Precise Control of Organic LED Emission Through Optically Resonant Microcavities

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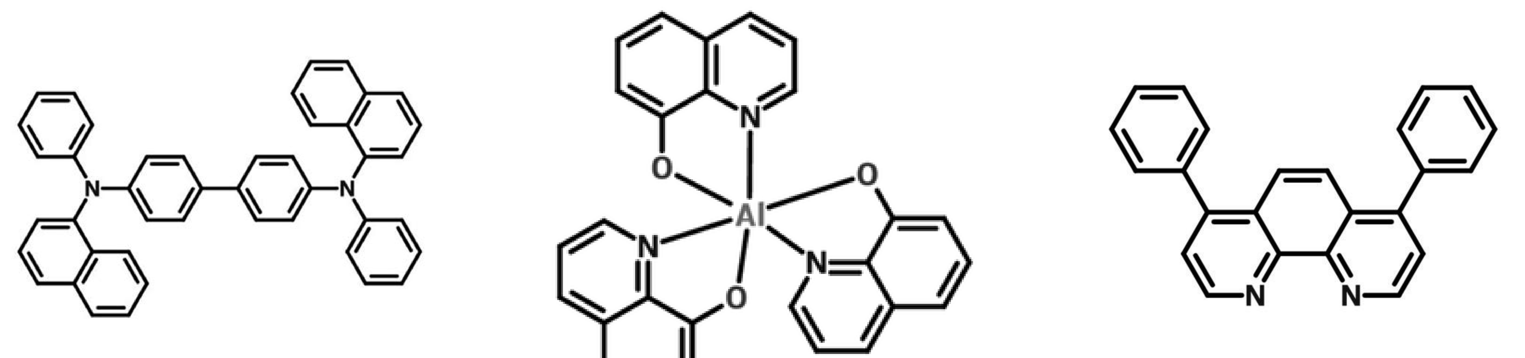
Introduction

Light emitting diodes (LEDs) have become an integral part of daily life, from television screens to headlights on cars. While LEDs have substantial benefits over incandescent bulbs, they have significant environmental impacts, often using hazardous materials [2]. This has been mitigated in part by the advent of organic LEDs (OLEDs), which are generally less harmful and expensive, but the emission spectrum of organic molecules is strongly dependent on chemical structure, and thus more difficult to control [1]. Conventionally, the emission spectrum is modified using dopants, with which small variations in concentrations can have very large effects on the emission pattern. In this project, we demonstrate a technique for taking a single organic emitter, and modifying its emission spectrum through device design alone. Additionally, we explore the ability to generate multi-peaked emission profiles with only a single organic emitter material, giving rise to the potential of designing a device to produce any emission pattern.

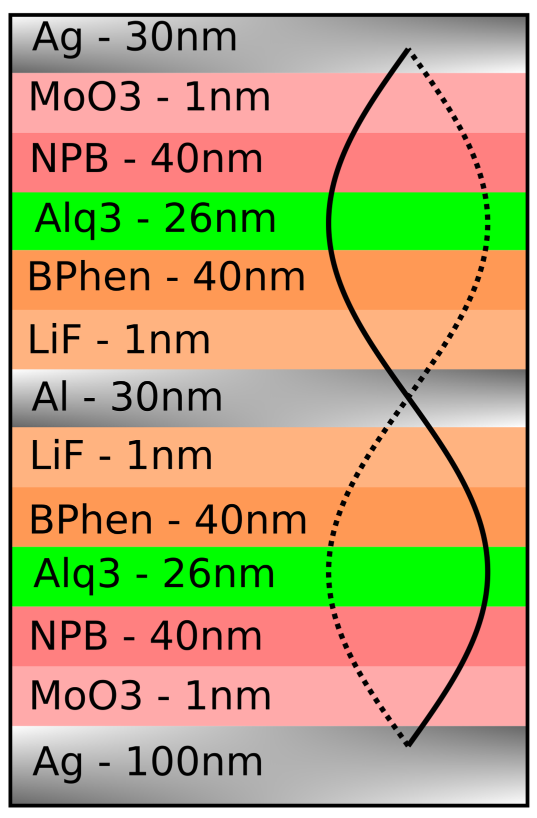


(a) (b) (c)

