Photonic Crystal Resonators and Light Emitters

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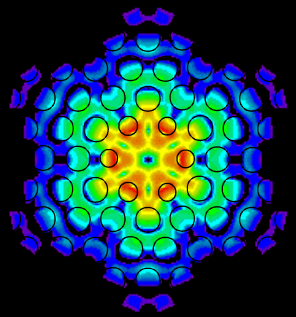

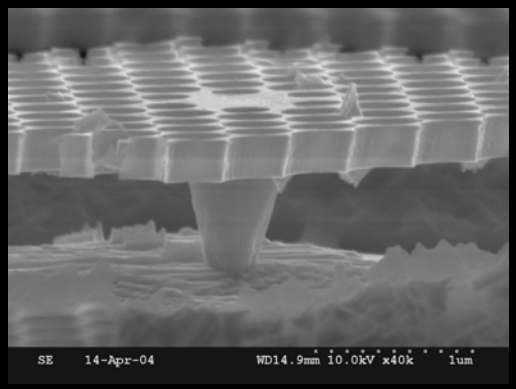

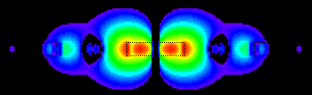

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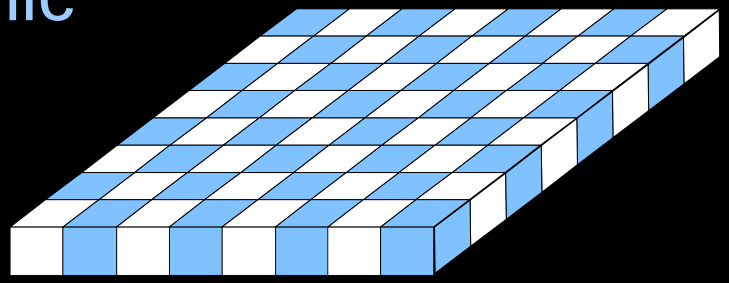

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Wavelength-size Laser

Strong Photon Confinement in Very Small Volume

→ 2-D Slab Photonic Crystal

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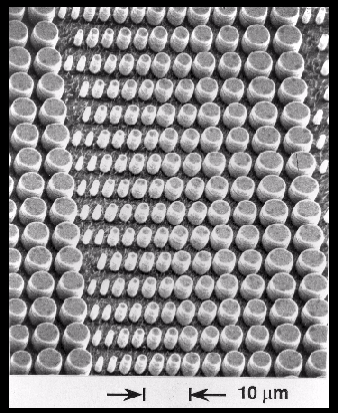
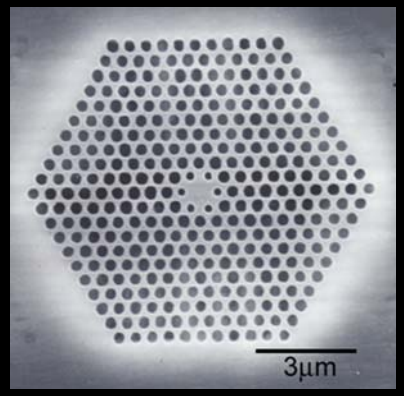
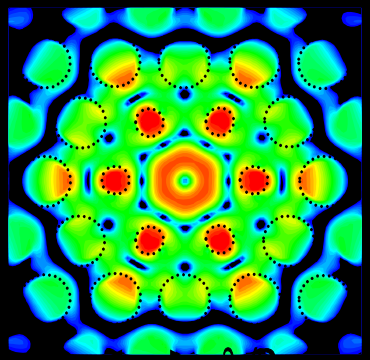
The Smallest Laser ?

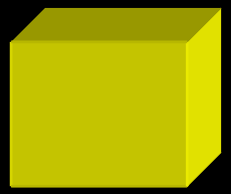


VCSEL





2D PBG Laser



$(\lambda/2n)^3$

Ultimate Laser

- V ~ $(\lambda/2n)^3$
- High Speed
- High Efficiency

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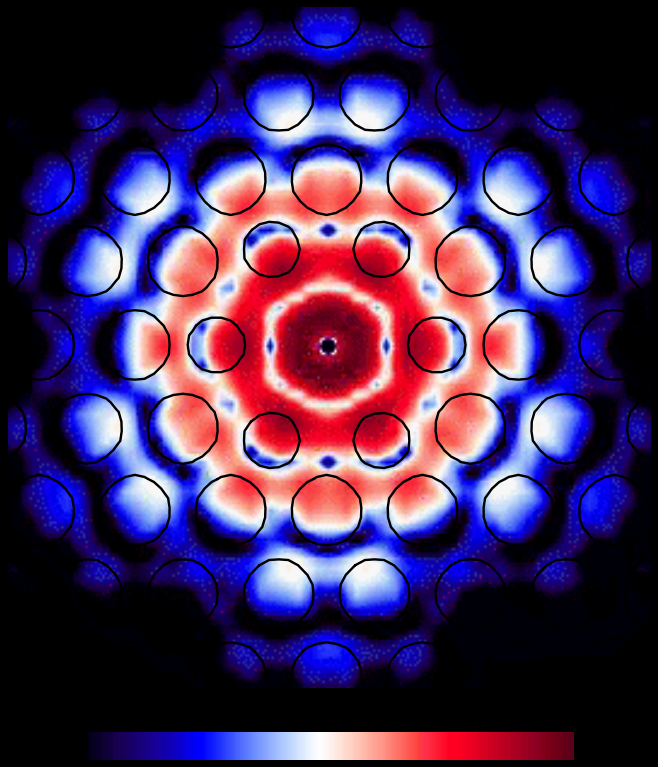
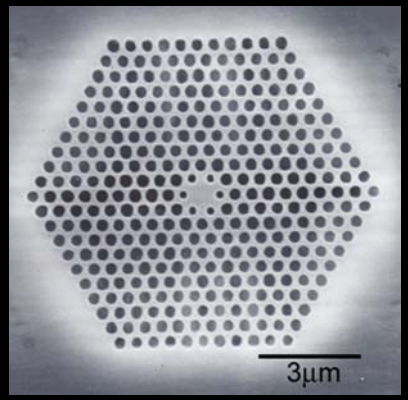
Monopole Mode





