Mid-term
Grenada & 13-14 November 2019

InterPol
Polariton lattices: a solid-state platform for quantum simulations of correlated and topological states

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This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 731473.
Motivation: exploring many-body physics in driven-dissipative systems

- New phases of light emerge from the interplay between on-site interaction, hopping, drive and dissipation
- Lattices with non-trivial topology?
- Properties are imprinted on the outgoing photons => Potential resource for quantum technology

Ciuti & Carusotto, Rev. Mod. Phys. 85, 299 (2013)
Le Boite et al., PRL 110, 233601 (2013);

Crucial parameter: $U/\gamma$

$U/\gamma << 1$ : mean field regime

$U/\gamma >1$ : blockade, quantum correlations
Motivation: exploring many-body physics in driven-dissipative systems

InterPol project: use cavity polaritons in semiconductor lattices

Properties

\[ |pol\rangle = X_k |exc\rangle + C_k |phot\rangle \]

- Photonic component → confinement in microstructures
  real space, k-space imaging
- Excitonic component → Interactions - \( \chi^{(3)} \)

K-space imaging

Real space imaging

Site selective correlation measurements

State of the art:

\[ U/\gamma \approx 0.1 \]
Work plan:

- WP1: Fabrication of static polariton lattices
- WP2: Fabrication of tunable lattices
- WP3: Quantum correlated phases
- WP4: Topologically protected states
- WP5: Theoretical methods for non-equilibrium systems
Sample design: combine expertise

Deep etching
CNRS

University of Oxford and Sheffield
Open cavities

Paul Drude Institut
Surface acoustic waves and mesa etching

Novel active materials
Sample design: reducing the mode area

PDU, Berlin

AFM micrograph of a 4 × 4 μm² trap overgrown at different temperatures Tg. Low Tg’s suppresses anisotropic elongation and interface smoothing.

Deep etching at C2N of optimized overgrown mesas
Single Polariton Nonlinear Faraday Rotation

**Polarisation**

<table>
<thead>
<tr>
<th>Probe Beam</th>
<th>Control Beam</th>
</tr>
</thead>
<tbody>
<tr>
<td>Linear</td>
<td>Circular</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>State</th>
<th>Energy (meV)</th>
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</thead>
<tbody>
<tr>
<td>(\frac{1}{\sqrt{2}})</td>
<td>-2</td>
</tr>
<tr>
<td>(0)</td>
<td>0</td>
</tr>
</tbody>
</table>

**Micropillar**

Preliminary results:

- Single polariton phase shift \(0.5 \times 10^{-3}\) rad

Can be improved by reducing area, increasing exciton content, increase
Flatband non-linear physics: 1D Lieb Lattices

Quantized non-linear domains: frustration in the lattice

Prospects: 2D Lieb lattices

Engineering of a spin-orbit coupling for photons

A microlaser with optically controlled OAM

N. Carlon Zambon et al., Optics Letters 44 (18), 4531 (2019)
WP4: Topological lattices:

Artificial gauge field in Photonic graphene (CNRS)

Observation of Landau levels and edge states

Non hermitian topological edge-mode lasing (Polish Academy of Science - CNRS)

Theory

Manuscripts under preparation
WP4 : Development of theoretical methods

University college, London
- Tensor Networks :
  - time dynamics and steady states of strongly correlated systems in 1D
  - Lindblad master equation with drive and dissipation
- Positive P (stochastic phase space methods )

Flat bands of quasi 1D Lieb Lattice. Anti-bunching is predicted

BGU, Israel
- Developed tDMRG technique for open systems, to access deep quantum regime for 1D polaritons: 6 coupled micropillars
- Employ Quantum Monte Carlo to study 2D hard core bosons & methods to extract their topological properties : Strained honeycomb lattice

Outreach

Publications

22 invited talks; 5 contributed talks

InterPol meeting: Palaiseau, February 2019