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Spatiotemporal fluorescent detection measurements using embedded waveguide sensors

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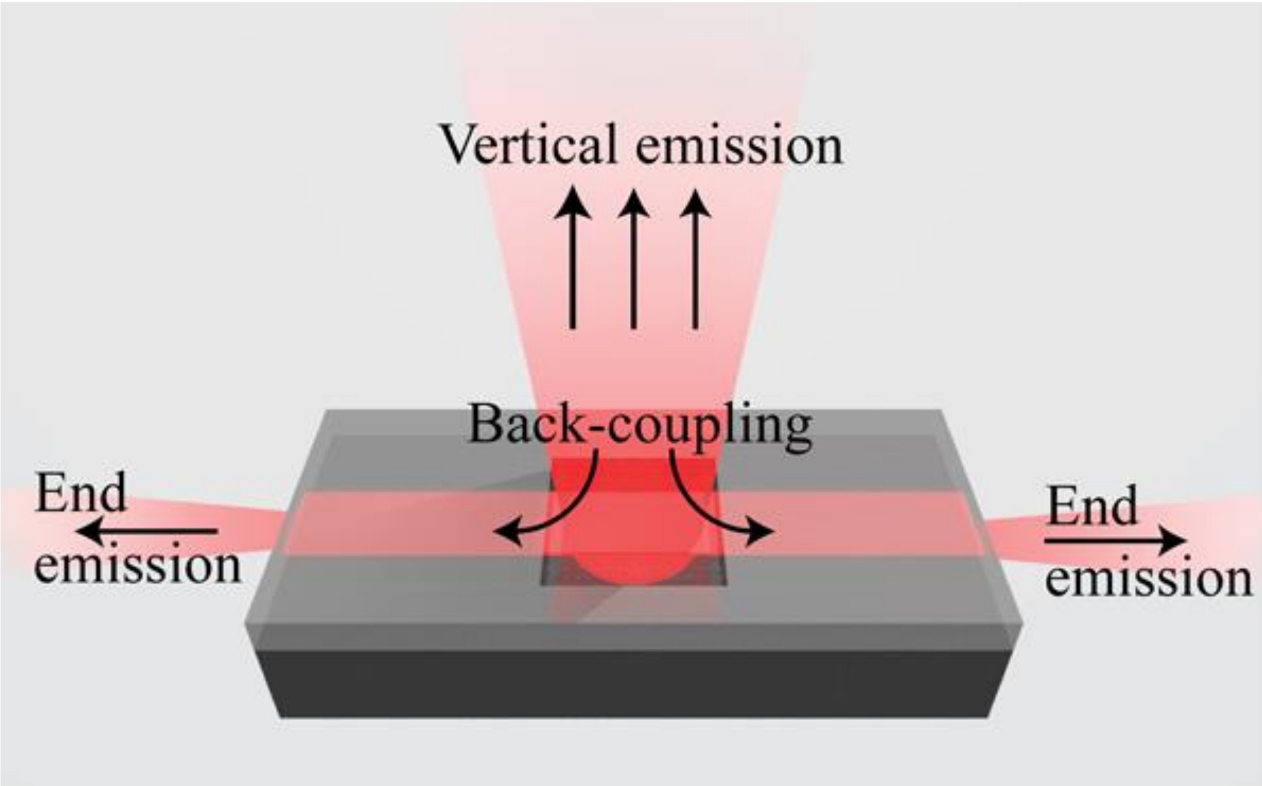
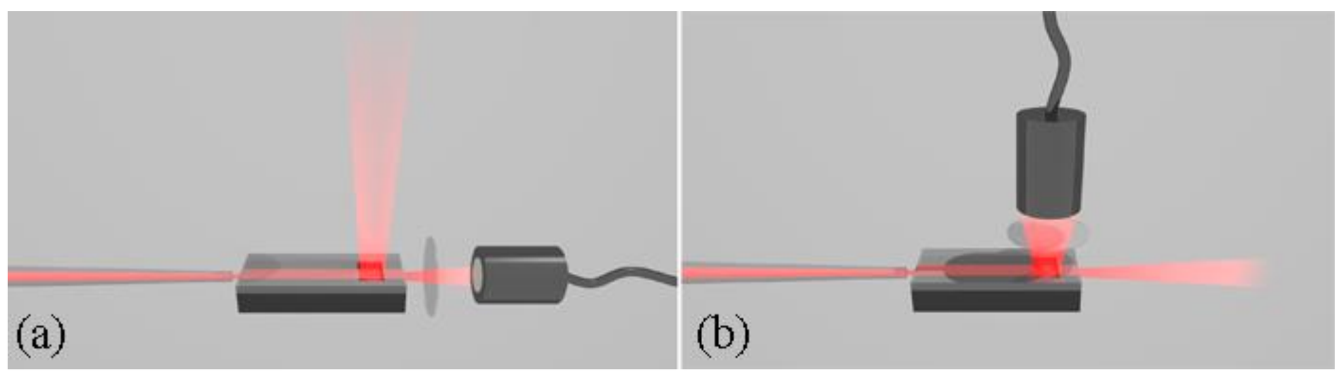
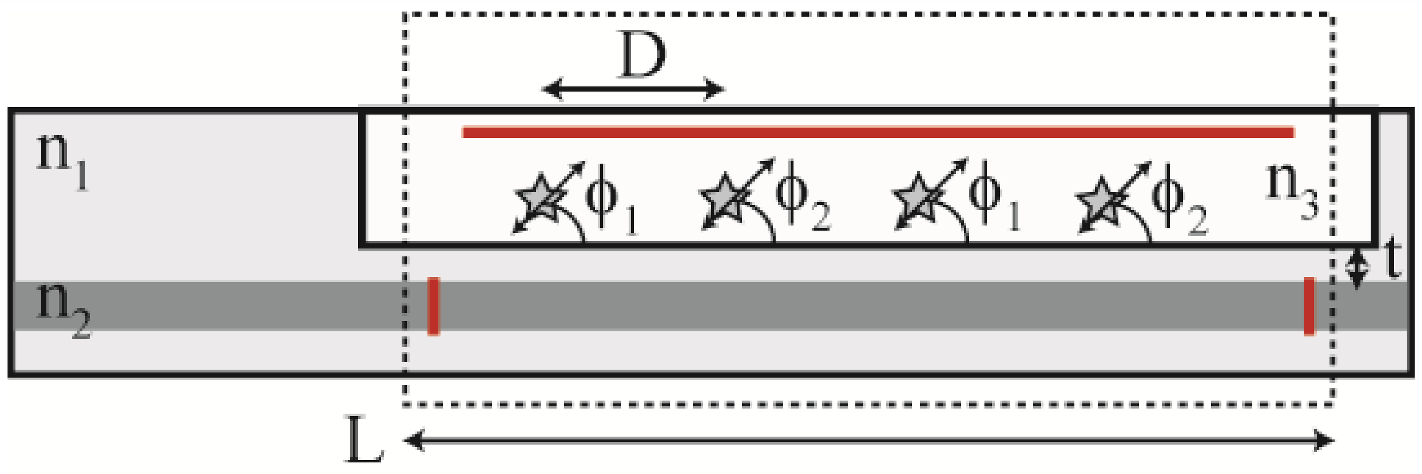
Background



