Novel Ultra-miniature Technology for Earth Observation and Sensing

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Introduction

- Motivation
- Spectrometer chip concept
- Design process
- Future work and prospects
“Ground Truth”: Satellite data need to be calibrated and validated with ground-based measurements.
Present: uniform area (desert)

Future: non-uniform area
(forest canopy: spectrum changes as the sun moves)
Issues with conventional spectroscopy systems

- Current spectrometers have multiple components
  - Alignment issues
  - Expensive to manufacture
  - Optical effects – loss of photons / stray light
  - Miniaturisation difficult – spectral resolution suffers as size of spectrometer is decreased
Our solution: Resonant Detector Array

Waveguide

Incoming spectrum

Microdisk resonators
Contour Map of $E_y$ at $cT = 102.403 \, \mu m$
Our solution: Resonant Detector Array
Dispersion and detection in one absorbing layer (quantum well).

- Conduction band
- Promoted electron
- Electrons in valence band
- Valence band

Photon
Advantages

- Tiny footprint
- Low mass
- Low power consumption
- Robust:
  - Wavelength separation and detection within a single photonic element
  - No electrical or mechanically moving parts
- Fast data acquisition
- Thermally stable
- Tuneable spectral features
- Maintenance-free
- Potential for low stray light, high resolution
- Potential for wide spectral range
System requirements:

• Wavelength range: 750-1000nm (ultimate aim: 300-1000nm)

• Resolution:
  – 5-10nm (broad spectrum)
  – 0.1nm (specific spectral bands of interest)
Design Aspects

Choice of materials

Waveguide

Full chip model

Quantum well

Resonators

Input optics

Electronics

Current work

Future work
Choice of Materials

$E_g (\text{Gamma}) \text{ (eV)}$

$Al(x)Ga(y)In(1-x-y)As$

$y$ (Fraction of Gallium)

$x$ (Fraction of Aluminium)
Layer structure:
quantum well

- Absorbing Layer (Quantum well)
- Cap layer (p-doped)
- Cladding layer (n-doped)
- Substrate (n-doped)

Absorption spectrum TE polarised
Transition energy cb001-hh001
Barrier band gap
Waveguide Design

High index layer

Cap layer (p-doped)

Cladding layer (n-doped)

Substrate (n-doped)

Refractive index

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National Physical Laboratory
Resonator design

Radius

Effective r.i. is fixed

Contour Map of $E_y$ at $cT = 102.403\ \mu m$

Free Spectral Range

Intensity (output/input) vs. wavelength ($\lambda$) (nm)
Future work: input optics

Optical motherboard (UK Patent application GB2494640A)

- Housing made of semiconductor or insulator
- Groove for bare optical fibre cable
- Groove or recess for sensor (in butterfly package?)
- Mirror
Possibilities include a Quantum dot LED or a DFB laser
Future work: hyperspectral imaging
Other applications

- Biomedical science
- Environmental/remote monitoring
- Industrial quality control
- Mobile technology
Summary:
- ZiNIR’s chip-based spectrometer integrates dispersion and detection elements on a single chip
- Current application: calibration of Earth observations
- Design stages:
  - Choice of material
  - Quantum well and waveguide
  - Resonator optimisation

Future work:
- Front-end optics
- Electronics
- On-chip light source
- Hyperspectral imaging

Other applications
- Biomedical
- Remote monitoring
- Industry
- Mobile technology
EMRP for funding this project

- The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union