Center for Energy Efficient Electronics Science

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Radiation Pattern and Scattering Properties of Optical Antennas

Zeyan Xu[1], Kevin Messer[2], and Eli Yablonovitch[2]

[1]University of Texas at Dallas, [2]University of California, Berkeley

Abstract: When light emitting devices (e.g. LEDs) are coupled to optical antennas of the same resonance frequency, their spontaneous emission rate can be enhanced drastically. The ultimate goal is to have the rate of spontaneous emission faster than the stimulated emission so that the LEDs would be as fast as lasers and enable us to achieve energy efficient interconnects for on-chip communication[1]. In this project, we theoretically and experimentally measured the far-field radiation pattern and the light scattering spectrum of a series of as-fabricated optical antennas. These measurements enabled us to characterize and better understand the fundamental behaviors of optical antennas.

Introduction

Optical antennas are the nanometer scale analog of radio-wave antennas. Their functionalities are the same: to convert free space electromagnetic energy into localized energy[2].

Optical antennas can potentially make LEDs' spontaneous emission faster.

Using LEDs for optical interconnects could lead to large energy savings in computing.

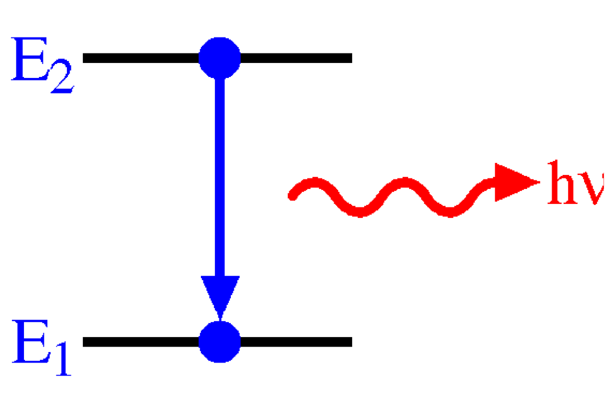


Figure 1: graph demonstration of spontaneous emission. Optical antennas can help make all energy transitions happen at the same energies[3].

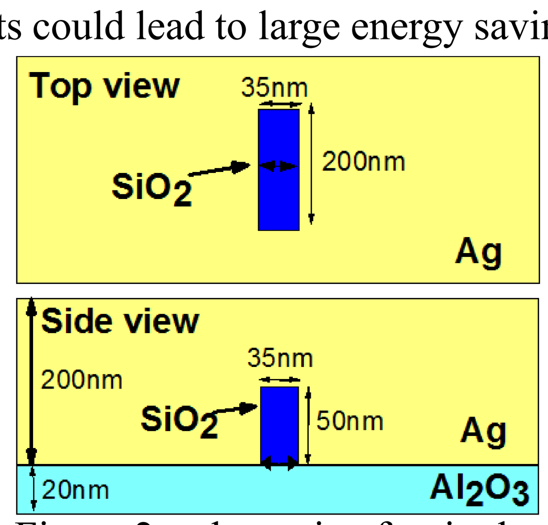


Figure 2: schematic of a single optical antenna from the arrayed sample. The longitudinal length are being varied: 100 nm, 20 0nm, and 250 nm.

