

# Monolithically integrated photonic lab-on-a-chip platform for biological applications

I.Raptis<sup>1</sup>, E. Makarona<sup>1</sup>, P. Petrou<sup>2</sup>,  
S. Kakabakos<sup>2</sup>, K. Misiakos<sup>1</sup>

<sup>1</sup>IMEL, NCSR 'Demokritos' Athens, Greece

<sup>2</sup>IRRP, NCSR 'Demokritos', Athens, Greece

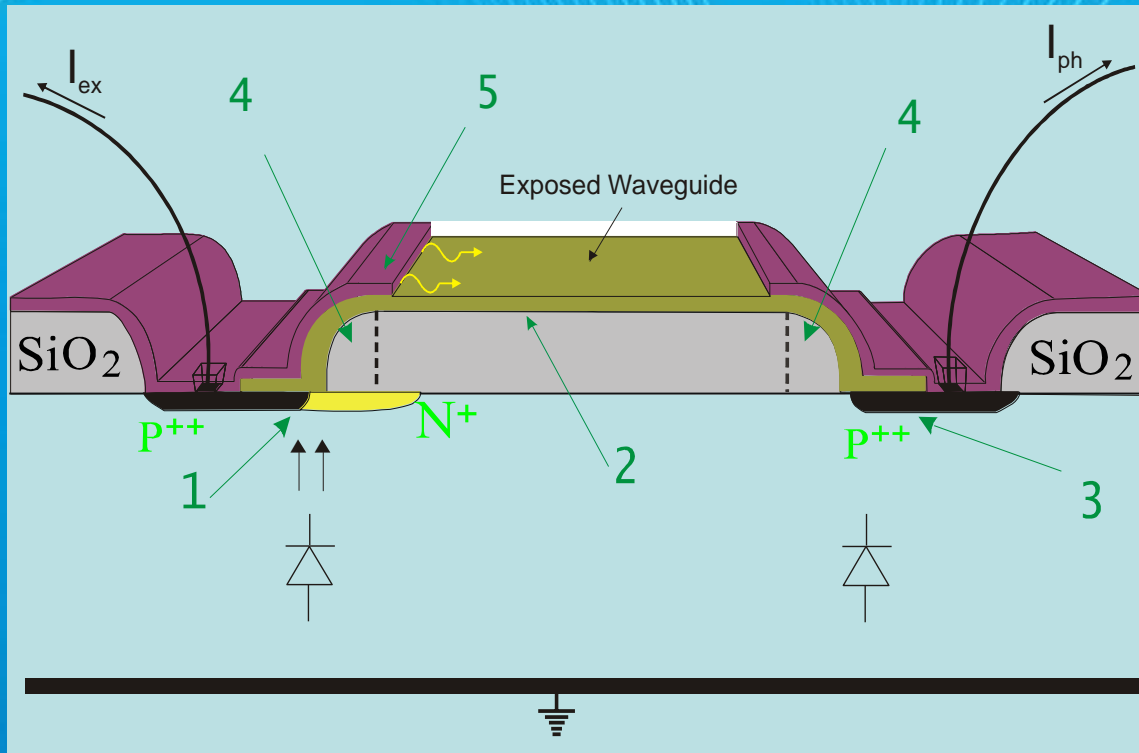


# Optical Transducer Issues

- **Difficult integration of all optical and electrical components on the same chip**
- **Need for external optical components**
- ✓ **Bulky set-ups (portability issues)**
- ✓ **Expensive experimental set-ups**
- ✓ **Need for alignment (tedious process, takes time)**

**Solution** : Monolithic integration of all passive and active optical components on the same Si chip

# Optoelectronic Platform Concept



- 1: LED
- 2:  $\text{Si}_3\text{N}_4$  WG
- 3: PD
- 4: spacer
- 5: top cladding layer

