Flagship C - Nanophotonique

volet « optique à petit nombre de photons »

COMBINER
- l'art de la nano-fabrication
- les progrès en science des matériaux
- des techniques expérimentales innovantes

DEMONTRER
- des fonctionnalités optiques -fondamentales ou appliquées-
- à très faible flux lumineux

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THÉMATIQUES ET DOMAINES D'APPLICATION

- NANO-SOURCES
  - OPTIQUE QUANTIQUE
    - IMAGERIE BIOMEDICALE
- NON-LINÉARITÉS ULTIMES
  - PORTES LOGIQUES QUANTIQUES
  - CONDENSATS de POLARITONS
    - LASER RAMAN sur SILICIUM
    - TRAITEMENT OPTIQUE DU SIGNAL
- NANOFILS
  - BOÎTES QUANTIQUES 1.5 µm INSÉRÉES
  - HÉTÉROJONCTIONS RADIALES
  - CROISSANCE III-V sur Si
    - APPLICATIONS PHOTOVOLTAÏQUES

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ANIMATEURS

- NANO-SOURCES

Jean-Pierre Hermier, GEMAC (UVSQ)

- NON-LINÉARITÉS ULTIMES

Sébastien Sauvage, IEF (CNRS et U-PSUD)

- NANOFILS

Jean-Christophe Harmand, LPN (CNRS)

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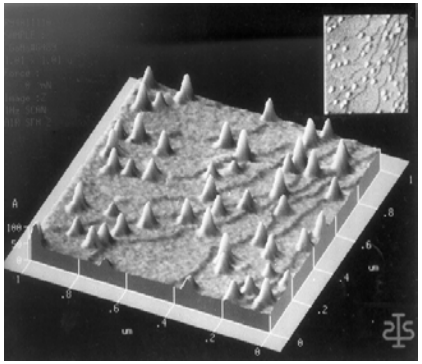
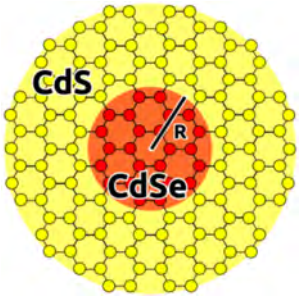
Synthèse et caractérisation de nano-émetteurs innovants…

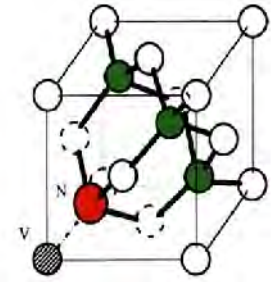


boîtes quantiques
auto-assemblées

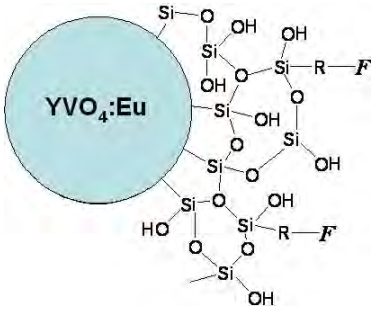


nanocristaux
semi-conducteurs

nanotubes
de carbone



centres colorés
dans le diamant



oxydes dopés
par des terres rares

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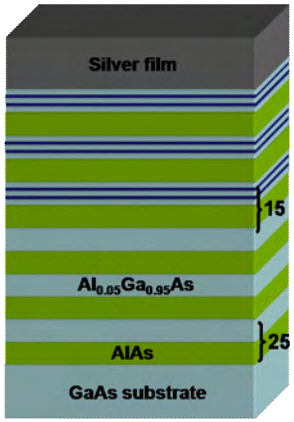
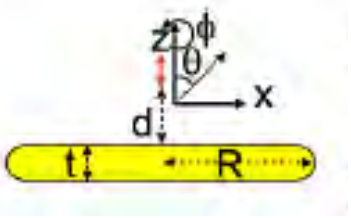
… insérés dans des micro-cavités innovantes

molécules photoniques



états de Tamm photoniques



nano-antennes… (cf. thème plasmonique)

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Les domaines d'application

- Le traitement quantique de l'information:

  - Photons uniques
  - Paires de photons intriqués
  - Photons indiscernables

- Applications multidisciplinaires :

