Precise Control of Organic LED Emission Through Optically-Resonant Microcavity Confinement

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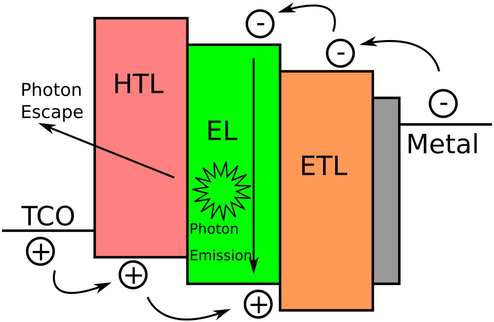
The University of Vermont

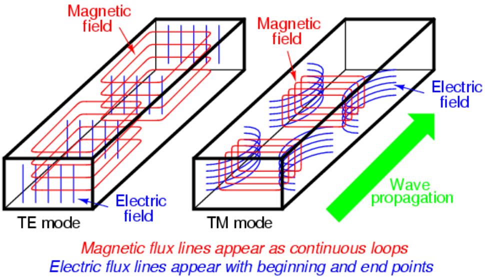
OLED Devices

- Electron-hole recombination in the emissive layer
- Use of TCO to maximize photon outcoupling
- Color determined primarily by the material in the emissive layer



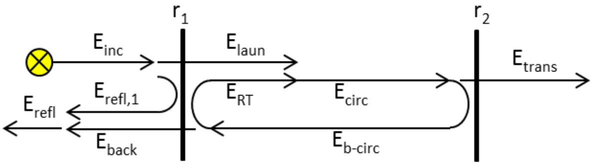
Waveguides

- Conductors provide bounds to Maxwell's Equations
- General modes of propagation
  - TE Mode
  - TM Mode
  - TEM Mode



https://www.allaboutcircuits.com/

The Fabry-Pérot Etalon



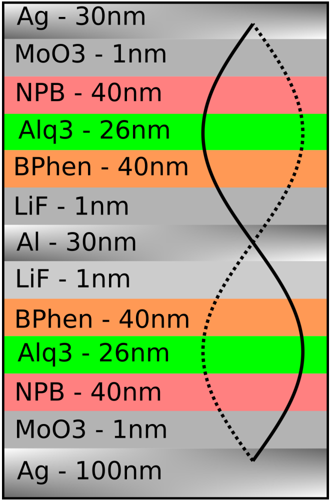
https://en.wikipedia.org/wiki/Fabry-Pérot_interferometer

$$T(\phi) = \frac{(1-R_1)(1-R_2)}{\left(1-\sqrt{R_1 R_2}\right)^2 + 4\sqrt{R_1 R_2}\sin^2(\phi)}$$

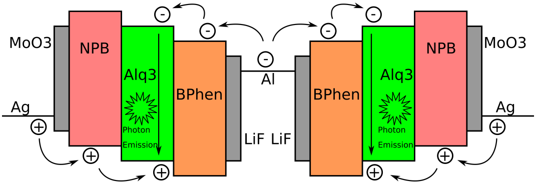
$$T_{\phi=0} = \frac{(1-R_1)(1-R_2)}{\left(1-\sqrt{R_1 R_2}\right)^2}$$

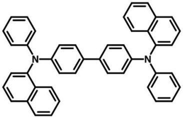
Microcavity-confined OLEDs

- Replace TCO with partially reflective metal film
- Fabry-Pérot etalon with emission source inside
- Resonant mode selected out of the broadband emission
- Standing wave resonance across multiple cavity stack