Chemical structures of (a) NPB hole transport material, (b) Alq_3 emissive material, and (c) BPhen electron transport material

Device Fabrication and Characterization

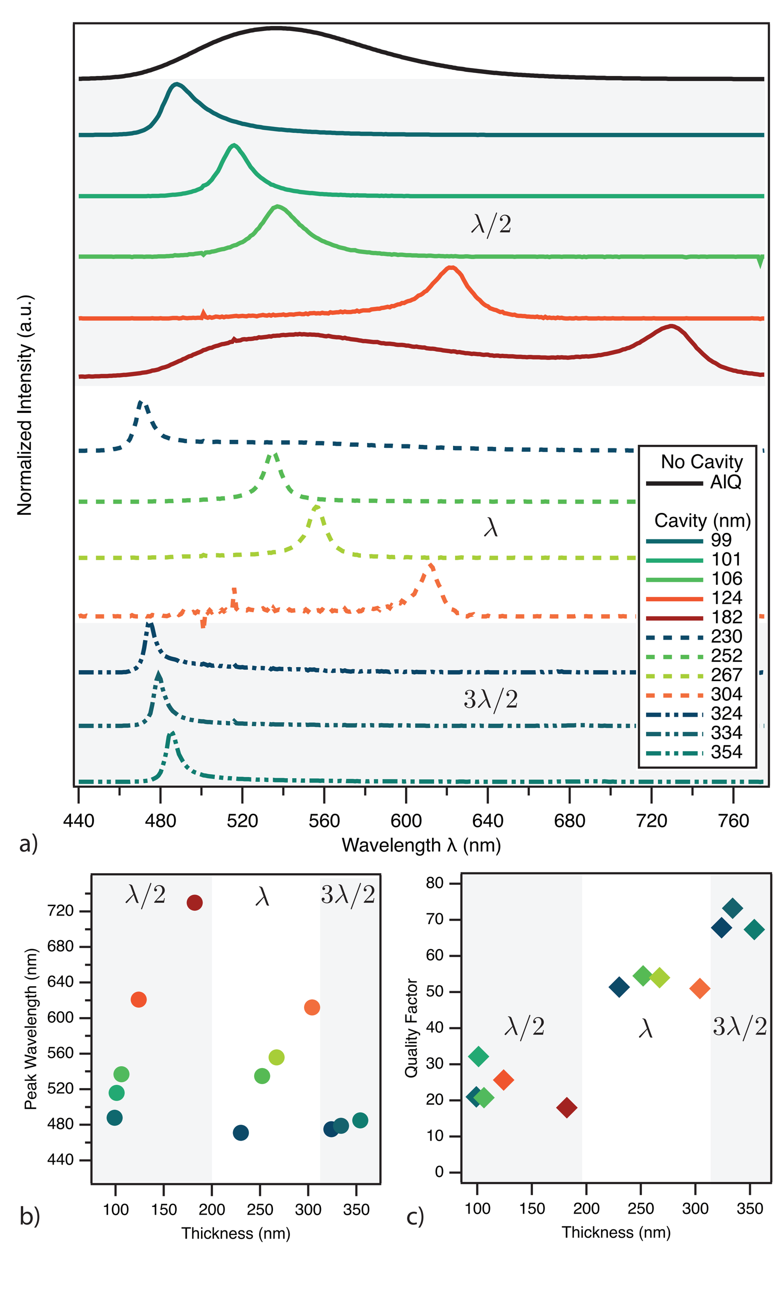
- 30nm metal electrodes act as partially reflective barriers between cavities
- Resonant modes, characterized by nodes at metal electrodes, are strongly selected by the cavity
- Emission spectra collected for varying angles with respect to the cavity



Device schematic for a 2 cavity device

Results of Forward Emission Spectroscopy

- Linear relationship of peak emission wavelength to cavity thickness
- Linear relationship of quality factor to bandwidth