H. G. Park, et al., Appl. Phys. Lett. 79, 3032 (2001).

1. λ-scale
2. Low-loss
3. Nondegenerate
4. Central-zero

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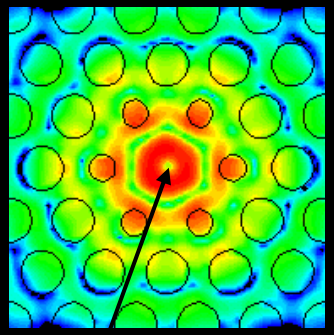
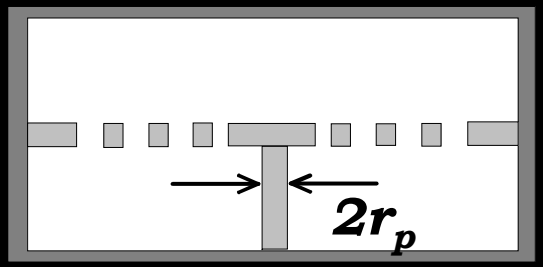
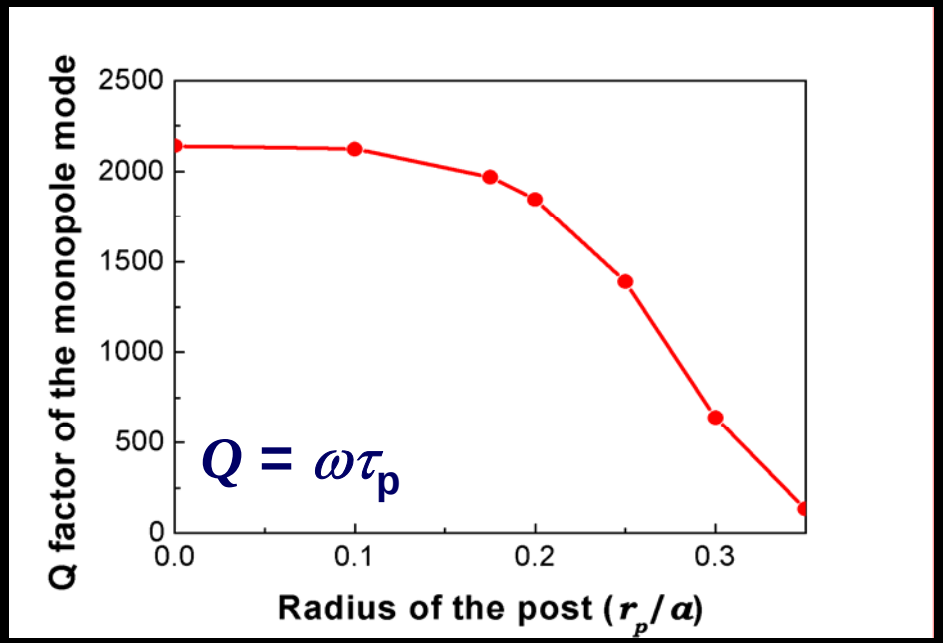
Introduction of Central Post



central node





A post does not affect Q factor significantly !!!

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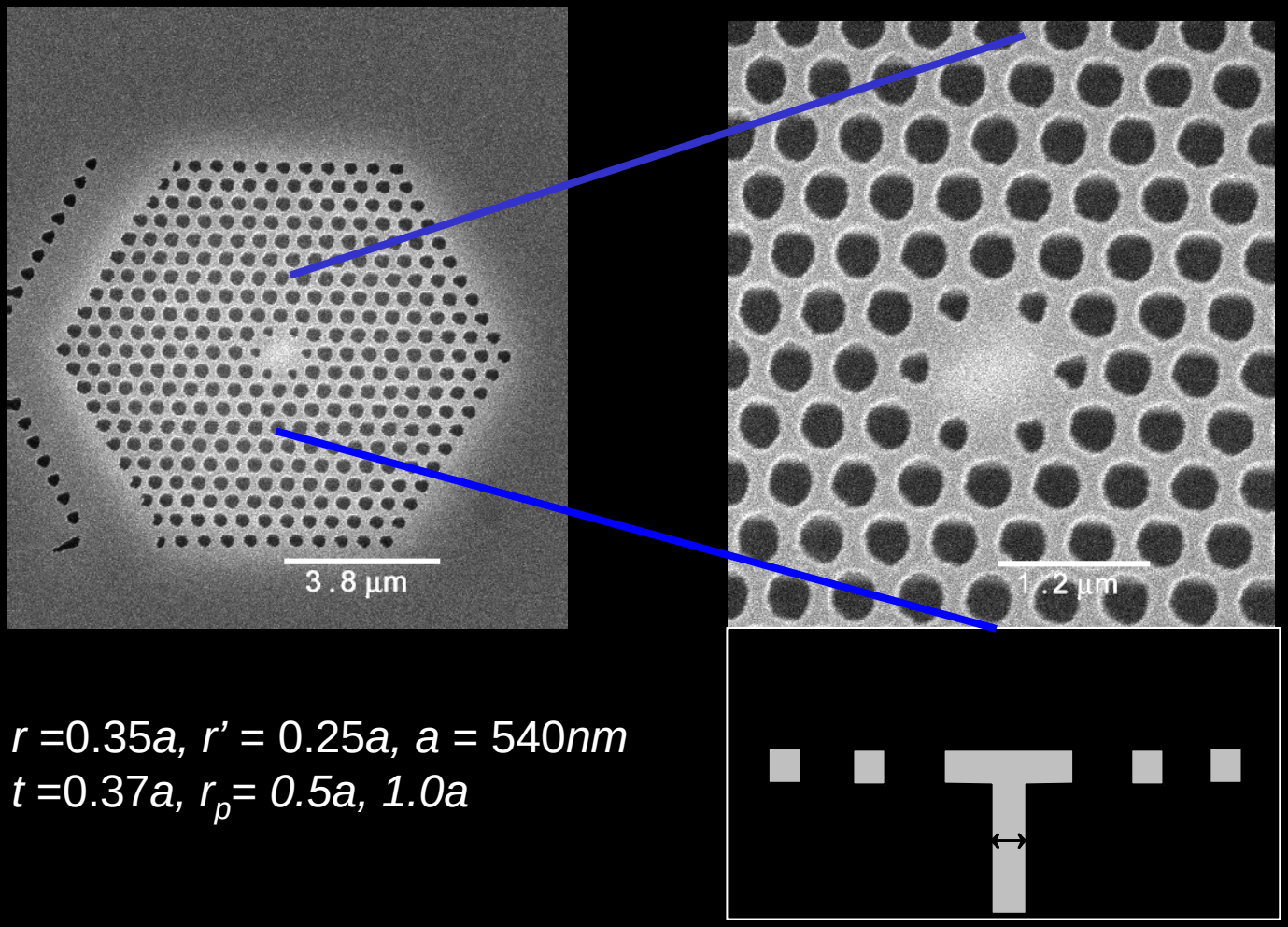
Single-cell Resonator with Post



