PhOREMOST "Nanophotonics to Realise Molecular-Scale Technologies"

# PhOREMOST
# network of excellence
## *Promoting Nanophotonics in Europe*

# PhOREMOST
# Emerging Nanophotonics Roadmap

*Silvia M. Pietralunga*

# Roadmapping: one main activity in our network

**Emerging Nanophotonics roadmap**

**Integration** — **Joint Research Projects** — **Education & Training**

Dissemination

# What?

## *Scientific* and *technical* roadmap

- Focus on selected *emerging (mid to long-term)* nanophotonic concepts, technologies and devices
- Identify main challenges and possible roadblocks
- Outcome should help to *steer and focus research* in nanophotonics for the scientific community at large and within PhOREMOST in particular

PhOREMOST

# How does it relate to MONA?

http://www.ist-mona.org/roadmaps

- MONA and PhOREMOST roadmapping activities were developed as a *coordinated effort*

- PhOREMOST's emerging nanophotonics roadmap is *complementary* to MONA's "Roadmap for Photonics and Nanotechnologies"

## How is it structured?

- We have chosen selected topics, with high potential impact and outstanding scientific and technological challenges in three different areas:
  - Concepts
  - Technologies
  - Devices

# Table of Contents: **Concepts**

- Random lasers
- Non-linear nano-optics
- Metamaterials in the visible
- Plasmonics
- Microcavities
- Optical trapping and sorting

# Table of Contents:
# Technologies

- Infiltration Techniques
- Functionalisation
- Self-assembly
- Hybrid nanotechnologies

# Table of Contents: Devices

- Photovoltaics
- Lighting and optical sources
- Sensing
- Light manipulation
- Nano-doped active materials

# Example 1: Random lasers

- **Motivations**
  - Obtain lasing in new random materials
    - Cheap and easy large scale fabrication
    - New optical properties
  - Understand physics of random lasing
  - Develop new applications in lighting, encryption, sensing...

# Example 1: Random lasers

- **Figures of merit**
  - *Lasing efficiency, material stability, temperature sensitivity, …*
- **Main challenges**
  - <u>Theoretical model that includes interference:</u> understanding localized and extended modes in random systems
  - <u>Mode competition, stability</u>: how stable is the output, when is it chaotic, and role of mode competition
  - <u>Electrical pumping</u>

# Example 1: Random lasers

| Timeline: | | | |
|---|---|---|---|
| | 2 – 5 years | 5 – 10 years | 10 years and more |
| Theoretical model that includes interference | Yellow | Green | White |
| Mode competition, stability | Green | White | White |
| Electrical pumping | Yellow | Green | White |

Red (No known solutions at this time), Yellow (Very hard but possible solutions), Green (feasible solutions under investigation), White (known solutions, first commercial products available)

# Example 2: Sub-wavelength plasmon optics

- **Motivations**
  - Enhanced light-matter interaction at the nanoscale
  - Plasmon routing at the sub-micrometer scale for short distance interconnects
  - New hybrid materials

# Example 2: Sub-wavelength plasmon optics

- **Figures of merit**
  - Molecular sensitivity in Surface Enhanced Raman Scattering (SERS)
  - Light guiding through submicrometer sections
  - SP-enhanced optical forces
  - ….
- **Main challenges**
  - Field confinement below the 20 nm level
  - Field Enhancement factor above 100
  - SP guiding through sections smaller than 100 nm
  - Controlling the dynamics of single molecules
  - Trapping objects as small as 100 nm

PhOREMOST

# Example 2: Sub-wavelength plasmon optics

| Timeline | | | |
|---|---|---|---|
| | 2 – 5 years | 5 – 10 years | 10 years and more |
| Field confinement below the 20 nm level | | | |
| Field Enhancement factor above 100 | | | |
| SP guiding through sections smaller than 100 nm | | | |
| Controlling the dynamics of single molecules ( | | | |
| Trapping objects as small as 100 nm | | | |

# Example 3: nanoparticle-doped organics waveguide optical amplifiers

- **Motivations**
  - Optical gain on short distances for applications in integrated PLC
  - Organic PLC are attractive due to good performances and cost-effectiveness
  - Optical amplification at telecom wavelengths in organics is an issue, due to both absorption and luminescence quenching

# Example 3: nanoparticle-doped organics waveguide optical amplifiers

- **Figures of merit**
  - Optical gain coefficient for the material
  - Waveguide propagation loss
  - Net optical gain for the implemented waveguide
- **Main challenges**
- Increased gain of PMMA-based EDWA at l = 1.50 mm.To reach  a gain parameter of about 4 db/cm
- Realization of PMMA-based WDM for optical pumping
- Realization of Chalcogenide doped single-mode waveguides
- Realization of Plug and play devices

# Example 3: nanoparticle-doped organics waveguide optical amplifiers

| Timeline: | | | |
|---|---|---|---|
| | 2 – 5 years | 5 – 10 years | 10 years and more |
| Increased gain of PMMA-based EDWA at λ = 1.50 μm | | | |
| Realization of PMMA-based WDM | | | |
| Chalcogenide doped single-mode waveguides | | | |
| Plug-and-Play devices | | | |

PhOREMOST

# Contacts

**PhOREMOST Roadmap Contact**

**Prof. Goncal Badenes**

ICFO, Barcelona

Goncal.Badenes@icfo.es

**PhOREMOST Coordinator:**

Prof. Clivia Sotomayor Torres,

ICREA Research Professor, ICN Barcelona and Tyndall National Institute, Cork

clivia.sotomayor@tyndall.ie

**Technical Examples:**

**Random Lasers**

Dr Diederik Wiersma

LENS, Florence

wiersma@lens.unifi.it

**Sub-wavelength plasmon optics**

Dr Romain Quidant

ICFO, Barcelona

Romain.Quidant@icfo.es

**PMMA-nanodoped amplifiers**

Dr Isabelle Ledoux

ENS-Cachan, Cachan

Isabelle.Ledoux@lpqm.ens-cachan.fr

**www.phoremost .org**

Public version (print and electronic) scheduled for May 2008

Watch for it at

**http://www.phoremost.org/**