Integrated photonic devices for sensing and optical communication in the near- and mid-IR

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Motivation:
Looking for Industrial Partner:
ICT-29-2016:Photonics KET 2016

Proposal Tentative Topic/Title
Integrated Photonic Lab-on-a-chip for Mid-IR Environmental and Biosensing

Topics
Integrated Photonic Circuits; Mid-IR Sensing; Optical Microresonators; Waveguide Lasers and Amplifiers
Optoelectronics Research Centre
@ University of Southampton

- Largest photonics group in the UK (~250 staff / PhD students)
- 200 Journal Publications/20 Patents per year
- A cluster of 11 start-up companies
- >£60M of secured research funding
- ~100 laboratories

- £120M Mountbatten clean room complex
  1500 m² (class 100 and 1000)

- State-of-the-art facilities for
  - Integrated photonics
  - Nanofabrication
  - Fibre fabrication
  - Biophotonics
  - Bioelectronics and thick film

- Facilities – Highlights
  - E-beam lithography
  - Photolithography
  - PECVD, LPCVD, ALD, Sputtering, Evaporation
  - ICP DRIE, Ion beam miller, FIB
  - He Ion Microscope
Integrated Photonic Devices Group

Generating advanced optical materials
Harnessing microelectronic fabrication
Exploiting optical interactions at surfaces

To realise integrated photonic circuits for
Telecommunications
Compact laser sources
Bioanalysis

Class 1000 flexible cleanroom facility for materials, processes and devices

Specialised mid-Infrared (2-14μm) waveguide characterisation and spectroscopy facility

http://www.orc.soton.ac.uk/ipd.html
Research - Examples

Integrated Photonics for Bioanalysis

Wideband Mid-IR waveguides (2-14 μm)

WIPFAB – ERC funded project (AdG to JSW)

Poled EO amorphous Mid-IR waveguides

Geometry control and Micrometric localization of optical anisotropy

(A1) Optical image of imprinted polarized line

(A2) Example of μSHG response geometry

(A3) SHG map

Poled Ta₂O₅ amorphous film

In collaboration with University of Bordeaux

Optofluidic integration

(Integrated microflow cytometers)

Planar integrated microlenses

WIPFAB

32 analyte biosensor chip

Estrone, 2-4D, simazine … in water

LoD <20 ng/L

AWACCS - EU funded project

Research - Examples

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Components for the all-optical chip

**Waveguide Lasers**
- Er & Nd doped glass
- Er, Nd & Tm: LiNbO₃
- Ti-diffused sapphire
- Nd, Er & Yb:Ta₂O₅

**Waveguide Amplifiers**
- ASE/Gain flattening filter
- Yb/Er doped section
- Pump multiplexer
- EO overlay

**Lasing spectra of Er:Ta₂O₅**
- Above $P_{th}$
- Below $P_{th}$
- $\Delta \lambda \approx 0.57$

**Lasing spectra of Yb:Ta₂O₅**
- $\eta = 27\%$

**Microring Resonators**
- for switches, lasers & add-drop mux
- Epitaxial KY$_{1-x}$Gd$_x$Lu$_y$(WO$_4$)$_2$
Research - Examples

Excitation & manipulation of spheres & cells

Microsphere fabrication and self-assembly

Integrated microsphere lasers

Microbottle resonator (add-drop filter)

Optophoresis

- Surface microsphere sorting
- Loop for standing-wave trapping

Microsphere and biological cell manipulation
With O.G. Hellesø, Uni. Tromso, Norway
Mid-infrared biosensing

Introduction

Compact mass-produced biosensors and analytical microsystems are required for biochemical monitoring in diverse applications such as water quality, personal and preventative medicine, and rapid point-of-care diagnostics. The microfabrication approaches that have advanced consumer electronics in recent years are expected to lead to a widespread use of bio/chemical microdevices, due to their low cost, robustness and potential for integration. Optical techniques play a major role in quantitative chemical analysis and remain the mainstay of detection in ‘lab-on-chip’ systems, but the degree of optical functionality integrated within these systems remains extremely limited. The mid-infrared spectral region covering wavelengths between 2µm and 20µm is of particular interest as it can provide much information on biochemical species through direct absorption ‘fingerprinting’ but research into microdevices in this spectral regime is in its infancy. Research at the University of Southampton is aiming (i) to generate highly sensitive, mass-producible waveguide devices for biochemical detection and (ii) to harness the massive growth in photonics telecommunications technologies for bioanalytical waveguide circuits with improved on-chip functionality.

Technology Roadmap

Research into mid-Infrared materials and devices started in 2012 under the Wideband Integrated Photonics For Accessible Biomedical Diagnostics European Research Council-funded grant. This programme builds upon three EU-funded research projects in the field of immunosensing for water pollution monitoring over a 10-year period, which included sensitive refractometric waveguide immunosensors using plasmonics and interferometry (1998/9) and specific and highly sensitive fluorescence-based multiple immunosensor chips for 32 simultaneous analytes at concentrations below 0.02 ppb (2005). Two Engineering and Physical Sciences Research Council (EPSRC)-funded projects on electrochemical plasmonics for monitoring and controlling surface reactions allowed demonstration of orthogonal sensing approaches on a single waveguide platform (2001/2). Contributions from the university’s Optoelectronics Research Centre have focussed on novel waveguide devices for surface sensing and we have worked with partners on surface chemistry, biochemistry, electrochemistry, instrumentation and environmental monitoring to realise and validate complete systems. We have now established materials and waveguides for mid-IR operation and an advanced mid-IR characterisation suite, and are seeking collaborations to exploit these in applications for healthcare and the environment.

Collaboration Opportunities

We are open to several types of collaboration, including EU research and technical development (RTD) projects with complementary partners in both basic science and applications, and collaboration with industry to exploit our devices, expertise and capabilities to provide solutions to industrial problems.