r =0.35a, r' = 0.25a, a = 540nm
t =0.37a, r_p= 0.5a, 1.0a

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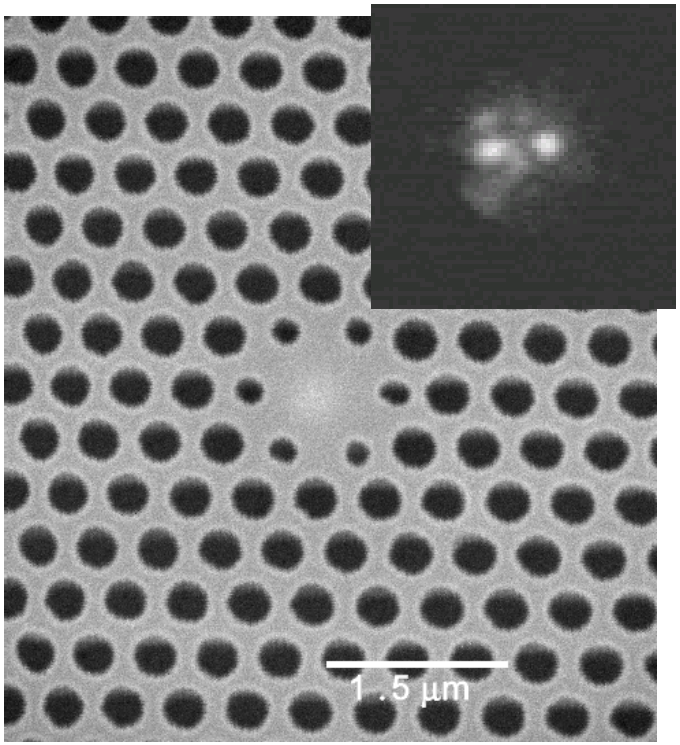
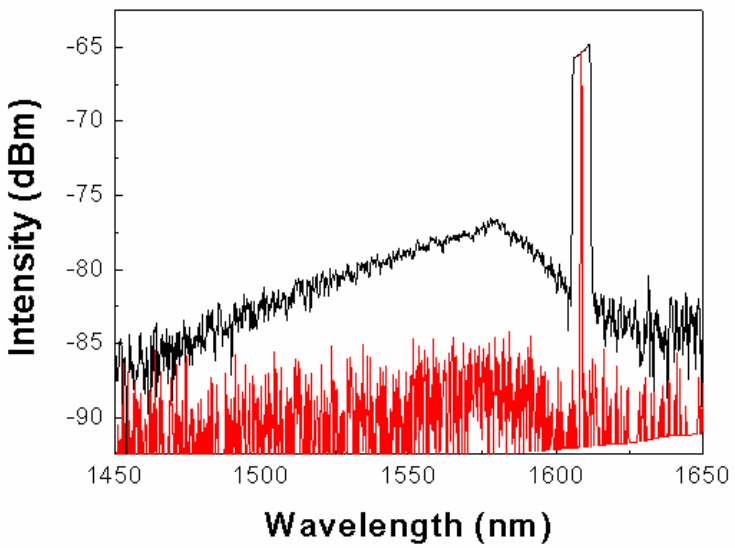
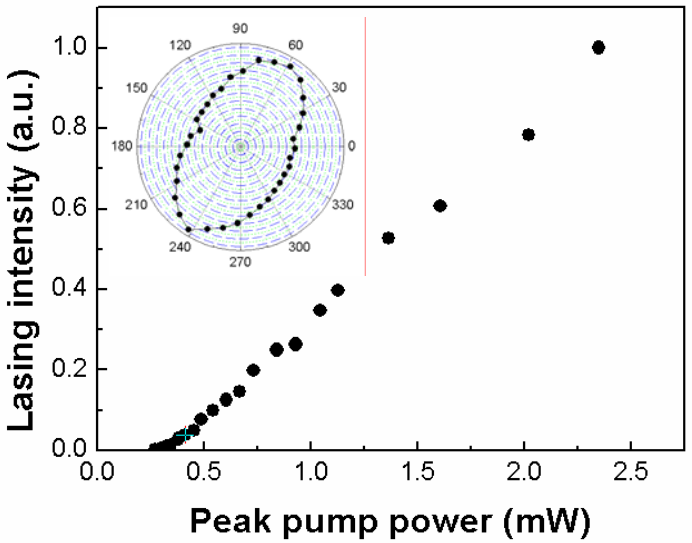
Experiments:

Single-cell Cavity with Central Post







- **Optical pumping**

  @ ~1% duty cycle

- **Quadrupole mode**

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Electrically-driven Photonic Crystal Laser

Dr. Hong-Gyu Park (Harvard)