- PCT WO2007/074348

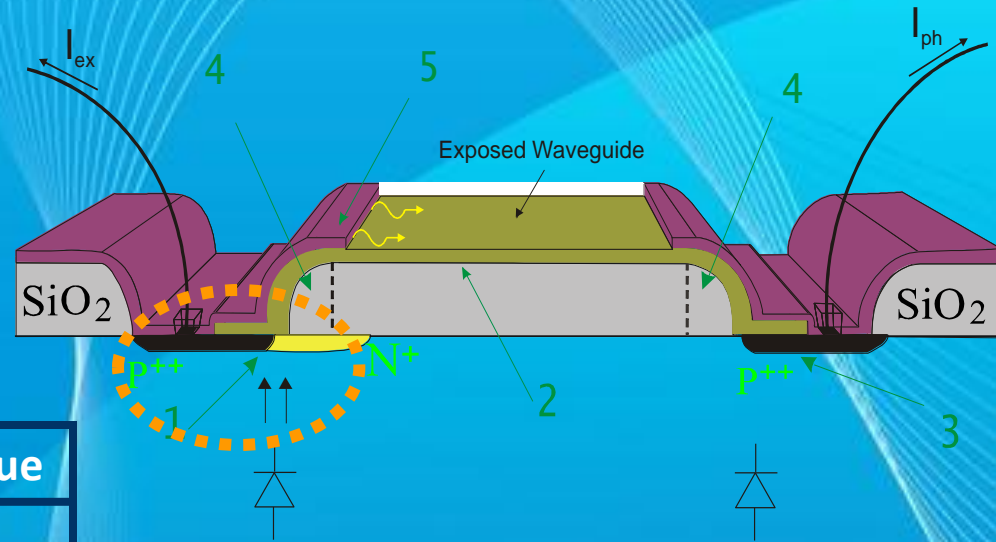
- K.Misiakos, S.E.Kakabakos, P.S.Petrou , H.H. Ruf, *Anal. Chem.* **76**, 1366(2004) “A Monolithic Silicon optoelectronic Transducer as a Real-time Affinity Biosensor”

- E. Mavrogiannopoulou, P.S. Petrou, S.E. Kakabakos, K. Misiakos *Biosens. Bioelectron.* **24** 1341(2009) “Real-time detection of BRCA1 gene mutations using a monolithic silicon optocoupler array”

# Optoelectronic Platform Concept

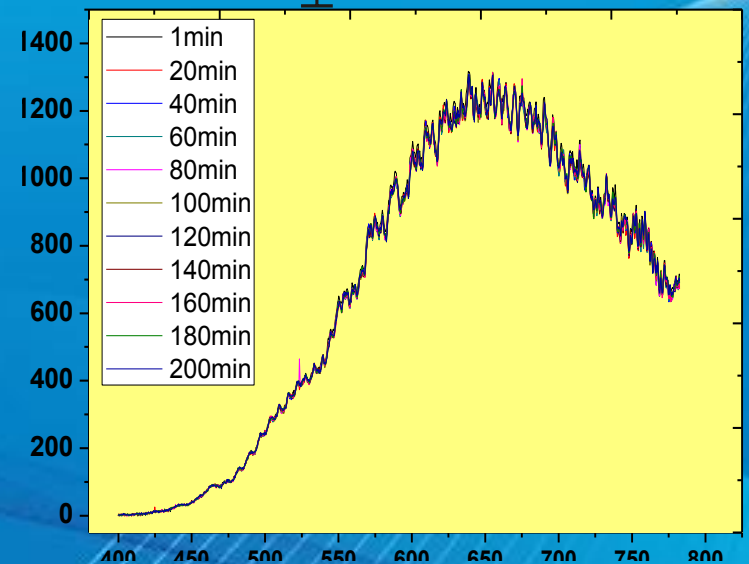
**Light Source (LED): Reverse biased avalanche diode**

**Spectral response: VIS-NIR (>450nm)**



Item	Maximum Rated Value
Power Dissipation	150mW
Current	10mA
Reverse Voltage	15V

- Reverse breakdown voltage: ~30V @ 25°C
- Reverse dark current:  $\leq 2\text{pA}$
- Measured Photocurrent: <700pA (mm long WGs, monomodal in the vertical direction, multimodal in the horizontal direction)
- Capacitance: ~2pF for 400×400μm pads



Output Spectrum: 3hrs continuous operation. Recorded by QE65000 cooled spectrometer.

