Living cells: sensors of the future?

Whispering gallery modes inside microresonators.

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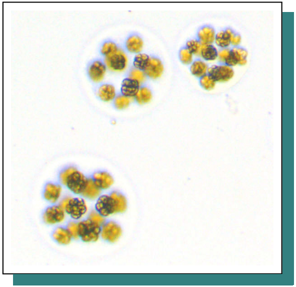

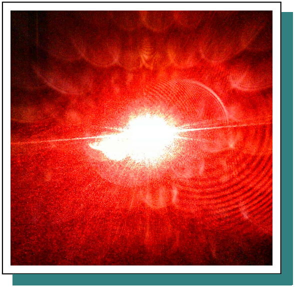

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Sensing with light

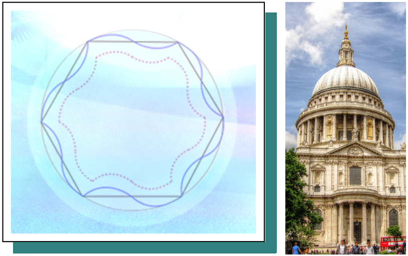
- Light can resonate inside microscopic devices: spheres, disks or shells.
- **What for?** Resonators act as detectors of nearby macro-molecules, such as viruses, bacteria or DNA.
- **How?** Resonators of a certain size (diam: 5-30 μm) can support special resonant 'whispering gallery modes'.

  $\rightarrow$ We can fabricate these resonators (e.g. polystyrene). Can we use living cells?

Illustration of a resonator. Polystyrene microspheres have been shown to **lase**.

‘Whispering gallery modes’

- Electromagnetic waves at the boundary of a sphere or disk can be reflected around the surface.
- These resonant ‘bound’ whispering gallery modes correspond to the number of surface nodes, and radial nodes. The are also narrow (‘high Q’) and trackable.
- At the material/medium interface, an ‘evanescent field’ extends outward, which is sensitive to the external environment.



Whispering galleries

Measurement setup: output radiation

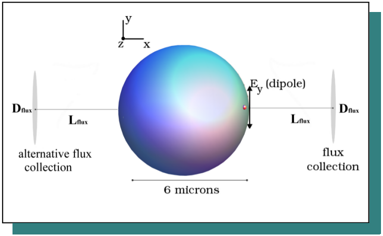
- Tests of microresonators (*pictured right*) involve three steps:

  (1) **excitation** (light source),

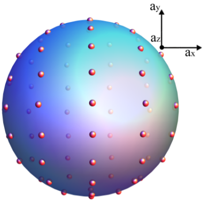
  (2) **collection** (a variety of scenarios exist to obtain the fluorescence), and

  (3) **characterisation** (is it exhibiting WGMs, is the lasing threshold good enough, etc.).

- Spheres, shells and odd-shape configurations have been considered, including inhomogeneous materials like cells.