Fluorescent waveguide sensors are commonly used sensors that use the evanescent field of the guided mode to generate a fluorescent signal, typically detected from above the device. Recently, a device was demonstrated which measures the fluorescent signal that back-couples into the waveguide. While this is attractive for building more compact lab-on-a-chip type sensors, the performance of the device was not fully characterized. By building a simulation model and performing experiments, the efficiency of the device can be determined.



Model

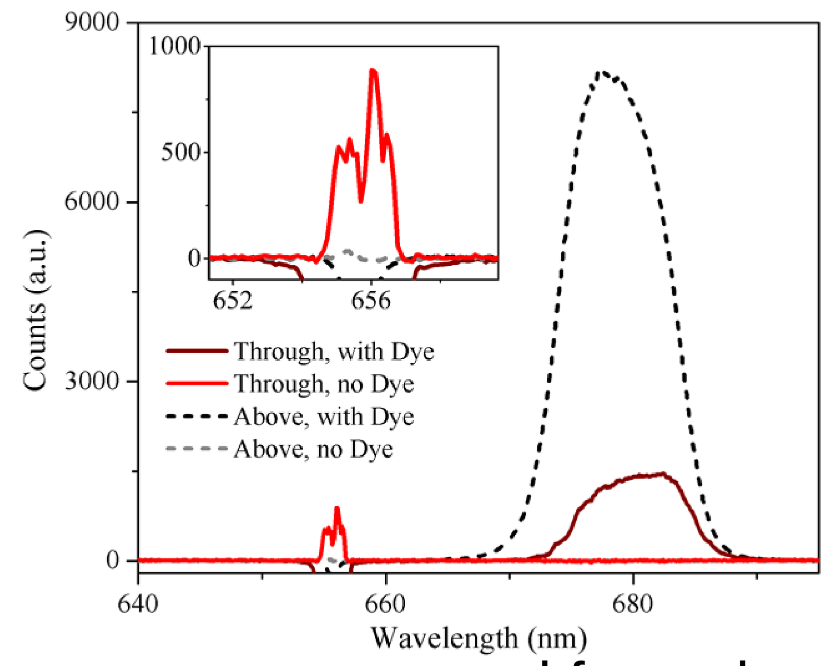


Left: Diagram of device geometry used for simulations. The locations of power monitors in the simulation are indicated by red lines, and the extent of the simulation region is indicated by a dashed line.

Right: Table indicating values of key simulation parameters. L = 500 µm and n_2 = 1.98

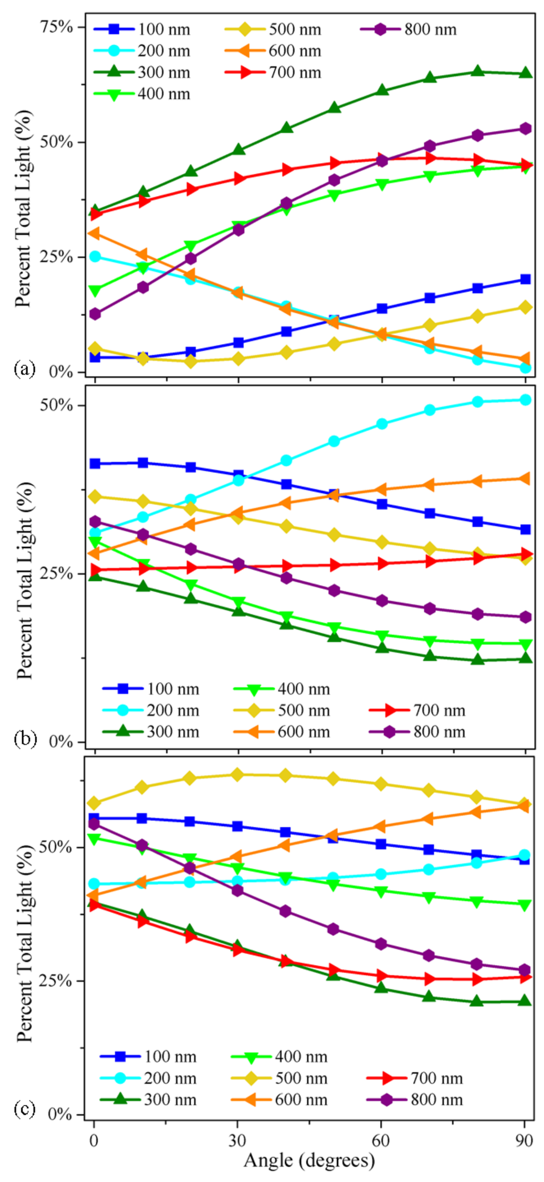
Model	T (µM)	D (µm)	# dipoles	ϕ_1 (°)	ϕ_2 (°)	n_1	n_3
1	0.010	0.1-0.8	2	0-90	90	1.4355	1.33
2	0.008-0.012	0.1	10	90, 90, 0	90, 0, 0	1.4-1.6	1.33
3	0.010	0.1	10	90	0	1.4355	1-1.4