  - Marqueurs biologiques
  - Imagerie biologique super-résolue
  - Médecine

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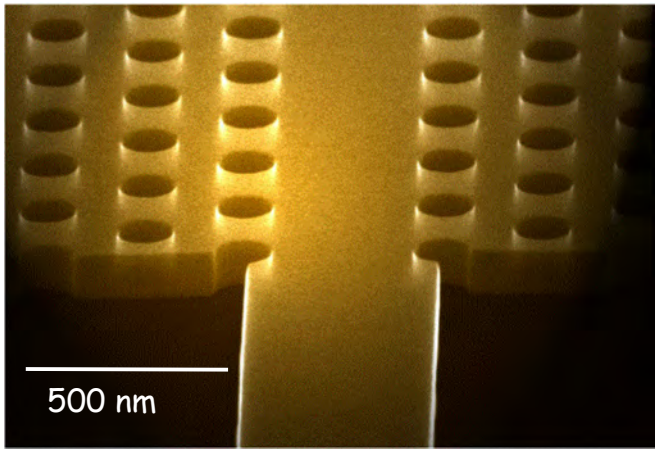
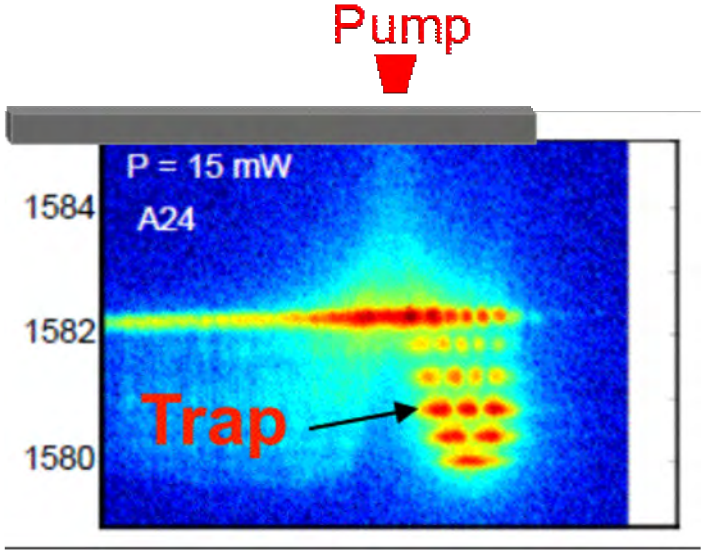
few photon optics: ultimate non-linearities



Photon – photon/phonon interaction ($Q=2x10^6$)



Photon-exciton interaction (Bose condensation)

Context

- Cavity enhanced light mater interaction in photonic crystals
- Extremely low power: from femtojoule down to 2 photons non-linearity

Goals and objectives:

- Basic studies
  - Polariton (Bose) condensates
  - Polarons in quantum dots
  - Carbon nanotubes
- Enhanced components
  - Raman laser (lower noise)
  - Si nanodetectors
- New functionalities
  - Ultrafast optical gates

Amo
Bloch
Lanco

Boucaud
Checoury
El Kurdi
Sauvage

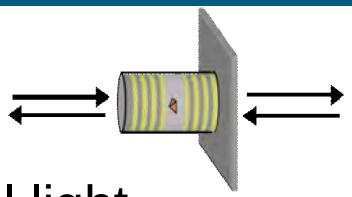
Combrié
De Rossi

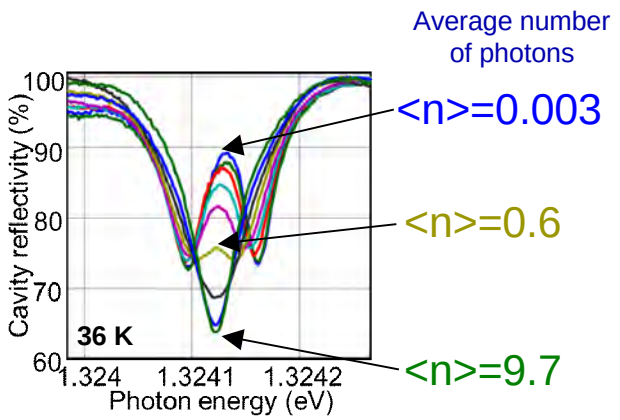
Deleporte

+

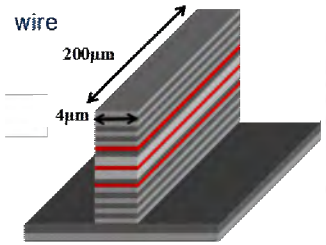
basic studies: strong light-matter coupling