Collecting flux from a microsphere

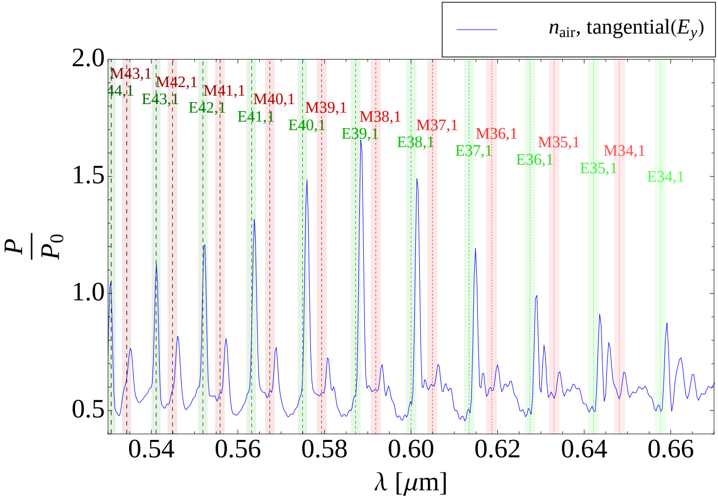


Fluorescent dye doping

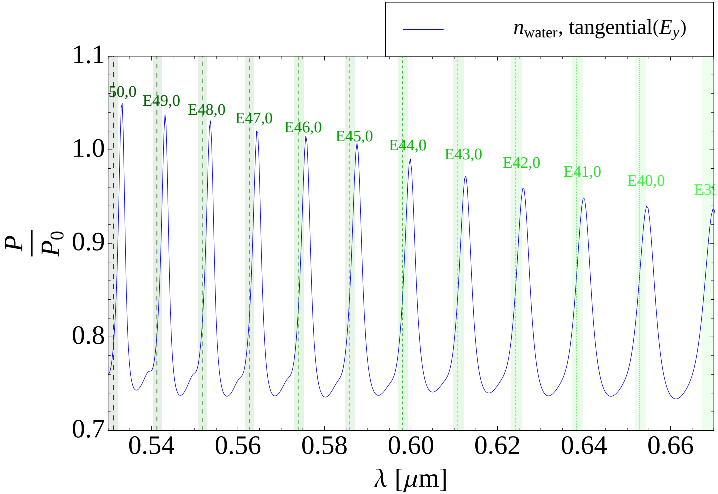
Guidance tools

- **Supercomputer simulations**: (a) good for 'higher index-contrast' scenarios, where *diameter ÷ wavelength* is not too large; (b) can do odd-shapes, distributions and collection methods.
- **Mathematical models**: (a) good for simulating 'lower index-contrast' scenarios, when *diameter ÷ wavelength* becomes large; (b) restricted to ideal collection methods and shapes.
- Note: If we have high index-contrast, and a large diameter compared to wavelength, modes are so narrow and closely-spaced we can't track them!

Example spectrum

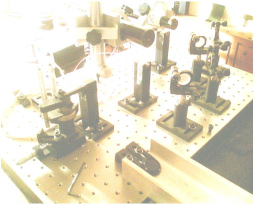


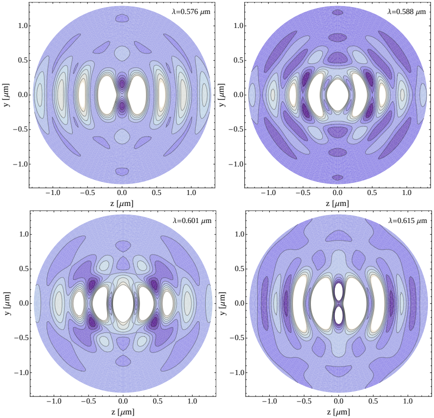
Example spectrum



Radiation distribution

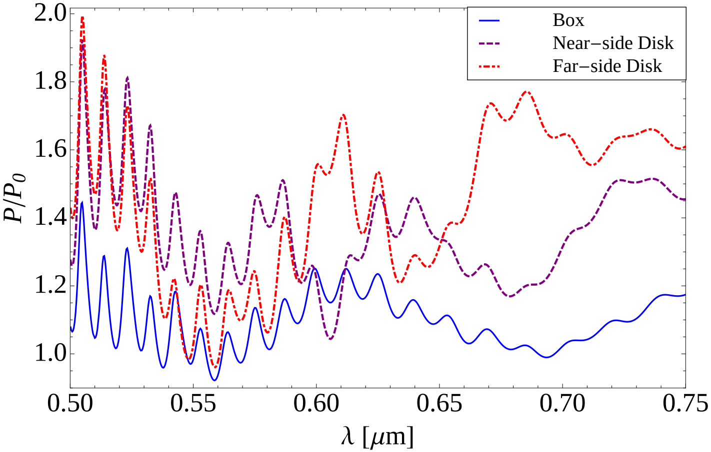
- We can also measure how the power is distributed, e.g. as seen by a fibre.
- More concentrated modes (smaller angular distribution) are less sensitive to changes in large collection apertures.