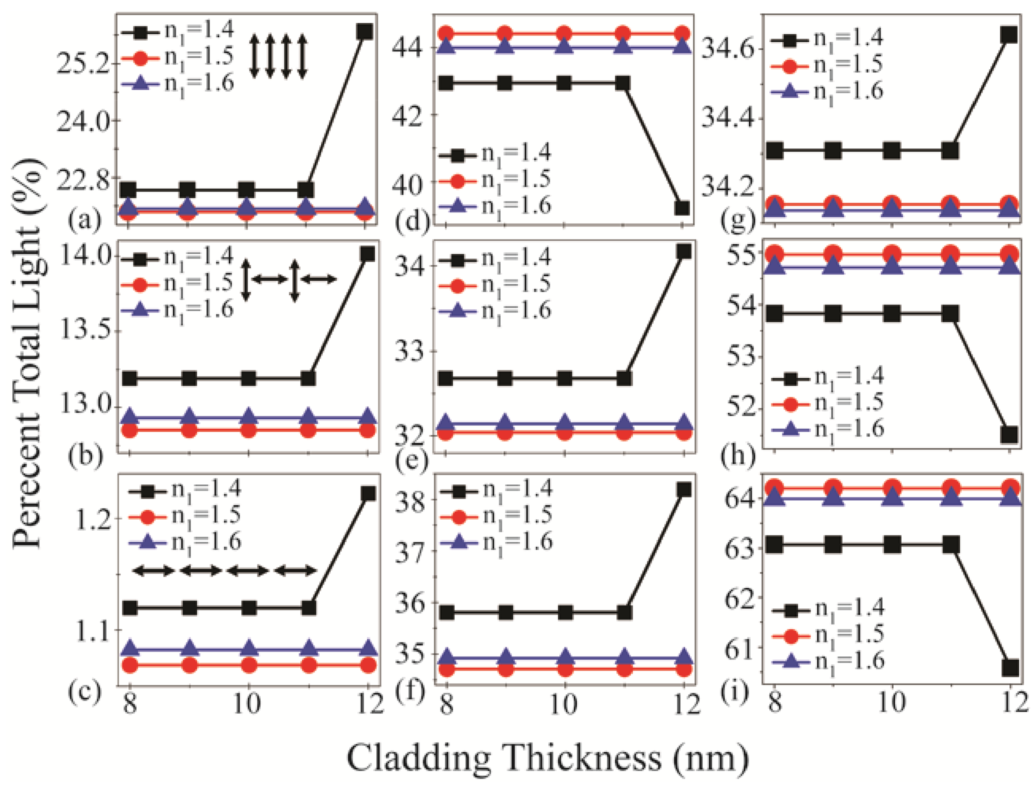
Experimental Data



Fluorescence measured from above and through the waveguide. Results corroborate simulation model.

