THE ROYAL SOCIETY

Advanced chemical sensors based on optical microcavity arrays

Dr Jason Smith and Dr Claire Vallance, University of Oxford, Paul Instrument Fund,

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Introduction

Many techniques exist for detecting and identifying chemicals and small particles using light. They rely on the fact that light can be *absorbed*, *emitted*, or *scattered* (changed in some way) by the presence of the particles. The way that different *colours* of light are involved provides information – sometimes detailed information – about which chemicals are present.

In this project we are constructing devices in which arrays of *optical microcavities* are used to confine light to very small volumes of space – roughly 1 cubic micrometre, or 1/100 the volume of a red blood cell – to increase the strength of interaction with chemicals that pass through it. This should lead to increased sensitivity in detecting minute trace quantities of chemicals, offering potential for use in medical and environmental sciences and defence/ security technologies.

How it works

An optical microcavity is formed between two opposing mirrors, one of which is concave in shape (figure 1), so that light bounces back and forth many times before escaping.

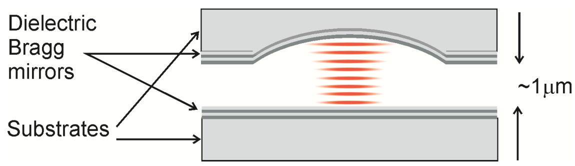

Figure 1 – An optical microcavity with a confined mode shown in red

Because light is made of waves, only certain wavelengths (ie colours) can form stable confined modes, so the cavity acts as a fine filter which can be tuned by changing the separation of the mirrors. This allows us to select wavelengths that interact most strongly with the chemicals we are interested in detecting, or to sweep the cavity length to measure the spectrum of the chemical response.

The small mode volume also means that each photon generates a large electric field, resulting in an increased interaction strength.

Progress so far

We have constructed the first generation instrument in which water is flowed through the cavity while we monitor the mode wavelength. In figure 2 below we can see a sudden change in the wavelength when salt is introduced into the flow. This comes about because the salt changes the *refractive index* of the water. The amount of salt present in the cavity at any one time is of order 1 picogram – about 1 billionth of a grain. A further factor of 1000 reduction should be possible.

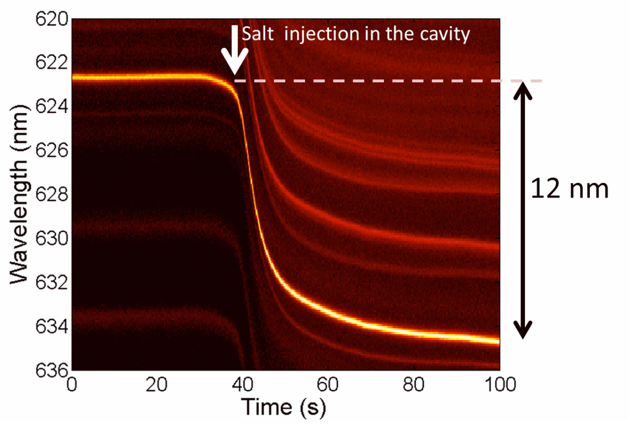

Figure 2 –detection of salt flowing through the cavity

My Paul Instrument Fund award has provided key resources for the development of these devices, including six months of postdoc time and consumables for development of the hardware. This comes at an important time in my research group where our innovation in cavity fabrication is opening up many new directions of study.

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