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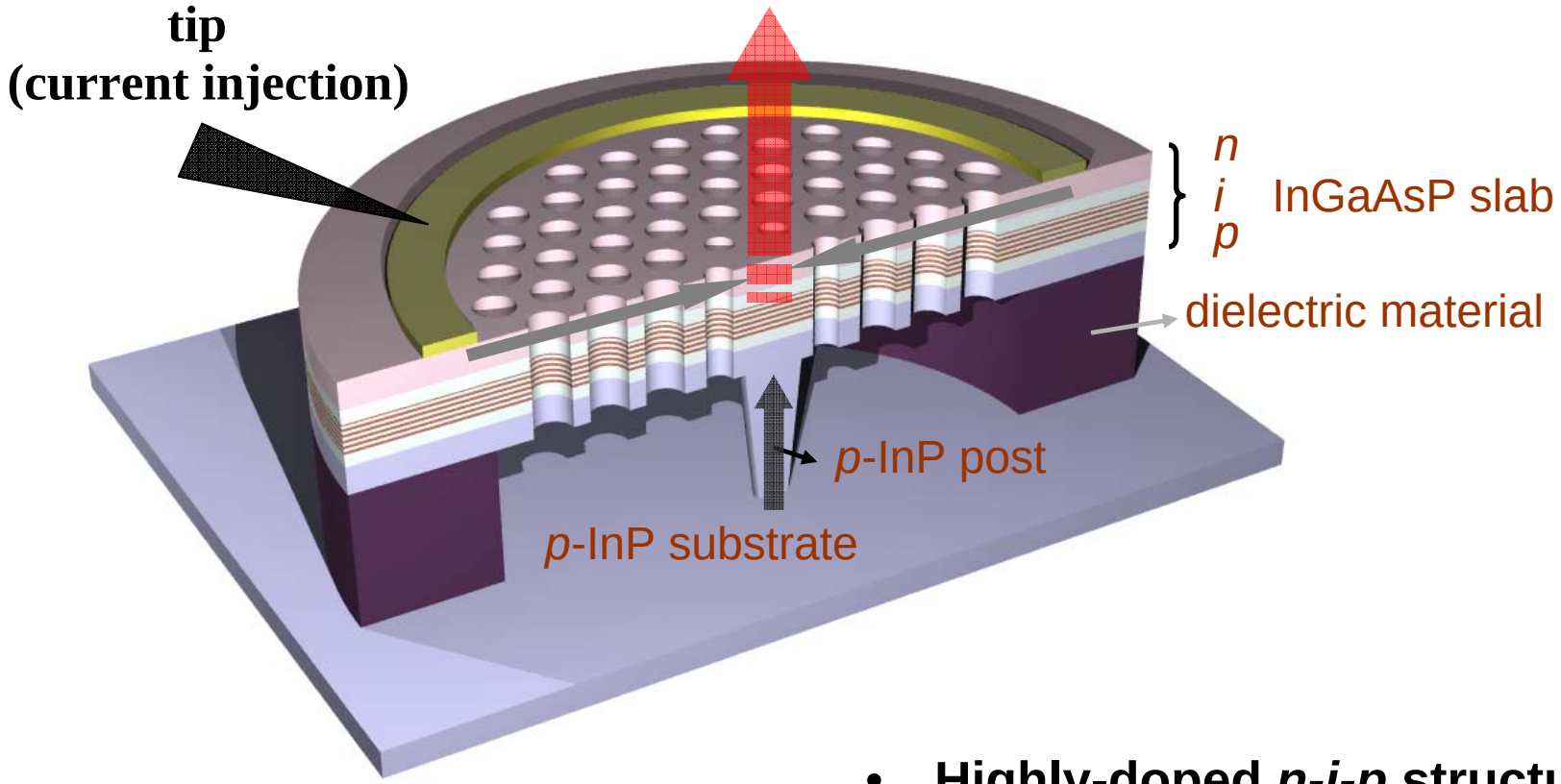
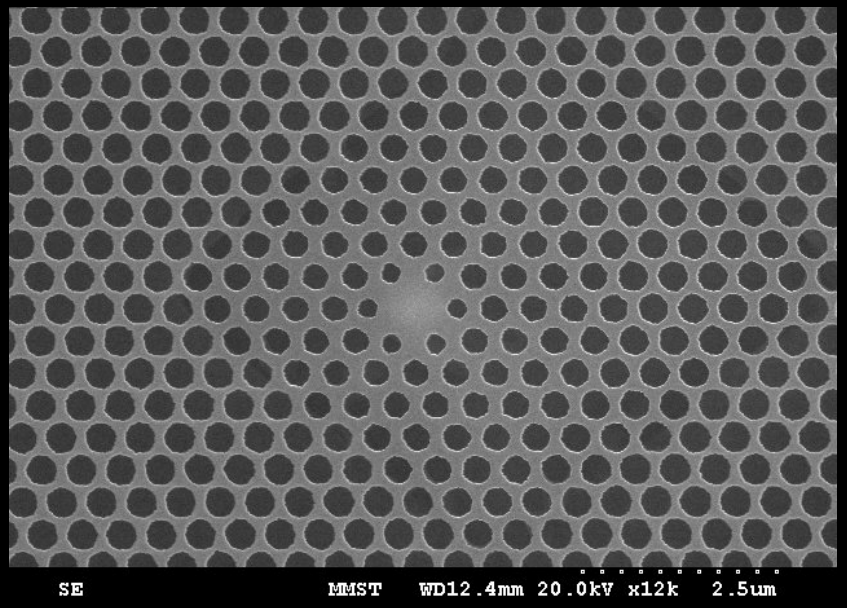
Current Injection Scheme