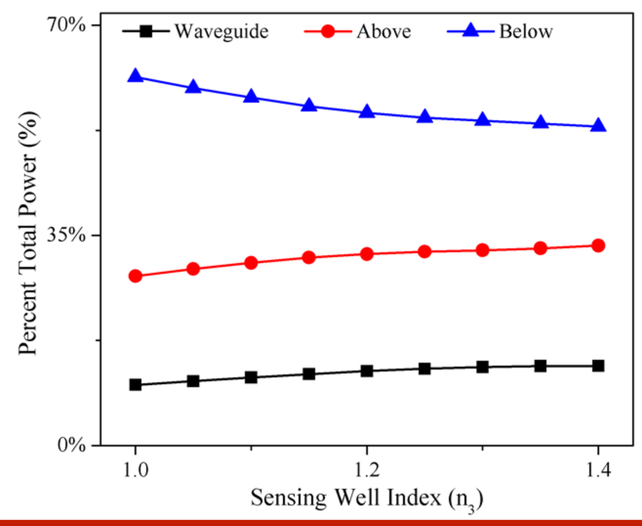
Modeling Results





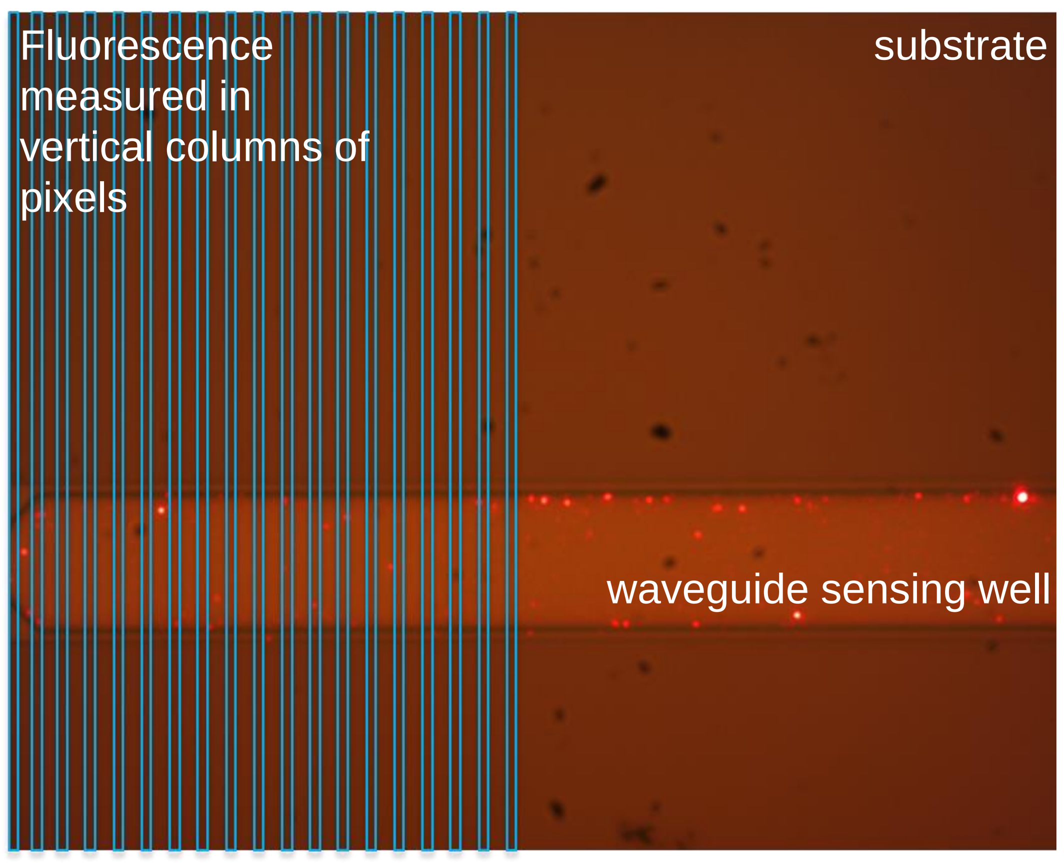
Below: Results from Model 3. Changing the refractive index of the sensing well improves overall efficiency, but does not lead to more light coupled into the waveguide. Equation used to calculate output.

