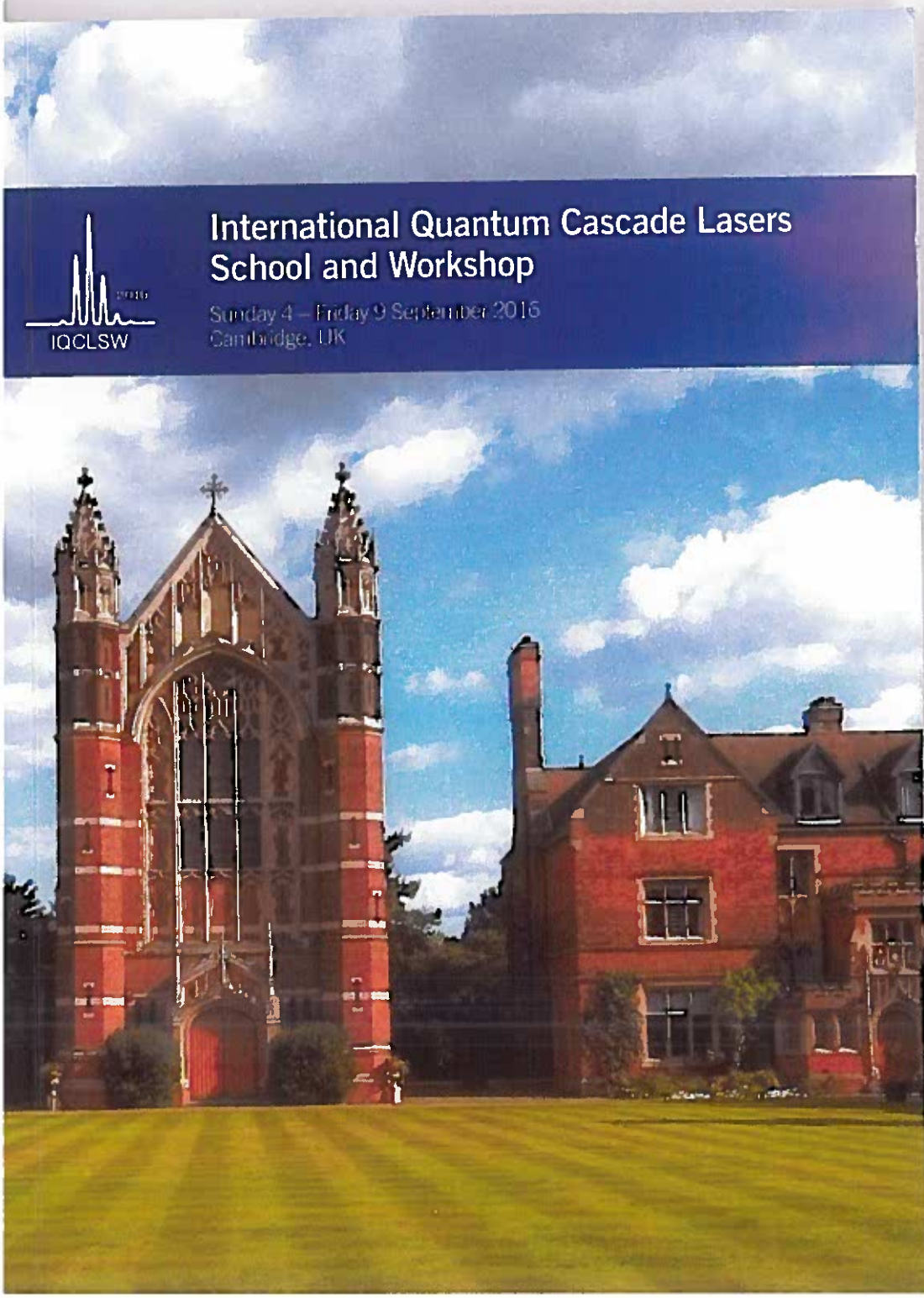
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Remote Gas Sensing with commutable Quantum Cascade Laser and Detector on the same Chip

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1. Introduction

Quantum cascade based mid-infrared spectroscopy [1], has become a reliable and powerful tool for various chemical sensing applications in science, industry and medicine. The tailorable emission characteristics of quantum cascade lasers (QCLs) enables sensing of a multitude of substances, since most molecules exhibit characteristic absorption features in the mid-infrared. Typical sensing setups consist of an emitter, a light-analyte interaction region and a separate detector. Our novel sensing concept is based on a bi-functional quantum cascade heterostructure [2], and incorporates the emitter and detector on the same chip [3]. This concept could enable a crucial miniaturization of future sensing devices and lead to compact hand-held remote sensors.