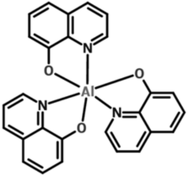


Device Fabrication

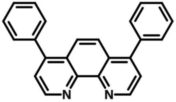




NPB hole transport material

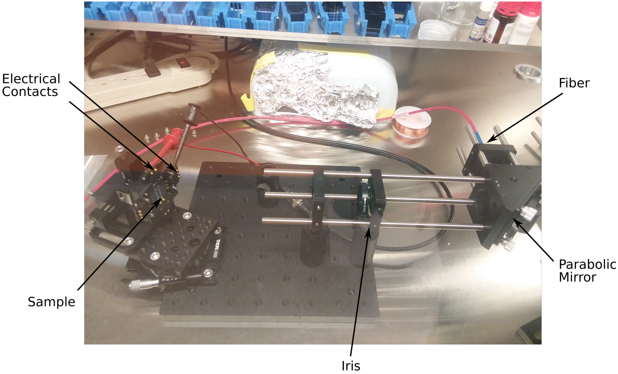


Alq_3 emissive material

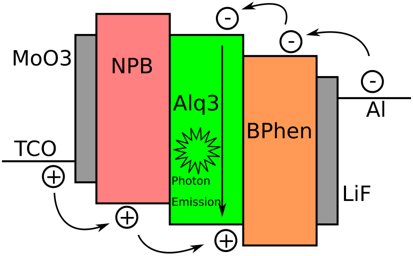


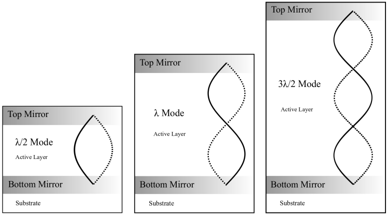
BPhen electron transport material

Angle-Resolved Electroluminescence Spectroscopy (ARES)



Single Cavity Devices





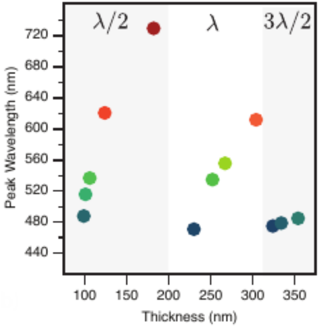
Peak Emission Wavelength

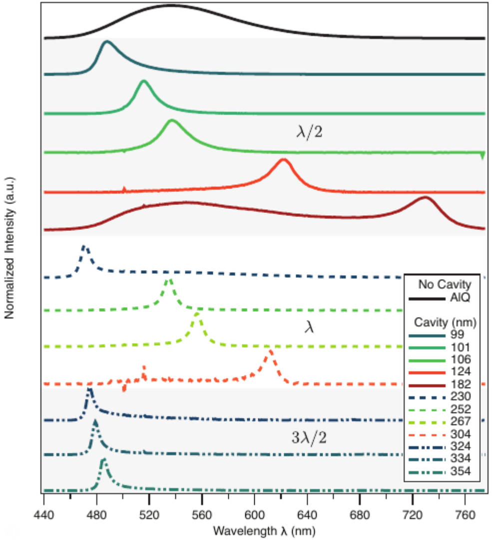
$$\lambda_0 = \frac{2nd}{q}$$

$n \rightarrow$ index of refraction

$d \rightarrow$ cavity thickness

$q \rightarrow$ resonant mode

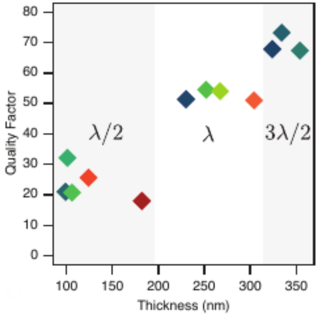


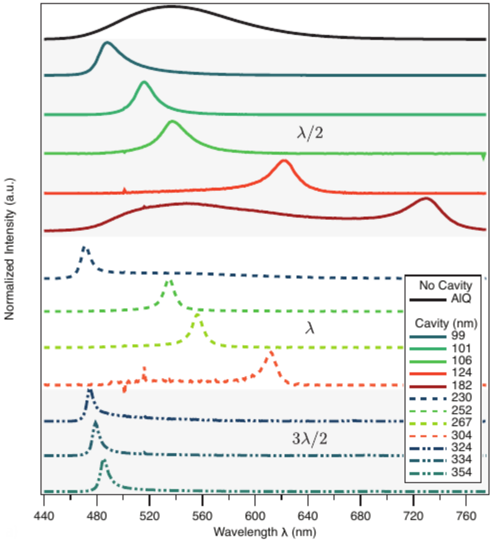


Band Narrowing

$$Q = \frac{2nd}{\lambda_0}\left\{\frac{1-\sqrt{R_1R_2}}{\pi(R_1R_2)^{1/4}}\right\}$$

