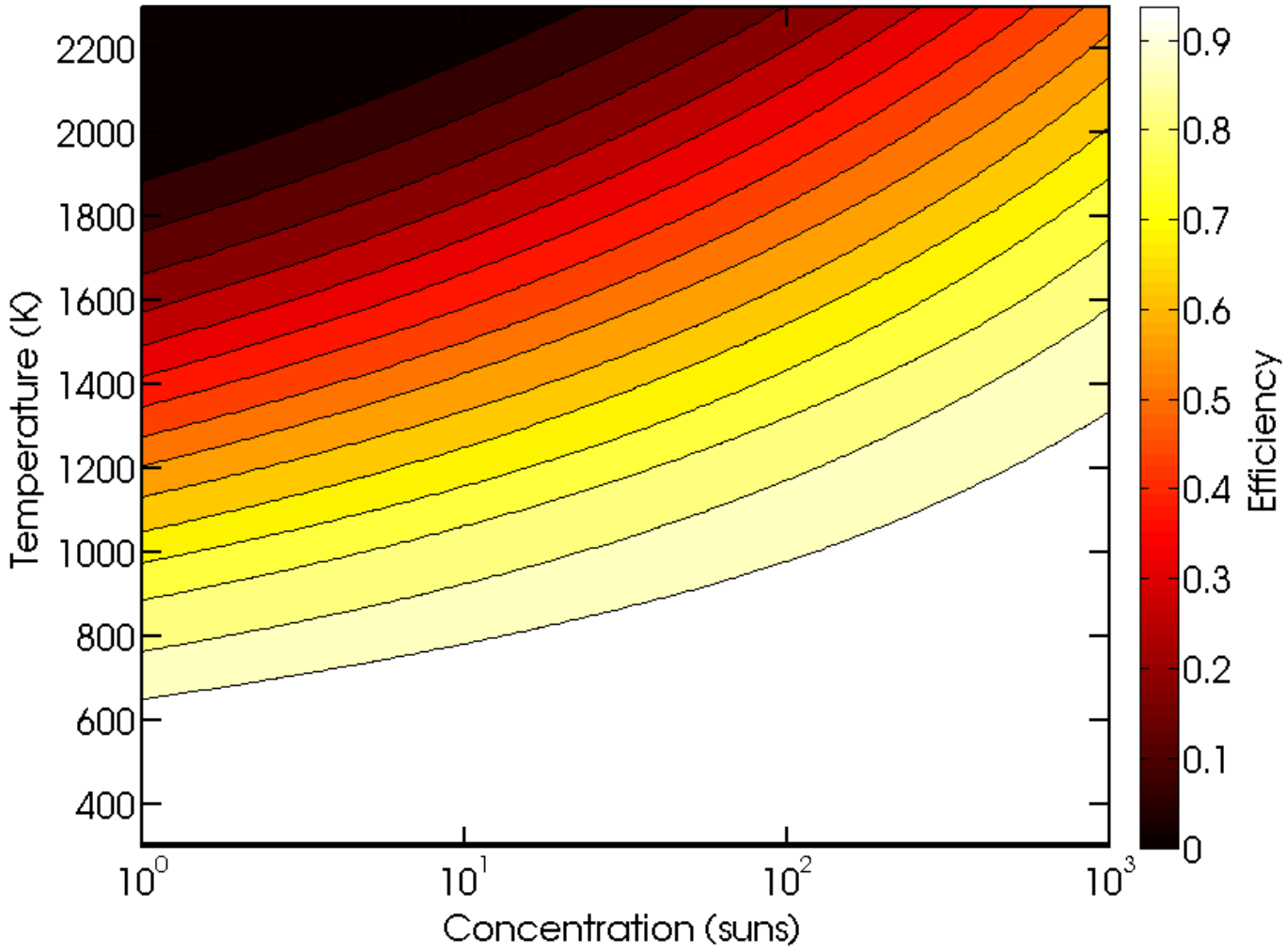

Measured Radiation Data

Y.X. Yeng et al., *PNAS* **109**, 2280 (2012)