2. Sensor

Our sensor consists of two concentrical ring quantum cascade lasers/detectors (QCLDs) with a second order distributed feedback (DFB) grating for vertical light emission [4], and detection. A sketch of the device is given in Fig. 1(a).

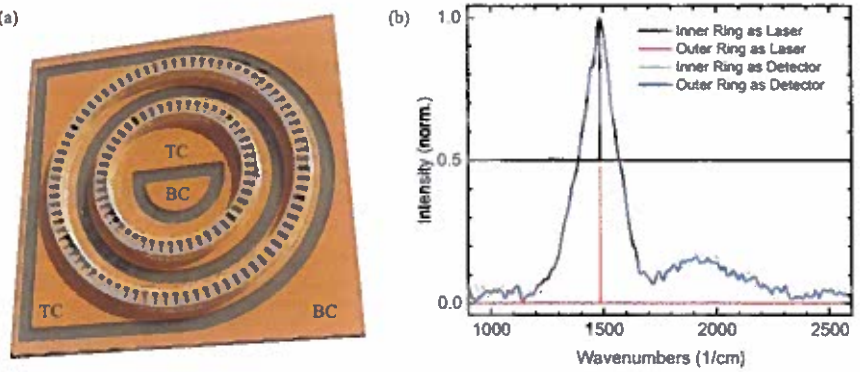

Fig. 1: (a) Sketch of the sensor with two concentrically aligned ring QCLDs. Both rings can be operated as laser and detector. Each ring is equipped with a top (TC) and a bottom (BC) contact. (b) Measured laser and detector spectra of both rings. The emission peaks lie exactly at the maximum responsivity peaks of the detectors, which enables an efficient sensing performance.

The use of a bi-functional quantum cascade heterostructure provides a spectral overlap between laser and detector. This allows the detector to detect the light emitted from the laser. Detector and laser spectra of the inner and outer ring are shown in Fig. 1(b). Our sensor can be operated in two configurations: (i) The inner ring works as a laser and the outer ring as a detector. (ii) The outer ring works as a laser and the inner ring as a detector. In addition, both rings emit at a different wavelength due to a differing DFB grating period. Therefore, our compact sensor provides room temperature lasing and detection of two different wavelengths monolithically integrated on the same chip.

3. Results

The vertical emission and the sensitivity to vertical incident light of our sensor facilitates the use as a remote chemical sensor [5]. Proof-of-principle gas measurements with a 10cm long gas cell using isobutene and isobutane as analytes were performed. The emitted light goes through the gas cell, is back-reflected by a flat gold mirror and passes the gas cell again before it recurs on the sensor chip. The results are given in Fig. 2.

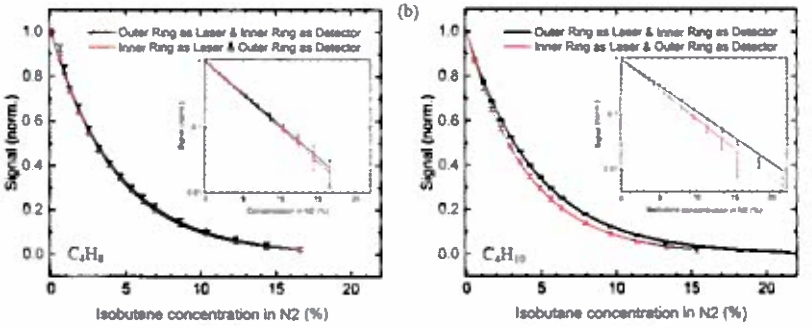

Fig. 2: (a) Measured detector signal as a function of the isobutene concentration in the nitrogen (N2) background. The inset shows the logarithmic representation and the solid lines represent the Beer-Lambert law. (b) Same as in (a) for isobutane. Due to the varying absorbance between the emission wavelengths the exponential decay for both configurations shows a significant difference.

The Experimental data is in very good agreement with the theoretical prediction from the Beer-Lambert law. For the isobutane measurement with the 10cm gas cell we reach a limit of detection of 400ppm. In conclusion, we introduce a compact remote sensor concept based on bi-functional and commutable quantum cascade lasers and detectors and present proof-of-principle gas measurements illustrating the high sensitivity of the sensor.

4. References

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