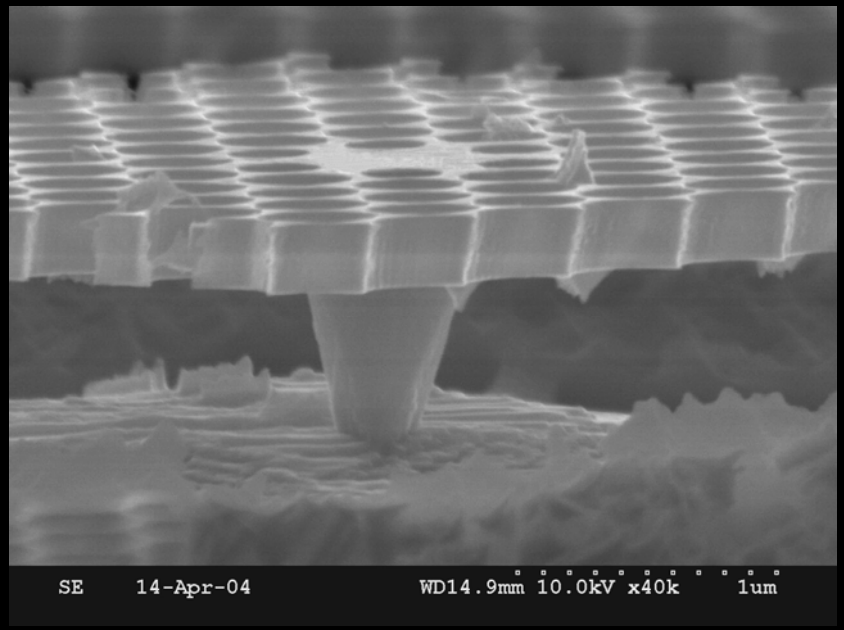


- **Highly-doped *n-i-p* structure:**
  mobility of electron > mobility of hole

Fabricated *e-PBG* Resonator



Top view



Cross-sectional view

H. G. Park *et al.*, ***Science***, vol. 305, 1444 (2004)

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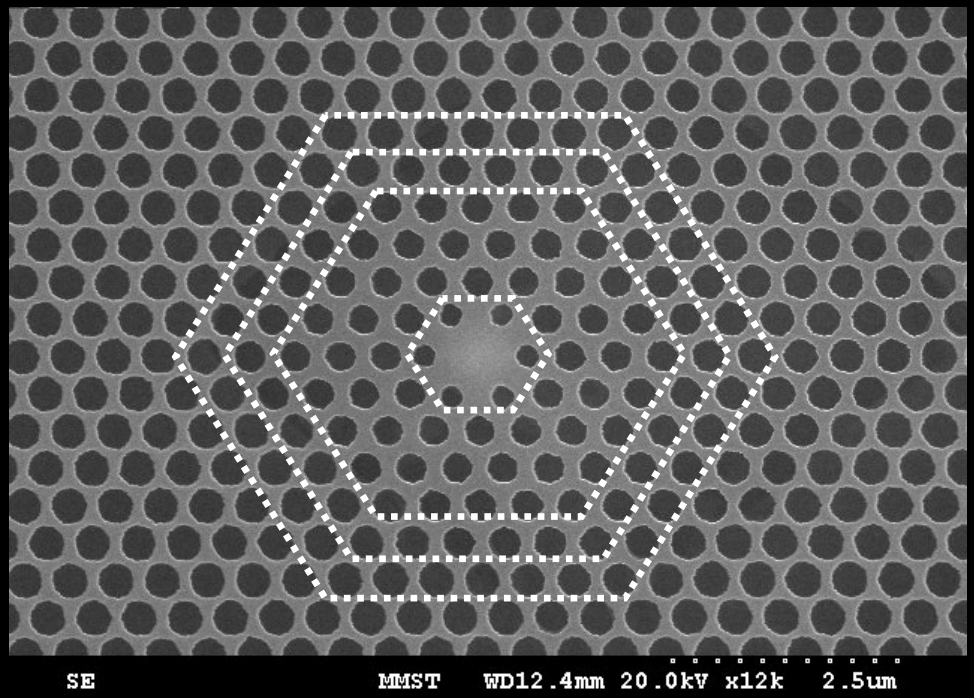
Design of Single-Cell Resonator



Chirped air-holes

- Control of position and size of the post in wet etching processes (locating the post at the center)

- Increase of *Q* factor

$r = 0.28a, 0.35a, 0.385a, 0.40a, 0.41a$

a = 500 nm

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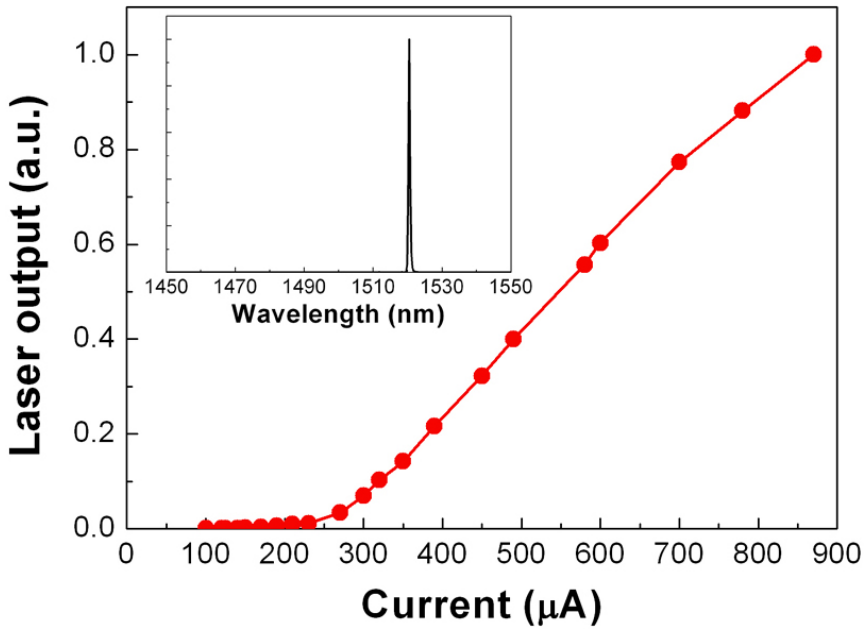
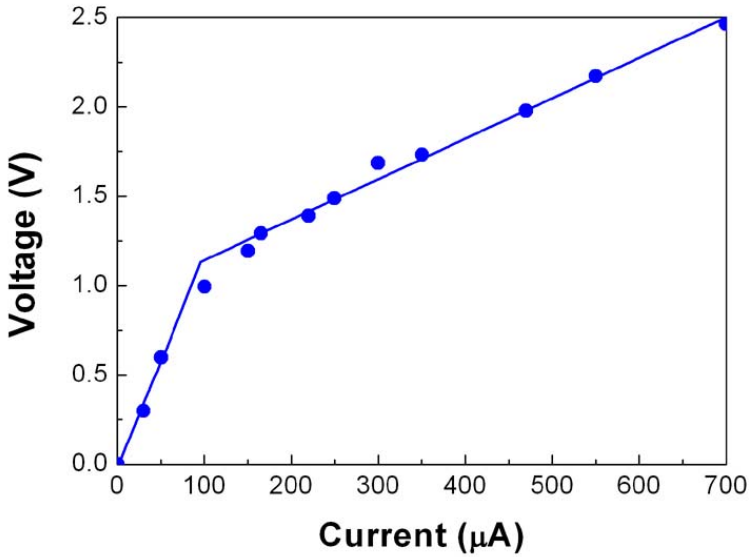
Characteristics of Lasing Mode

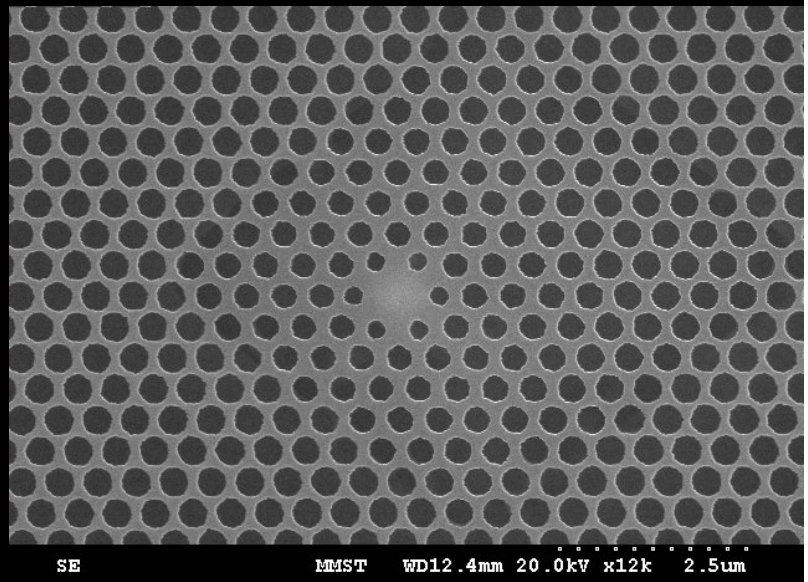




I_{th} ~ 260 μA

Pulse pumping : *6ns / 2.5μs*

Confirmation: The Monopole Mode



<CCD near-field image> <Calculated Poynting vector> <Calculated E-intensity>

Experimental measurements agree well with 3D FDTD computations based on structural data taken directly from the SEM picture.