# Integrated Optoelectronic Platform Advantages

- All active (LED, PD) and passive (Waveguides) optical components on the same chip
- Multiple transducers on the same chip
- Standard Si processing
- Very small size (depends on the sensor principle of operation)
- Potential integration of read-out electronics on the same chip

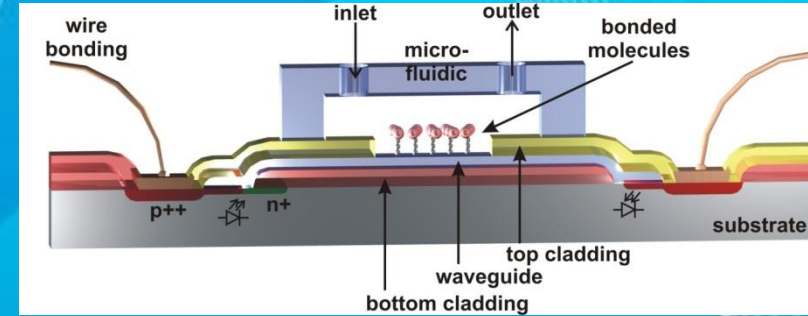
# Integrated Optoelectronic Platform Applications

- OptoElectronic
- OptoElectroMechanical

# Monolithically integrated interferometric biochips for label-free early detection of Human diseases (PYTHIA)

## PYTHIA Objectives

- Broad Band Mach-Zehnder Interferometry: Proof of concept
- Arrays on a chip with wafer scale encapsulation
- Real-time label-free monitoring of biochemical reactions with high sensitivity and dynamic range
- Generic platform for portable diagnostic tools for early detection of diseases (Antibody assay (free and bound PSA- for prostate cancer), Oligonucleotide based detection (MEN2, RP))



WO/2009/115847: "Monolithically integrated physical chemical & biological sensor arrays based on broad-band Mach-Zehnder Interferometry"

# PYTHIA partners

A multidisciplinary team of eight partners (4 SMEs, 2 research centers, and 2 university departments) from six EU countries with complementary skills.



**NCSR 'Demokritos', Greece**

Optoelectronic sensor chip fabrication & functionalization



**PhoeniX BV, Netherlands**

Optical sensor simulation and design



**LioniX BV, Netherlands**

Optical sensor chip fabrication



**Jobst Technologies GmbH, Germany**

Microfluidics & encapsulation



**Jagiellonian University, Poland**

Sensor surface characterization



**VTT, Finland**

Read-out electronics and measuring system



**Biogenomica SA, Greece**

Biochip & system evaluation

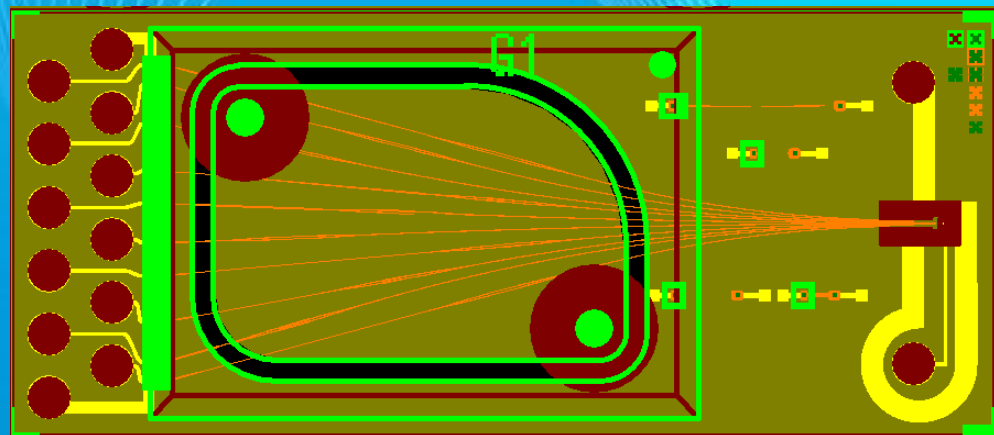


**University College London, UK**

Biochip & system evaluation

# PYTHIA: technical details

PYTHIA chip layout



**10 label-free all Si-based monolithically-integrated optical transducers on a single-chip**

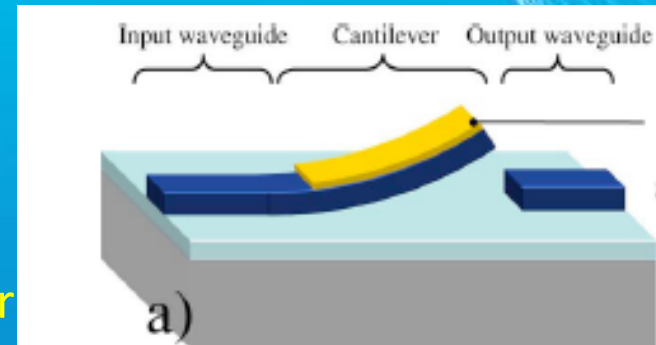
- ❑ chip length = 9.25 mm, width = 4 mm
- ❑ die size ~40mm<sup>2</sup>
- ❑ ~150 dies/wafer (4")

