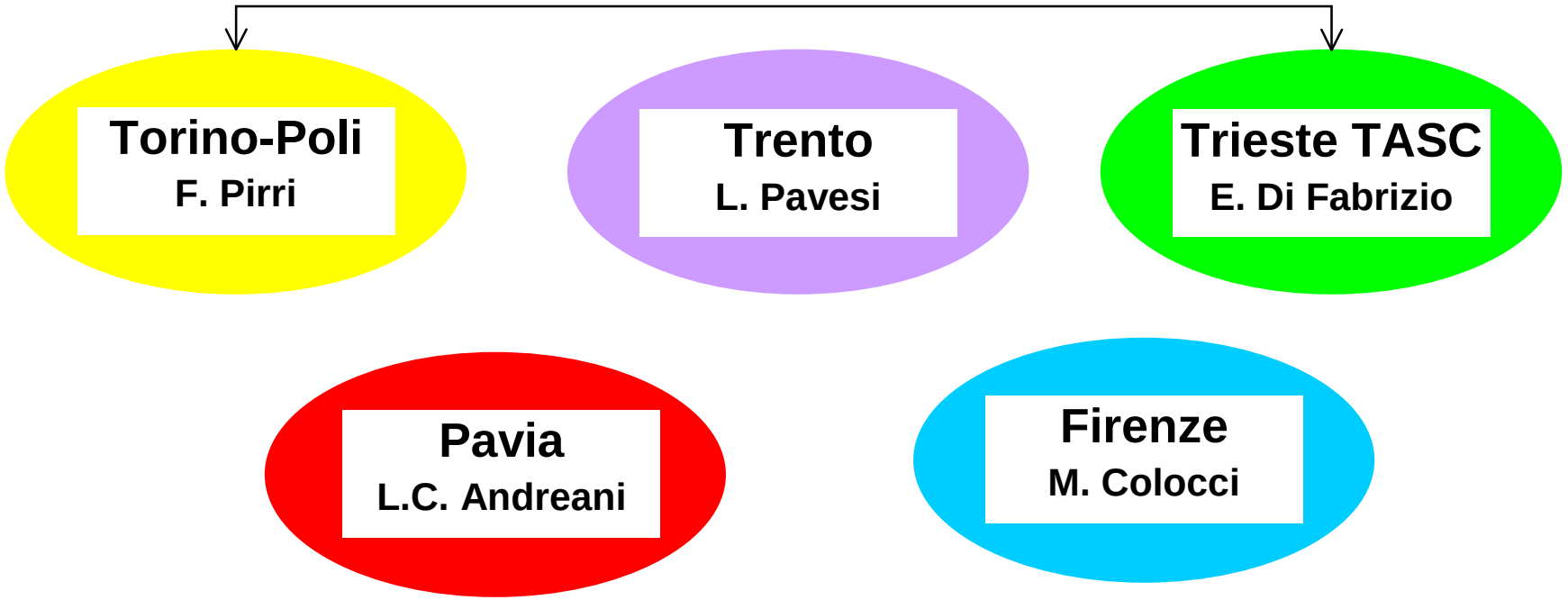
MIUR-Cofin 2002 project

Si-based photonic crystals:
technology, optical properties and theory

Project manager: Lucio Claudio Andreani

Duration: 2003-2004 **MIUR funding: 390 K€**



Objectives

(i) To develop the fabrication technologies of Si-based photonic crystals of different dimensionalities (2D, waveguide 2D, 3D) and of their infiltration with active media;

(ii) to produce samples with various photonic patterns, including line and point defects, as well as with embedded light emitters;

(iii) to perform a detailed study of optical properties and, for active systems, of radiation-matter interaction;

(iv) to develop the theory of photonic bands and of the optical response for the investigated photonic crystals.

Technology and materials (1)

By combining deposition techniques, lithography (electron-beam, X-ray and nanoimprint), wet and dry etching, sedimentation and infiltration the following kinds of photonic crystals with a gap in the near-infrared or in the visible will be produced:

(i) *two-dimensional systems*: macroporous silicon, films based on amorphous silicon (a-Si:H) and amorphous silicon nitride (a-Si(1-x)Nx:H) with high photoluminescence intensity;

(ii) *two-dimensional systems embedded in planar waveguides*: SOI-Silicon on Insulator structures (a-Si:H on SiO2);

(iii) *three-dimensional systems*: macroporous silicon with vertical modulation of the pore diameter, periodic multilayers (a-Si:H/a-Si3N4:H) patterned with a lattice of holes, opals and inverse opals (Si and TiO2), Yablonovite and inverse Yablonovite.

Technology and materials (2)

In all kinds of structures obtained by lithography,
linear defects (channel waveguides also with sharp bends) and
point defects (photonic cavities) will be defined…

… also in order to realize *demonstrators* for devices
(=linear waveguide with a channel length 0.1-0.3 mm
and propagation losses lower than 10 dB/cm)

The structures will be infiltrated with *Erbium*, *dyes*, *liquid crystals* and *colloidal quantum dots* in order to obtain active media with an emission frequency at the band gap.

In order to have active media in controlled positions, *local infiltration techniques* will be developed.

Optical studies

- characterization of the optical response and of the position of the gap by reflectance and transmittance;

- measurements of the photonic band dispersion by variable-angle reflectance from the sample surface and by phase-sensitive Mach-Zehnder interferometry;

- measurements of transmission in channel waveguides and in microcavities with butt-coupling and near-field optical microscopy techniques;

- studies of the effects of disorder by time-resolved spectroscopy and coherent backscattering;

- measurements of spontaneous emission modifications in photonic crystals infiltrated with active media.

Theory

• calculations of photonic bands and density of states for 2D, waveguide-embedded 2D and 3D systems;

• calculations of reflection and transmission spectra, and of diffraction phenomena, for finite and semi-infinite photonic crystals;

• simulation of electromagnetic wave propagation in photonic crystals and in channel waveguides, also with disorder effects, and study of time-resolved propagation of wavepackets;

• calculation of modified spontaneous emission for an emitter placed in periodic photonic crystals of different dimensionalities and in photonic cavities;

• modelling of near-field optical microscopy.

Activities of participating units

Torino Politecnico

- PECVD growth, electron-beam lithography, reactive-ion ething
- Opal fabrication, infiltration by CVD
- Theory of photonic crystals: pulse propagation, near-field

Trieste-TASC, LILIT beamline@ELETTRA:

- Electron-beam and X-ray lithography
- Deep reactive-ion etching (RIE, RIBE, ICP)

Trento University and IRST-ITC:

- Electrochemical etching (macroporous silicon)
- Waveguide measurements, “optical bus”

Pavia University:

- Optical measurements: variable-angle reflectance, transmission, interferometry
- Nanoimprint lithography
- Theory of photonic crystals: photonic bands, optical properties, emission

Firenze - University and LENS:

- Infiltration of holes with liquid crystals, dyes and colloidal quantum dots
- Optical measurements: NSOM, time-resolved spectroscopy, fluorescence