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Parts-Per-Million level detection of Carbon Monoxide using grating array waveguides in InP/InGaAs at λ=4.6μm

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Introduction

On-chip Spectrometers

- Unlike their on-chip commercially available counterparts offer sensing in portable applications.

Mid-infrared Absorption Spectroscopy

- Unique rovibrational signatures of compounds of interest in the molecular fingerprint region.
- At least two orders of magnitude larger absorption cross-sections than in the near-IR

Carbon Monoxide

- One of the major air pollutants is dangerous even at very low concentrations. For real-time and precise detection of trace amounts of this gas we need a compact highly sensitive and selective sensor.

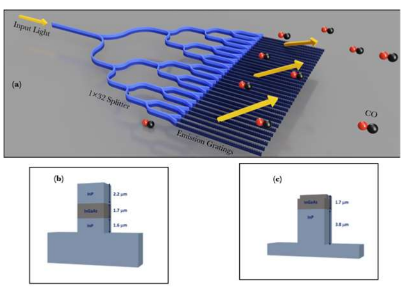

Fig. 1. (a) Schematic representation of grating array sensor. (b) Schematic cross-section in the strip waveguide region. (c) Schematic cross-section in the grating region.

Device Structure

- A grating array device in the InP/InGaAs platform for trace detection of carbon monoxide.
- an InGaAs strip waveguide with InP as the top and bottom claddings
- split-cascaded into an equally spaced array of 32 separate optical paths. The splitter is a tree-array of Y-junctions and 500 μm radii s-bends, with a total length of 1500 μm.
- shallow etched subwavelength emitter gratings couple the light out. The emitter waveguides have no cladding

Fabrication

- Selective wet etch (HCl/H2O) of InP in the emitter region only, to remove the cladding and leave the InGaAs layer exposed. → The gratings are shallow-dry-etched into the InGaAs layer by Cl2/N2 inductively-coupled plasma reactive-ion etch (ICP-RIE). → The waveguides are dry-etched by Cl2/CH4/H2 ICP-RIE, etching through the InP and InGaAs layers and into the InP substrate to a total depth of 5.5 μm

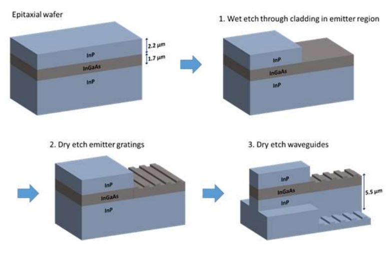

Figure 2: Fabrication process.

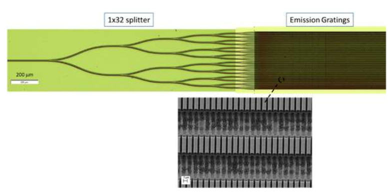

Figure 3: Top-view images of fabricated device: (a) entire structure, and (b) SEM of the emission gratings.

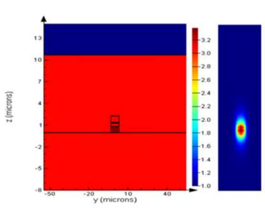

Fig. 4. Simulation results for mode profile in strip waveguide region

Gas Sensing

Measurement Results

- Gas sensing is experimentally demonstrated down to a concentration of 5ppm at the mid-IR wavelength of λ=4.6μm.

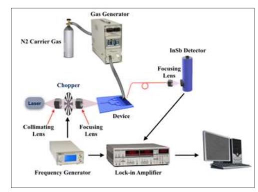

Figure 5: Schematic of the measurement setup

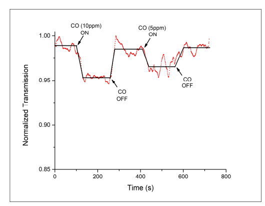

Figure 6: Carbon Monoxide detection results at 10 ppm and 5 ppm

Monolithic Structure

- In the proposed monolithic structure, light generated in the QCL ridge is coupled downwards by a taper to an InGaAs waveguide and 1x32 tree-array splitter distributes the light into a series of identical parallel waveguides with gratings for emission to the QCD.

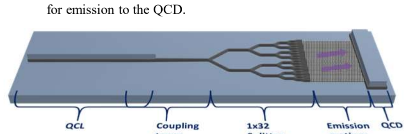

Figure 7: Proposed monolithically integrated device structure with distributed waveguides

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