# Integrated Photo-Electro-Mechanical Transducer

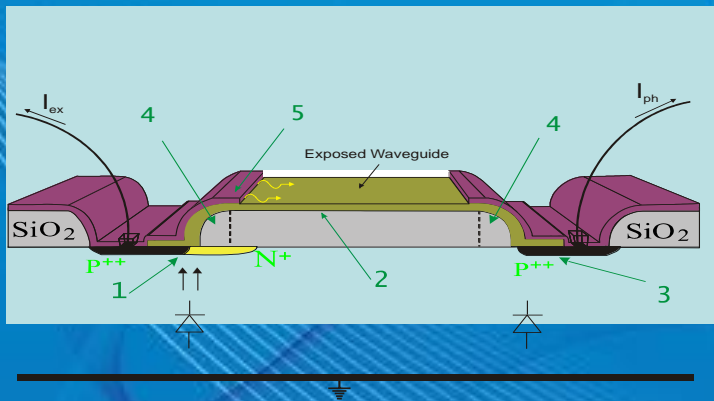
**Optical cantilevers:** Miniaturized devices  
Very high sensitivity, Very good LOD  
Arrays of cantilevers on the same chip  
External light source and detector

**The Solution:** Integrated Light Source  
Integrated Photodetector  
Planar Waveguides

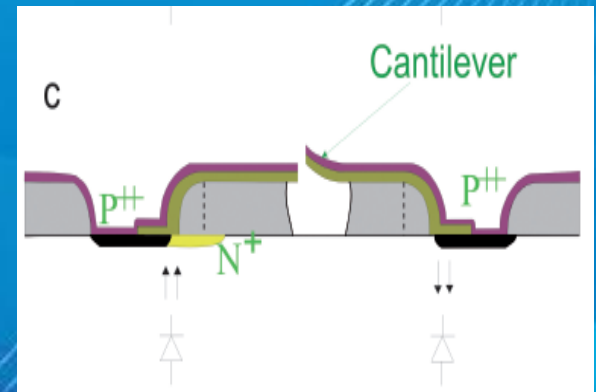
**The Concept:** The light travels through the cantilever



‘Horizontal’ Illumination



PMMA resist  
E-beam Litho  
RIE of Si<sub>3</sub>N<sub>4</sub>  
SiO<sub>2</sub> wet etching  
Waveguide/  
cantilever release



K.Misiakos, I.Raptis, A.Gerardino, H.Contopanagos, M.Kitsara **Lab on a Chip 9 1261(2009)**  
“A Monolithic Photonic Microcantilever Device for in-Situ Monitoring of Volatile Compounds”

# Conclusions

**Monolithically integrated platform that combines light source (VIS/NIR), planar waveguides, photodetector**

## **TRULY INTEGRATED PHOTONIC LoC**

Various Transduction Principles have been explored:

Mach-Zehnder Interferometer

Cantilever

Others are in progress.....

## **CHARACTERISTICS**

- ✓ Label-free detection
- ✓ Array of sensors on the same chip

# 4<sup>th</sup> Workshop on MultiAnalyte BioSensing Devices

*first*  
ANNOUNCEMENT

**4<sup>th</sup>** INTERNATIONAL WORKSHOP  
ON MULTIANALYTE  
BIOSENSING DEVICES  
SEPTEMBER 7-8, 2011  
ATHENS, GREECE

[www.iwmbd4-2011.org](http://www.iwmbd4-2011.org)

## IMPORTANT DATES

Submission Deadline for 1-page abstract:

*April 15, 2011*

Notification of Acceptance:

*May 27, 2011*

Early Registration Deadline:

*June 10, 2011*

Registration for the Workshop closes:

*August 26, 2011*

Organized by:



National Center for Scientific Research "Demokritos"  
15310 Aghia Paraskevi, Athens, Greece  
<http://www.demokritos.gr>

Where: **Athens, Greece**  
When: **7-8 September 2011**

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