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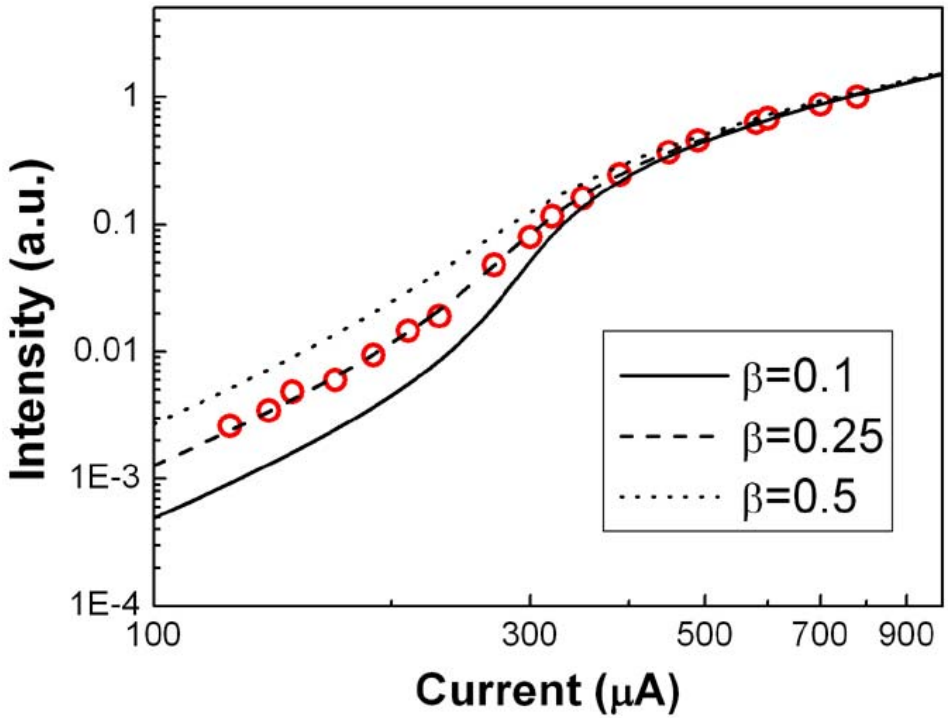
H. G. Park *et al.*, ***Science***, vol. 305, 1444 (2004)

Spontaneous Emission Factor β



- **Record-high β value**

  β ~0.25

- Effective carrier localization by electrical pumping
- Nondegenerate monopole mode
- Small modal volume

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μ-fiber Coupled Photonic Crystal Laser

Prof. In-Gak Hwang (Chun Nam University)

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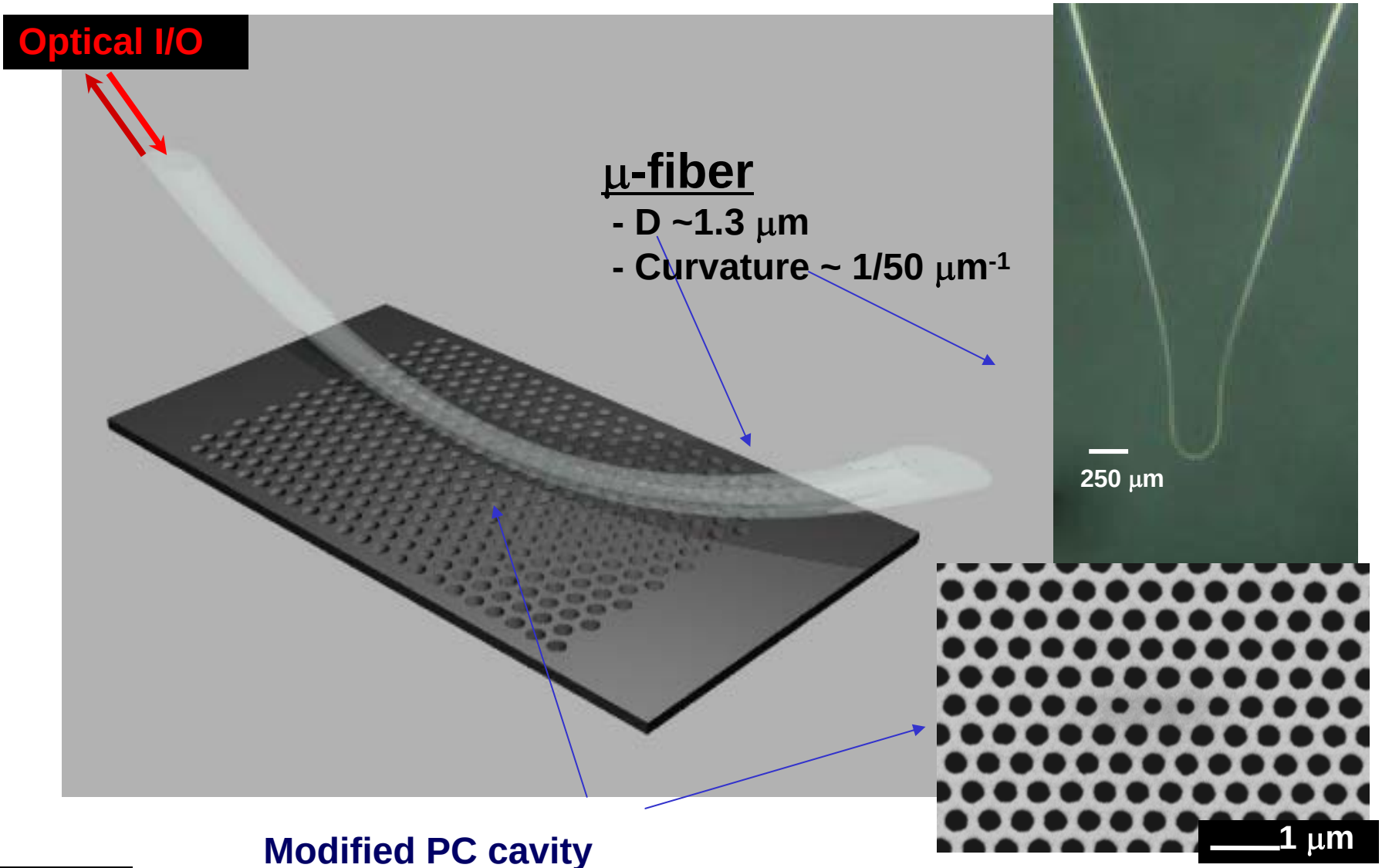
Curved μ-fiber Coupling