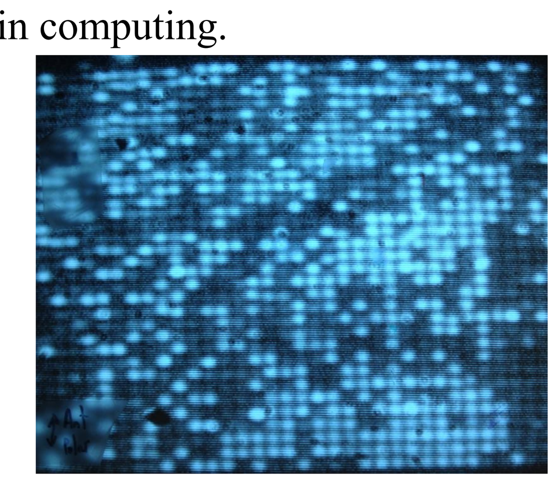
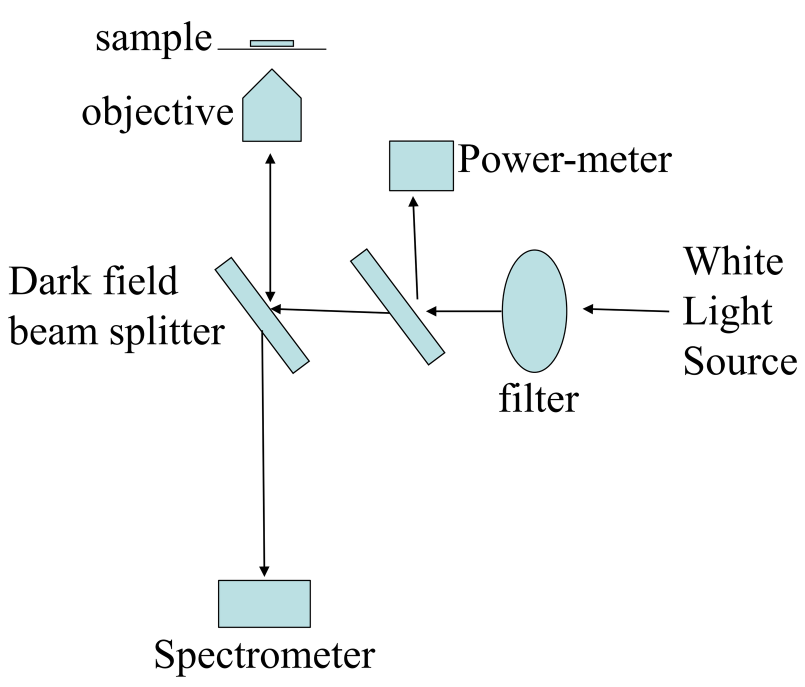


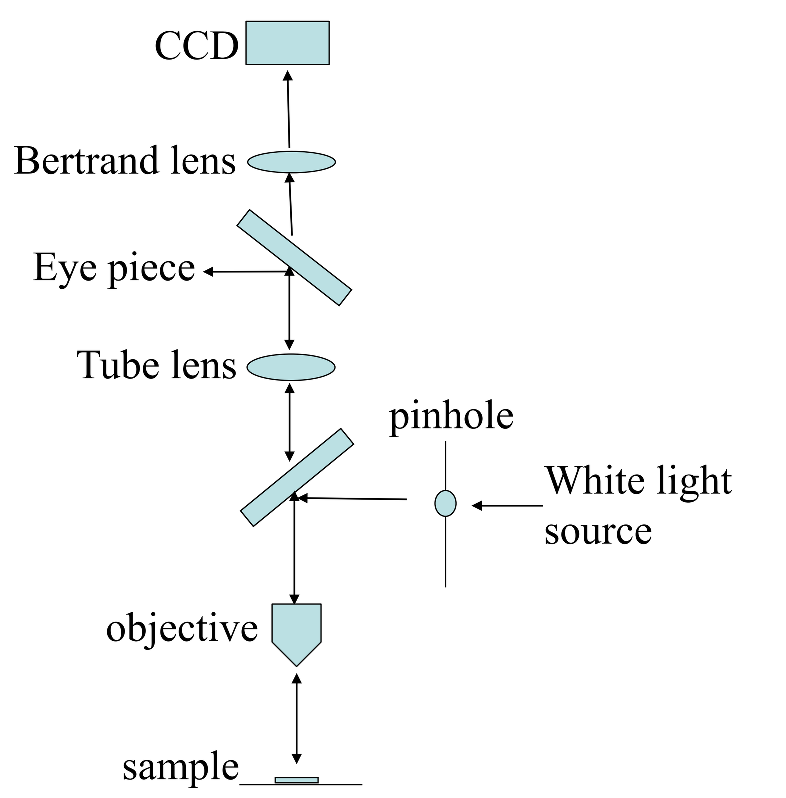
Figure 3: a dark field image obtained from an array of optical antennas. The variations in brightness are caused by defects.