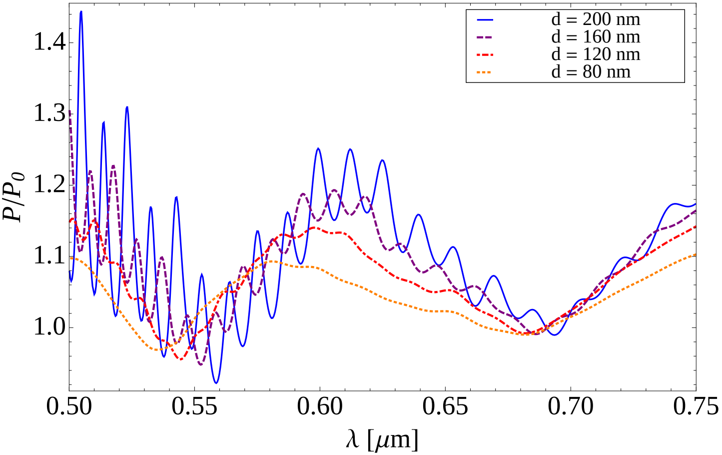


Power distribution for four different modes (wavelengths).

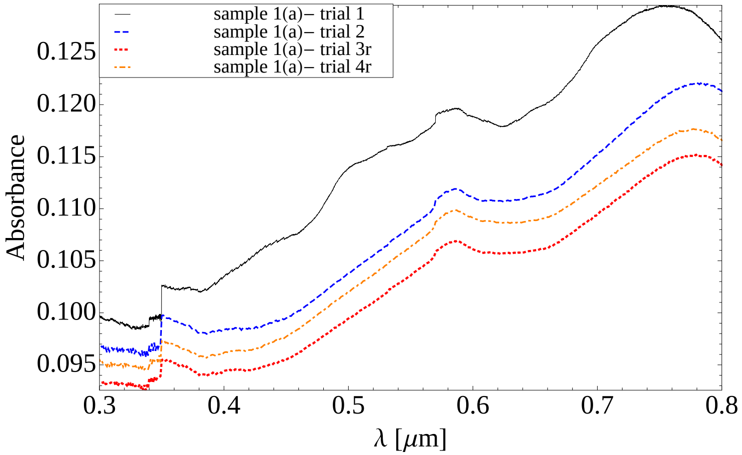
Fluorescent micro-shell simulation



Fluorescent micro-shell simulation



Yeast Absorbance - ctr9Δ gene deleted



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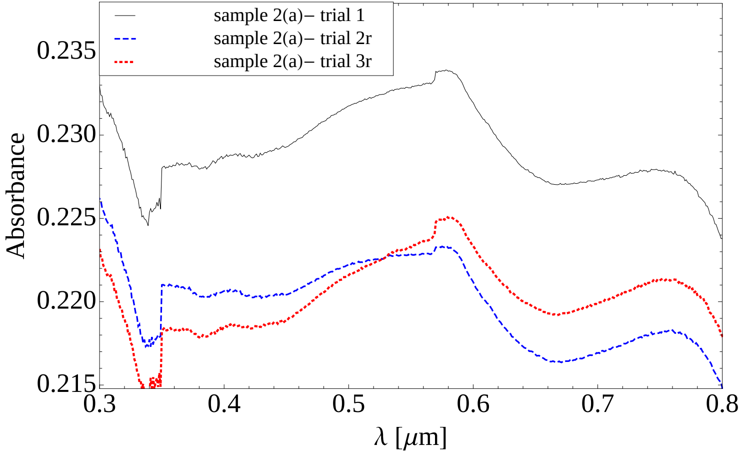
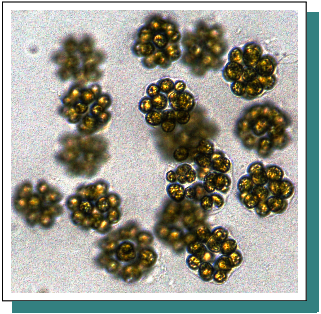


Plan for the future & wishlist

- **What we can do:**
  We are mapping out resonator configurations suitable for bio-sensing. Realistic structural imperfections are incorporated.
- Cells that match viable design solutions will be sent for experiment.

What we could use:

- *Biology:* sourcing & sorting cells, genetic-engineering.
- *Medical:* mobilising device & physical properties of bio-markers.



Sensing technology of the future?