FINAL REPORT

Project Title:	PNPCs – Purely Nonlinear Photonic Crystals
Duration:	01.05.2009 - 30.04.201
Project Type:	Marie Curie Intra-European Fellowship for Career Development
Ref:	PIEF - 2009 - 234798 / PHY
Grant recipient:	Dr. Katia Gallo
Host:	Prof. Fredrik Laurell *Department of Applied Physics* *KTH - Royal Institute of Technology* *10691 Stockholm (Sweden)*

Project Objective:
The project explored a brand new approach to photonic crystals, namely Purely Nonlinear Photonic Crystals (PNPCs), based on structured optical nonlinearities. Its main objective was to develop an integrated nonlinear nano-photonic platform on ferroelectrics of the lithium niobate crystal family and achieve with it a few basic device demonstrators. The ultimate research aim encompasses photonic devices with applications to telecom and quantum optics and potentially also biology and sensing.

Project Overview:
The Marie Curie fellowship allowed Katia to join the group led by Prof. Laurell at KTH, where she was trained on state-of-the nanotechnologies, established a photonic platform for $LiNbO_3$ materials (bringing in her previous expertise from 10-years research outside Sweden) and then combined these capabilities to implement novel PNPC devices. The latter rely on a new approach to material engineering, affecting the nonlinear properties (as opposed to the refractive index) of the substrate. The key technology for achieving such a purely nonlinear structuring is known as 'periodic poling'.

Fig. 1. *Cascaded frequency up-conversion in a 2D purely nonlinear photonic crystal.*

Main scientific achievements

Technology. The technological activity of the project addressed in the first instance the challenge of controlling the periodic poling in two-dimensions, to implement non conventional (2D) lattice topologies and achieve high aspect ratios (depth over width) in the periodic patterning. To this aim Katia explored new solutions combining conventional patterning (performed with external electrodes) and chemical methods (to create in-built space charge fields in the crystals to enhance the poling spatial resolution). This allowed the reliable fabrication of 1D[1] and 2D[2] PNPCs with record aspect ratios (4:1000=feature-width/depth) as well as the achievement of sub-micron patterning (Fig.2, to be published).

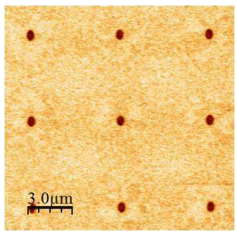


Fig. 2. *AFM image of a 2D PNPC in $LiNbO_3$*

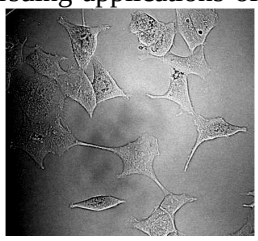
Theory and experiments. With this technology toolbox, extended to new $LiNbO_3$ and $LiTaO_3$ substrates with enhanced optical performance (Mg-doped and stoichiometric), Katia implemented a few basic PNPC demonstrators, for frequency up- and down- conversion as well as cascaded conversion processes (Fig.1).[3] Recent highlights include: the broadest bandwidth to date (180 THz) achieved in parametric generation;[4] and he demonstration of twin-beam parametric generation, a scheme unique to 2D PNPCs;[5]

Applications. A continued collaboration with Katia's previous research institution (the ORC), a world-leading research centre on **optical fibres and telecom systems**, led to of a number of new

applications of her devices to advanced all-optical signal processing in ultra high-capacity telecom systems.[6-12]

With the quantum optics groups at KTH and Stockholm University we are pursuing applications of the most recent outcomes of the PNPC project[5] to **quantum cryptography and quantum communications** (PNPC sources of multi-entangled photons).

The interdisciplinarity of the Host Institution is giving rise to additional synergy, which could enable the convergence of opto- nano- and bio-technologies on the PNPC platform of this project towards lab-on-a-chip applications. In this initial exploratory phase, we are investigating the properties of 2D PNPCs as templates for cell growth and biological assays (fig. 3).



ig. 3. *Cell growth on $LiNbO_3$.*

Marie Curie Fellow career development

As a result of the scientific activity and of the complementary training activities of the PNPC project, Katia has now successfully integrated her Host Institution and can envisage the pursuit of a long-term academic career in Sweden. She has gained the qualification of 'Docent' (Assoc. Prof.) and has now the formal status of main supervisor and principal investigator at KTH. Thanks to the recent award of a Research Fellow position by the Swedish Research Council, she can now pursue an academic career at KTH and develop more ambitious research objectives building on the results of her PNPC project.

Results in short.

- Scientific publications:
  - 12 journal papers and 1 book chapter in preparation,
  - 9 invited talks and 12 regular contributions to international conferences.
- Student supervised & trained through the project:
  - at KTH (Sweden): 2 degree students, 2 M.Sc. students and 2 PhD students;
  - at the ORC (UK): 1 Ph.D. student and 1 postDoc;
- Established 5 new intra-European collaborations,
  between KTH and research institutions in the UK (2), Ireland (1), France (2) and Italy (1)
- Fellow's career development:
  - Docent (Assoc. Prof.) in Physics at KTH - dec 2010
  - Research Fellow of the Swedish Research Council in electronics and photonics - jan 2011

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