Emission characteristics of single cavity devices:

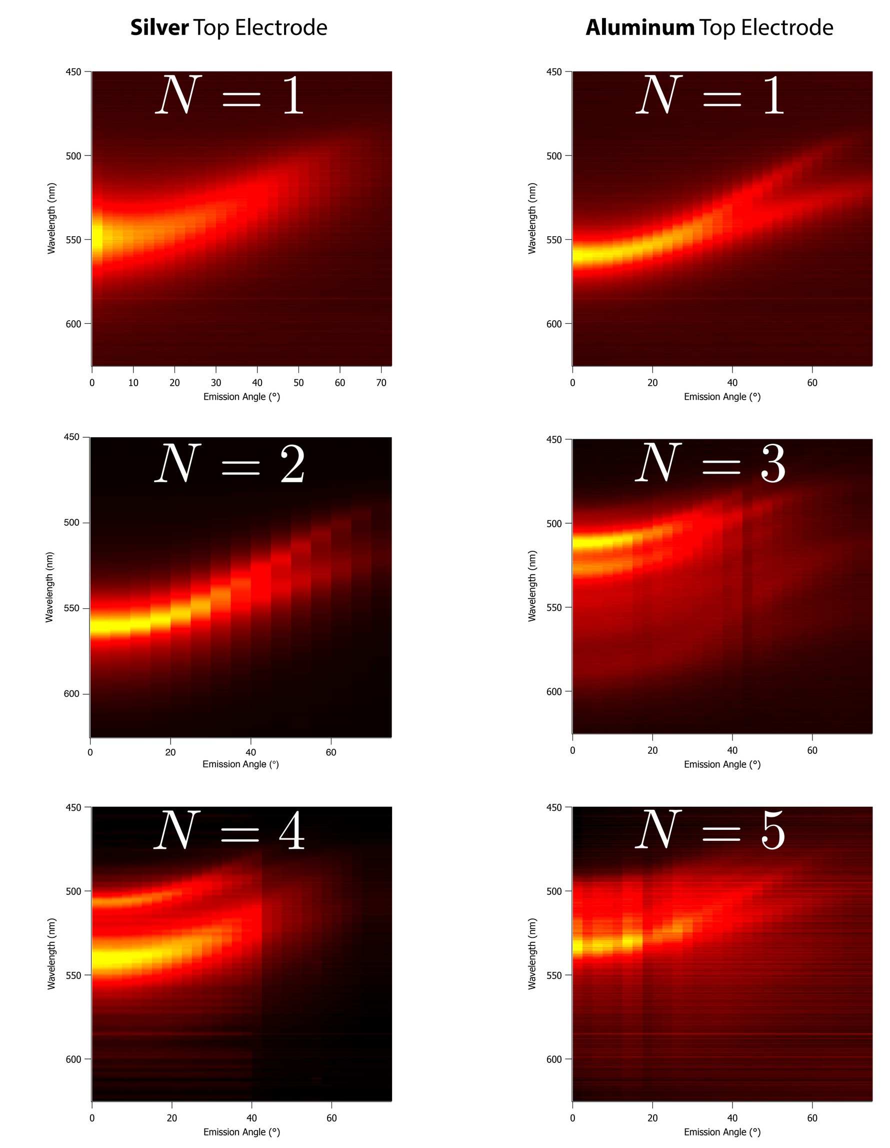
a): Emission spectrum as a function of cavity thickness,