Optical Setup

Scattering:



Far field:

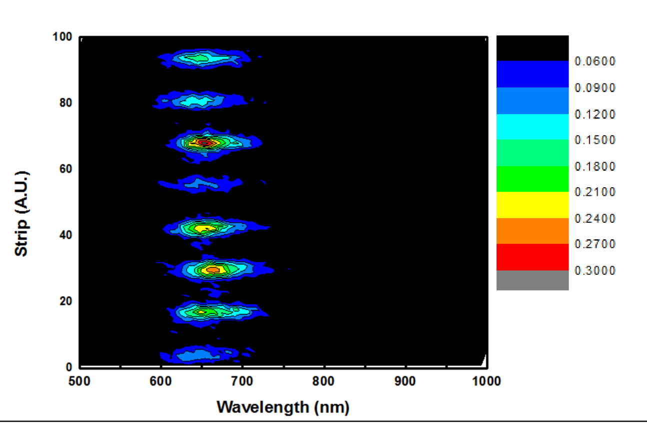


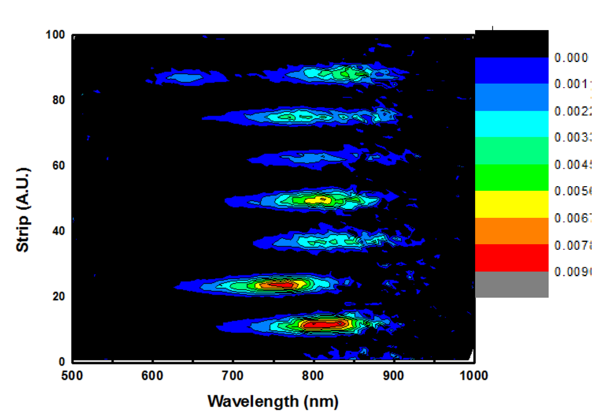
(Conoscope: image the back focal plane[4])

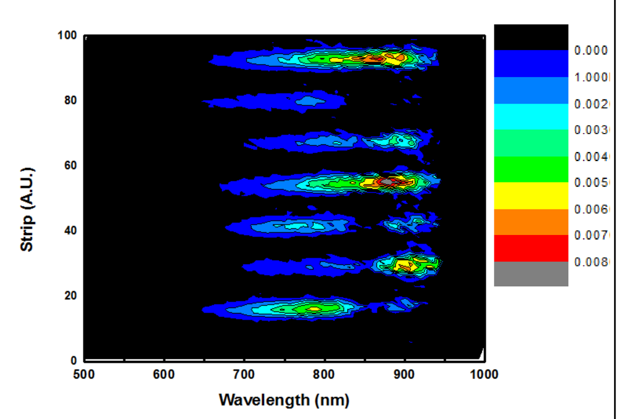
Scattering Spectrum

Longitudinal lengths: Experiments:

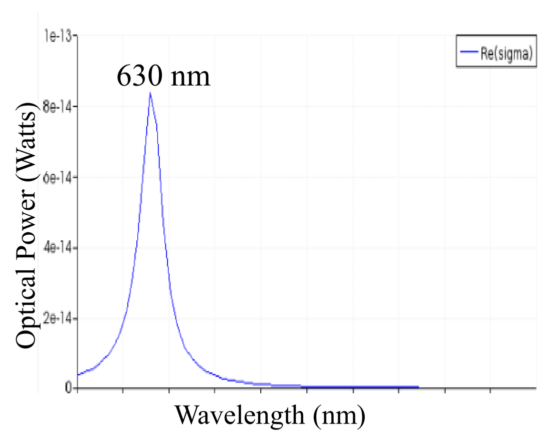
100 nm 200 nm 250 nm

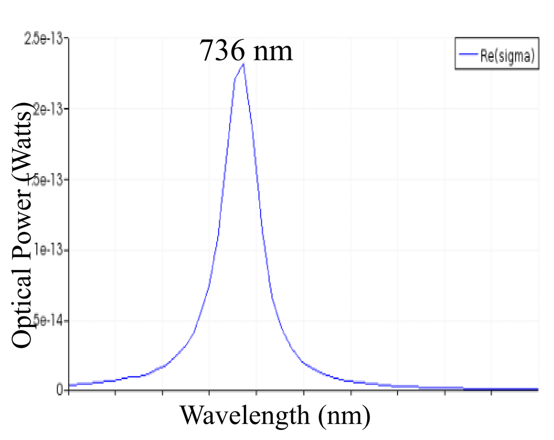


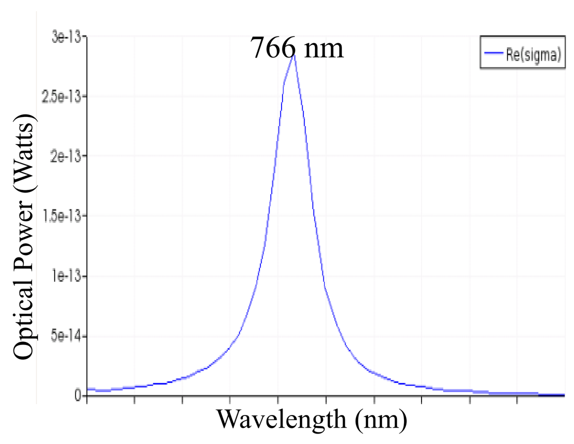




Simulations:







Far Field Radiation Pattern

Experiments:

Back focal plane image of a 2D grating

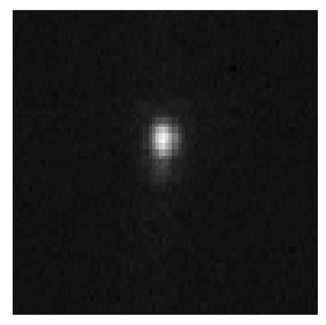
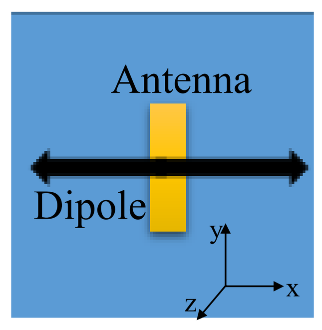


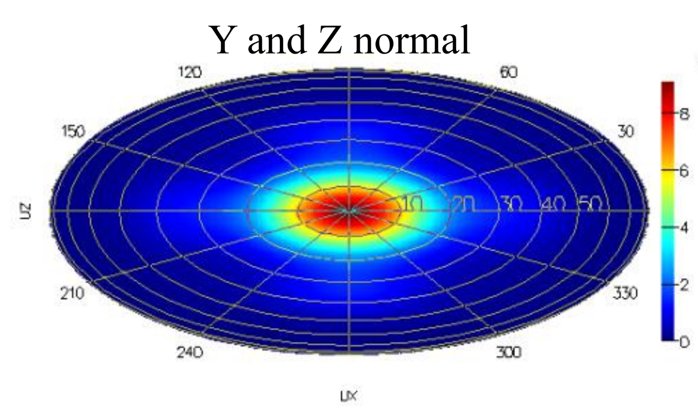
Image of an optical antenna

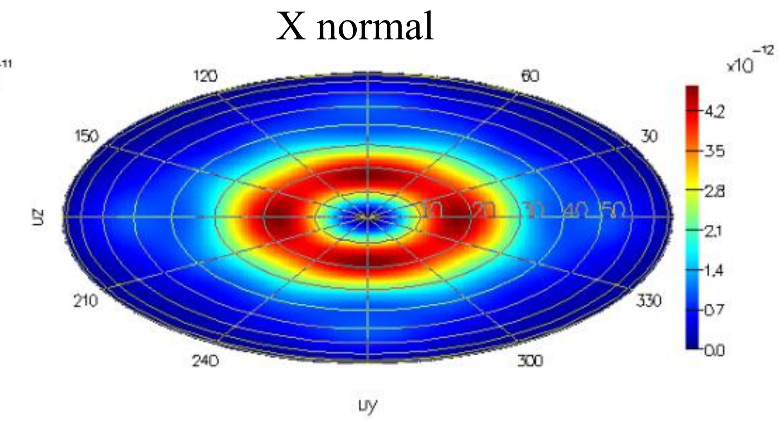
Radiation pattern of antenna

Simulations:

Structure:







Conclusion/Future Work

- We observe that the wavelength of emission of optical antennas is dependent on its longitudinal length. The longer the antenna, the longer the wavelength of emission, resulting in a shorter resonance frequency. Knowing the correlation between frequency and length is important for antenna design.
- We observe that the simulations and experiments of the far-field radiation pattern of the optical antennas are consistent. Knowing this, the next step is to study how different antenna geometries change the radiation pattern. Controlling the radiation pattern is a key factor in antenna design.
- In the future, it is important to do photoluminescence experiments to quantify the exact enhancement we get for having those antennas compared to without them.

References

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Contact Information

Zeyan Xu

zxx120730@utdallas.edu

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