$$Q = q\left\{\frac{1-\sqrt{R_1R_2}}{\pi(R_1R_2)^{1/4}}\right\}$$

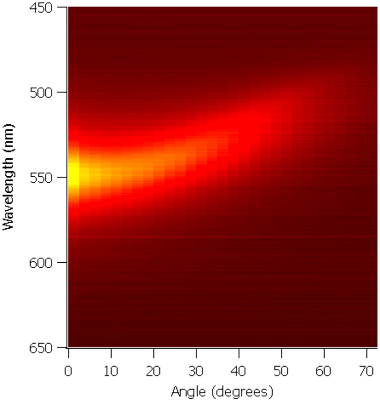




Impact of Electrode Geometry

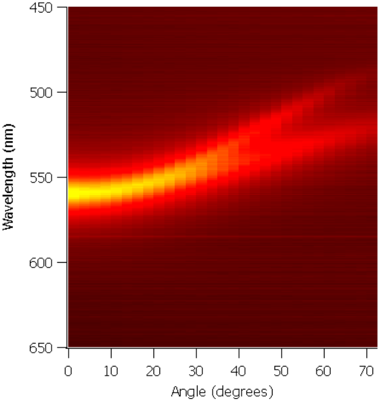
106 nm cavities

30nm Ag top electrode



100 nm Al bottom electrode

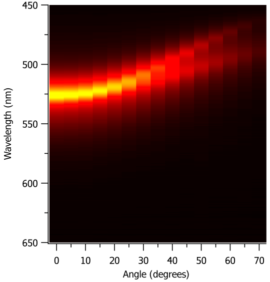
30nm Al top electrode



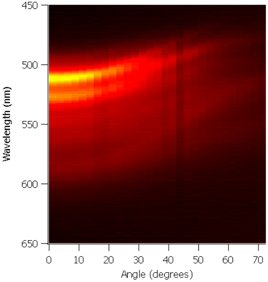
100 nm Ag bottom electrode

Multi Cavity Devices

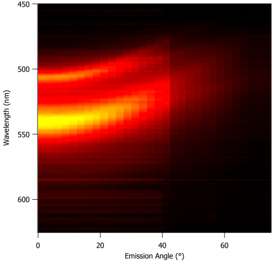
N=2 cavities



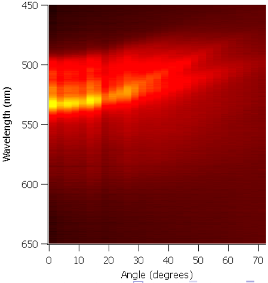
N=3 cavities



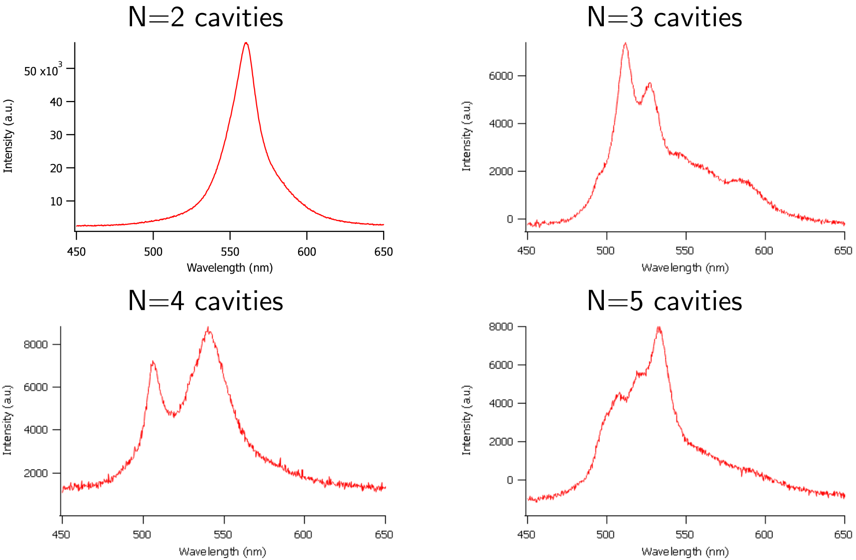
N=4 cavities



N=5 cavities



Number and Bandwidth of Resonant Modes



Conclusions and Future Work

- Control of peak emission wavelength with cavity thickness
- Control of bandwidth with cavity thickness and multi-cavity devices
- More research into controlling the multi-peak emission of multi-cavity devices
- Push towards the lasing threshold with devices of $N > 10$

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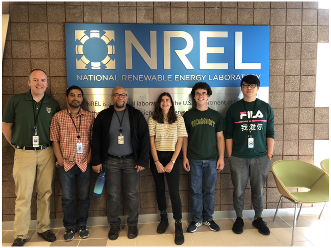

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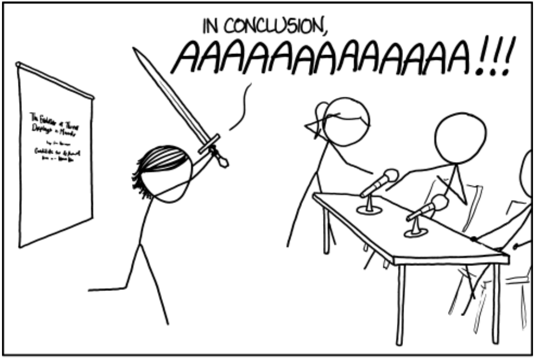
  - Dr. Matthew S. White

Questions?



THE BEST THESIS DEFENSE IS A GOOD THESIS OFFENSE.

https://xkcd.com/1403/

Thank you for your attention!