b): Peak wavelength as a function of cavity thickness,

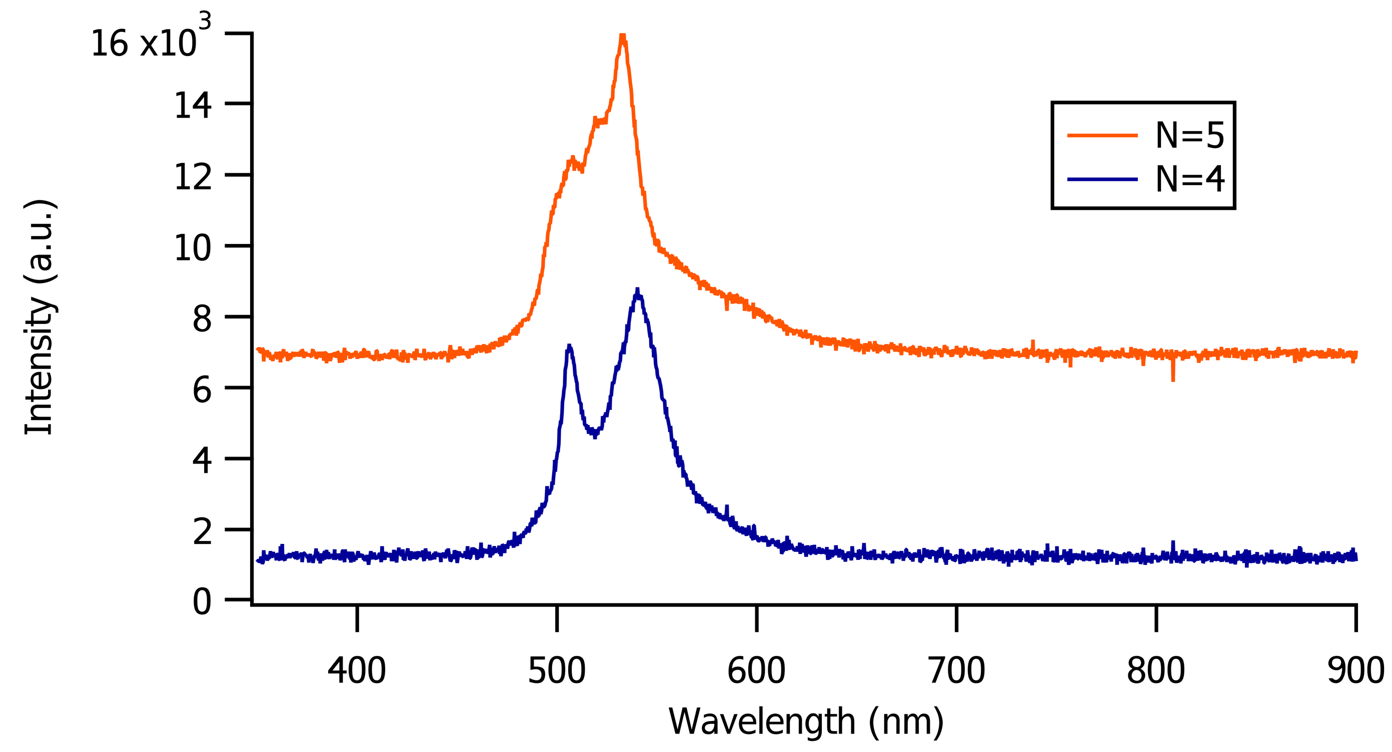
c): Quality factor as a function of cavity thickness

Results of Angular Resolved Emission Spectroscopy

- Blueshift and TE/TM mode splitting as expected for resonant modes [4]
- Narrower band for aluminum topped $N = 1$ device due to increased absorption of Al [3]
- More complex modal structure for $N > 2$
- Bands narrow as number of cavities increases



Angular resolved emission profiles for resonant microcavity devices with N cavities



Forward emission spectrum for $N = 4$ and $N = 5$ devices

Conclusions and Future Works

In this project, we have demonstrated a technique to precisely control the peak emission wavelength and bandwidth of an organic LED as well as a method for generating more complex emission profiles. The linearity between cavity thickness and peak emission allows for very exact prediction of emission wavelength for a device, to within the resolution of our ability to deposit films. The modal structure of the multi-cavity devices provide several avenues of potential future exploration, including dependence of modal separation on cavity thickness, behavior at higher numbers of cavities, and structure under high current densities. A strong understanding of these modal structures could lead to fabrication of devices to match any desired emission spectrum, which could be used in the manufacture of high quality OLED screens and potentially organic diode lasers.

Acknowledgements

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