Modified PC cavity
→ designed for efficient fiber coupling

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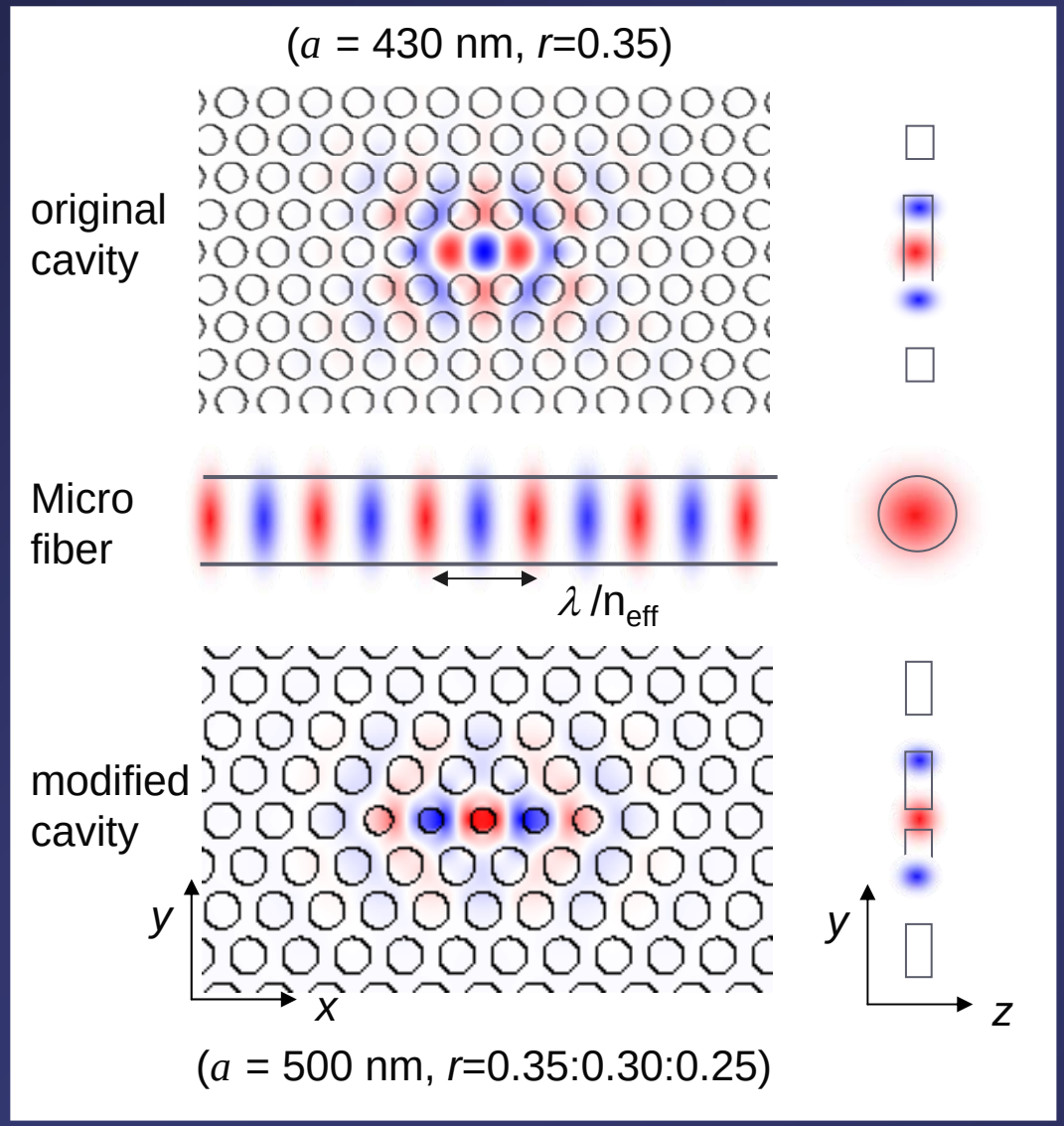
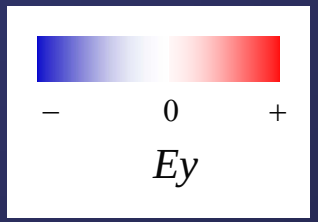
Modified Linear PhC Cavity



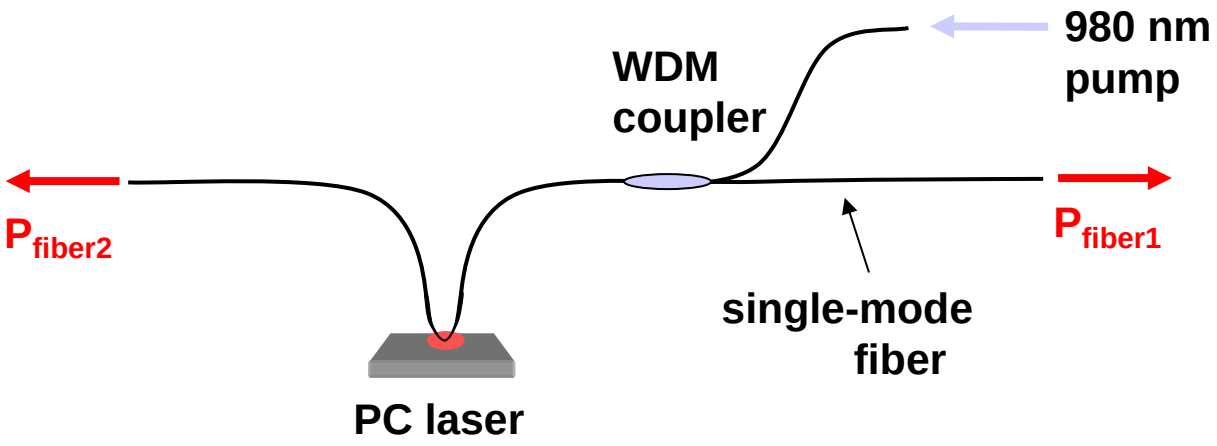
*+ better **phase matching (along x)***
-modified linear cavity