# Selective Absorber: Ideal Cutoff Wavelength

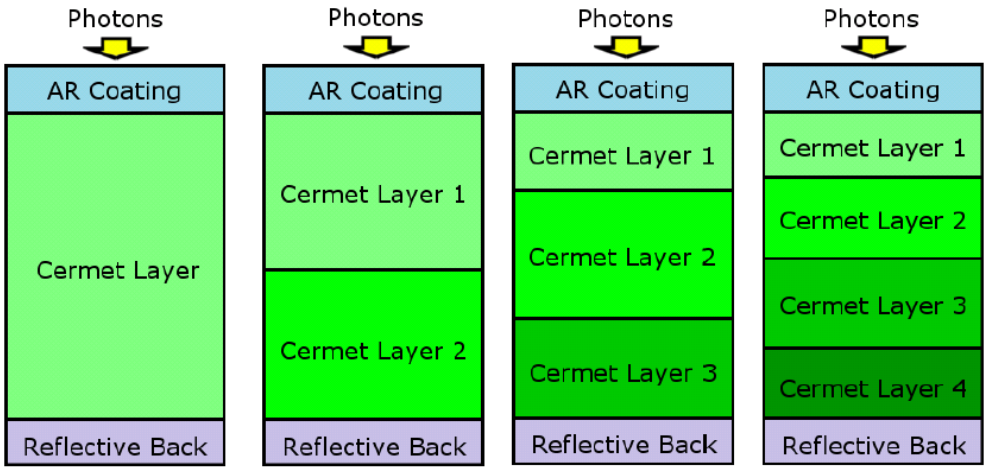


# Selective Absorber: Maximum Thermal Transfer Efficiency



# Cermet Selective Solar Absorbers: T=1000 K (100 suns)

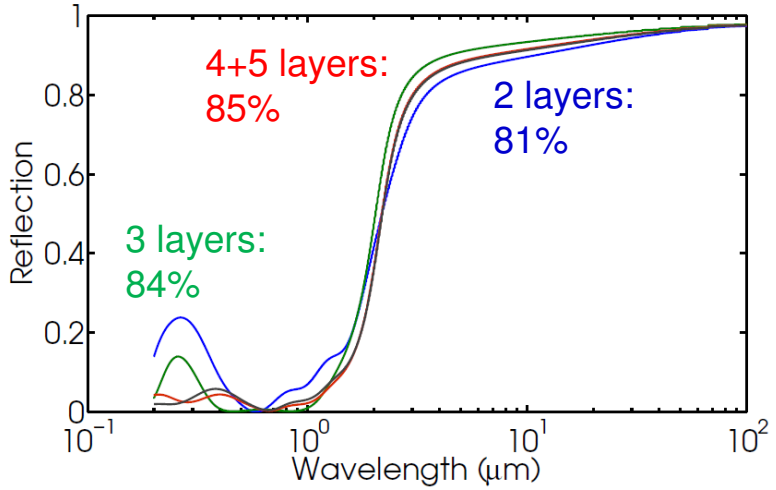
4 Selective Absorber Designs

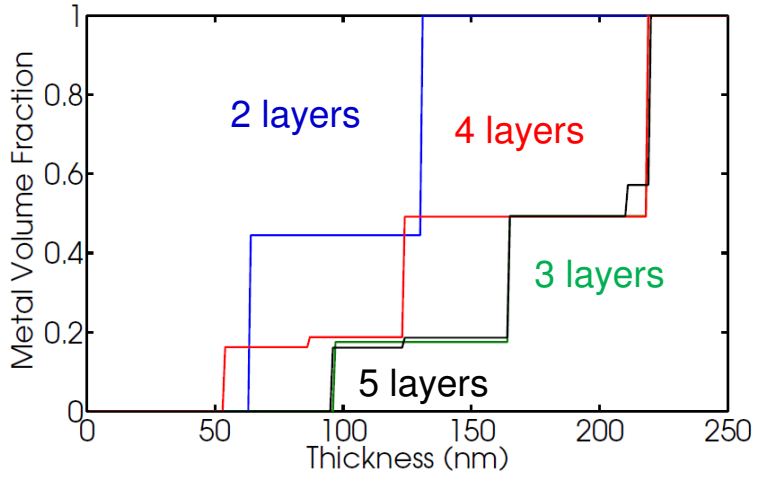



5 layer optimization yields:

$\eta_t = 85\%$; $\alpha = 95\%$

$\varepsilon = 17\%$




D. Chester *et al.*, *Opt. Express* **19**, A245 (2011).

# Conclusions

- Photonics can enhance high-efficiency CPV application in a variety of ways:
  - Spectral splitting
  - High-performance filters
  - Selective solar absorbers for efficient utilization of MWIR
- Future work – integrate novel photonic crystal designs into reliable, high-performance systems

# Acknowledgements


- Profs. Marin Soljacic, John D. Joannopoulos, Gang Chen, Vlad Shalaev; Dr. Ivan Celanovic
- Collaborators at Purdue, MIT, and UPM (Spain)