$$O = W/(W + A)$$

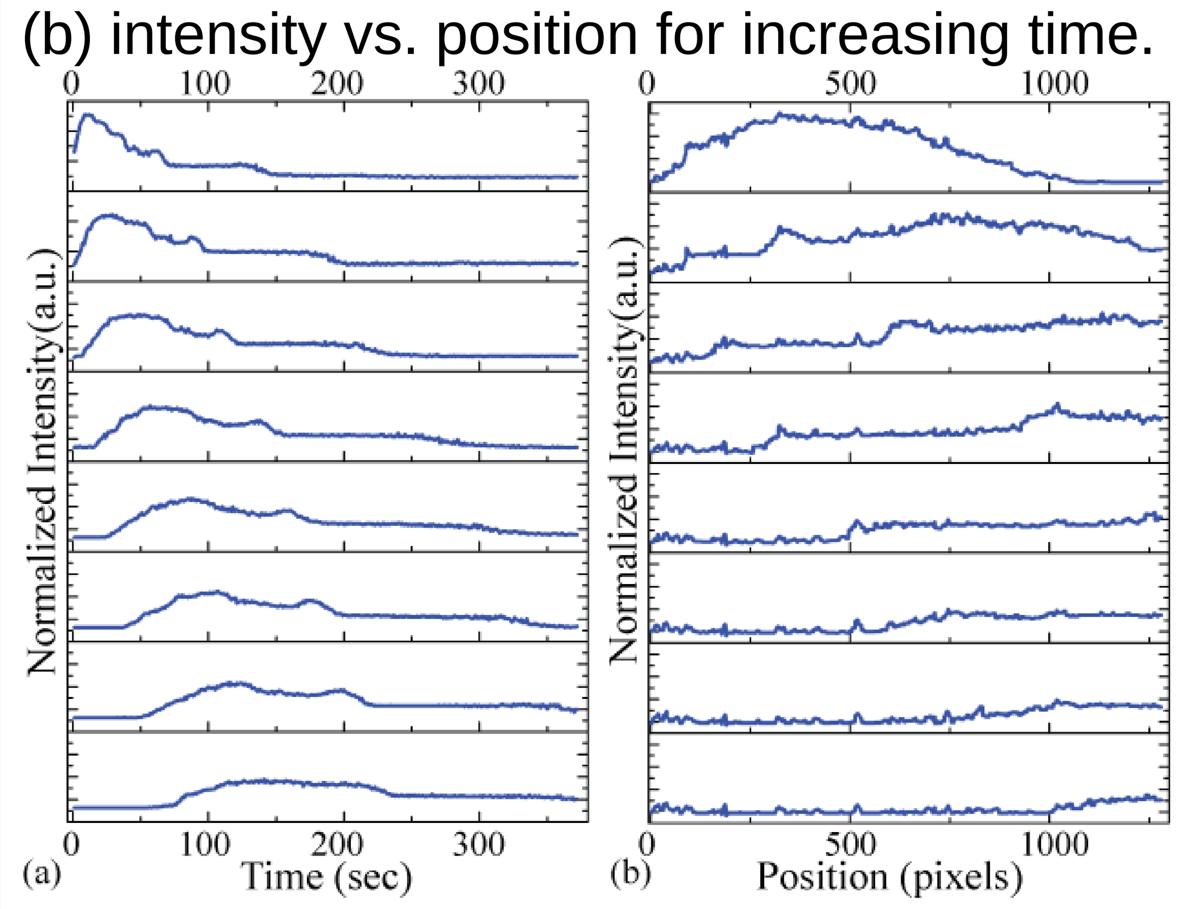


Left: Results from Model 1. Two dipoles is not enough for a complete picture of device behavior. Above: Results from Model 2. The device is relatively insensitive to variations in fabrication.

Spatiotemporal Data



Above: Spatiotemporal fluorescence data was captured with a camera placed above the device and analyzed with a custom LabVIEW program. Below: (a) Intensity vs. time for positions down the waveguide and (b) intensity vs. position for increasing time.



Conclusions and Future Work

The operation and efficiency of an embedded waveguide sensor was fully characterized using a simulation model and the results were verified experimentally. Using the equation above, the output from the simulations was calculated to be 0.278-0.327 and the output from experiments was calculated to be 0.257. Additionally, spatiotemporal fluorescence measurements were performed. These measurements have potential to be used to calculate fluorescence decay rates in a wide variety of operating environments, or to be used for complex multiplexing, allowing sensing assays that search for multiple analytes in series. These advances can improve optofluidic sensors, allowing more fully-integrated lab-on-a-chip devices.

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