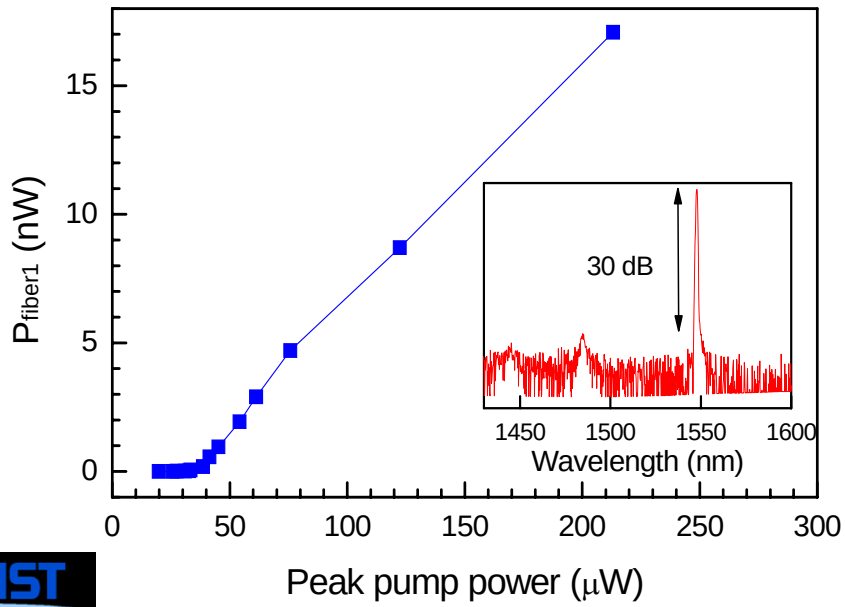
*+ larger **mode overlap (along y)***
–μ-fiber

$Q_{int} \sim Q_{air} = 26000.$



PC Laser with Fiber I/O





All-fiber PC laser
- Low threshold of 35 μW
- High output power of >10 nW

- Extremely local pumping
- Highly efficient out-coupling

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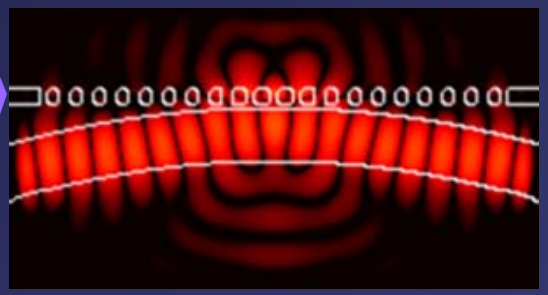
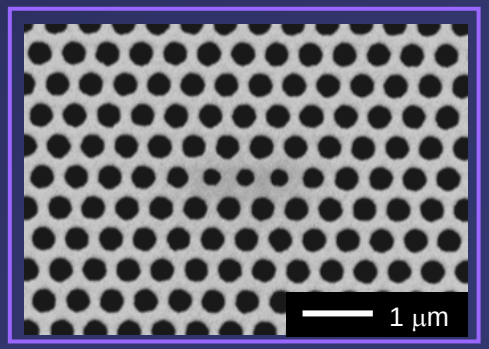
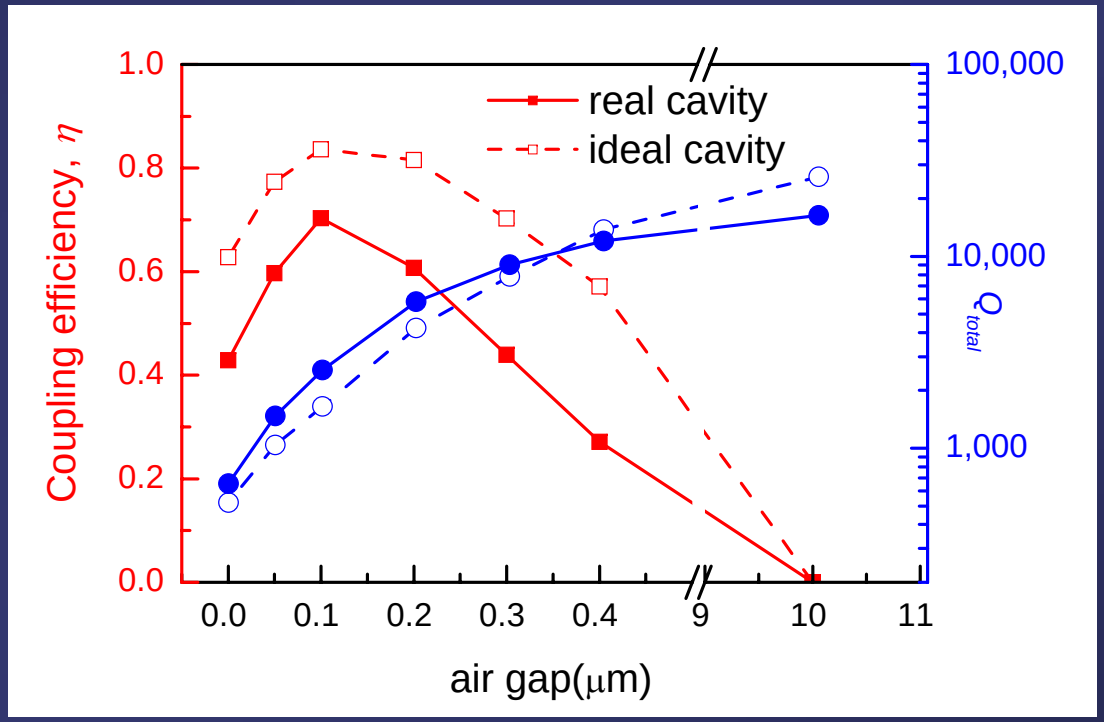
Computation, *as fabricated*





SEM image of real structure



Max. η estimated to be ~70%

→ imperfectly-fabricated cavity structure

To Close

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Toward the Ultimate Photon Source

- $(\lambda/n)^3$, High-*Q* Resonator (Q/V)
- QD Active Material
- Photon Out-coupling
- Reliable Current Injection Scheme
- Strong Coupling Regime / Cavity QED
- *On-demand Single Photon Gun ?*

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For more information, visit, http://pbg.kaist.ac.kr

The Team

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