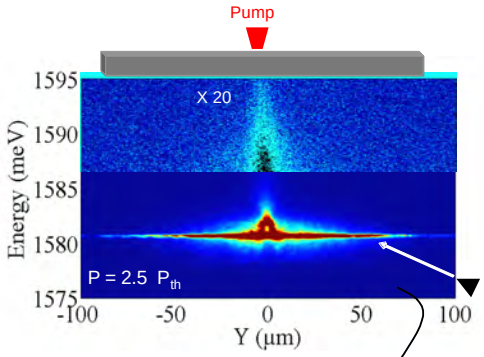
- Giant photon-photon non-linearities (LPN)
  - Generation of non-classical light
  - Photonic logic gates
    - Low photon number at resonance
  - & Towards photon number QND measurement





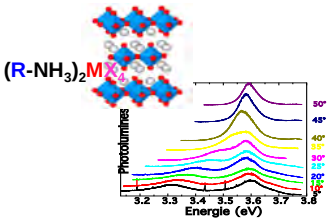
- Exciton-photon polariton (LPN)
  - Generation of Bose-Einstein condensates in photonic wires
  - Spontaneous spatial coherence
  - Optical manipulation of condensates
    - Trapping, tunnel barrier
  - Towards
    - Optical gates, Interferometers
    - Electrically pumped polaritons
    - Localization versus superfluidity



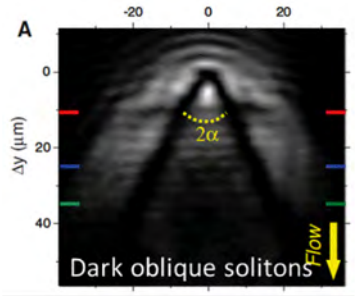


Nature Physics (2010)

III-V Polariton condensates (LPN)



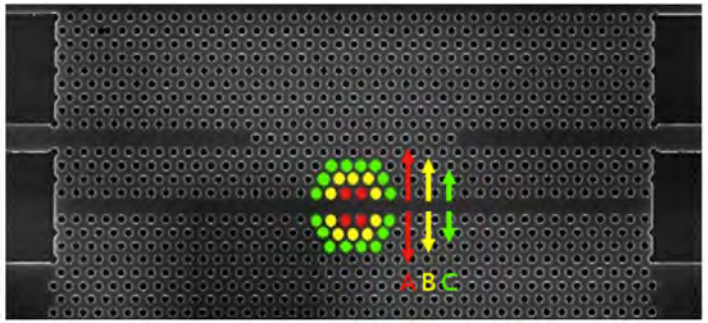
Perovskite Polaritons (LPQM)



Science (2011)

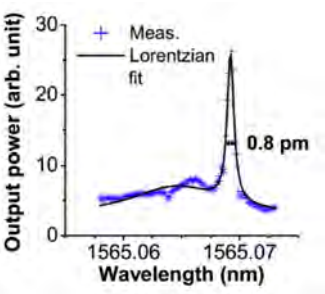
enhanced optical interactions

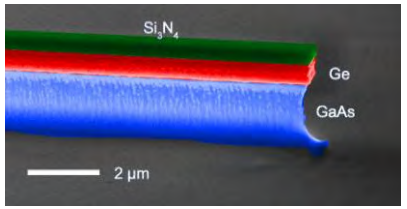
- Photonic crystal cavities on silicon (IEF)
  - Record quality factor (2 millions)
  - Raman emission
    - Spontaneous & stimulated stokes
    - Deterministic Purcell factor
  - Towards Lasers on silicon
    - Raman laser
    - Germanium laser
  - Diamond photonic crystal



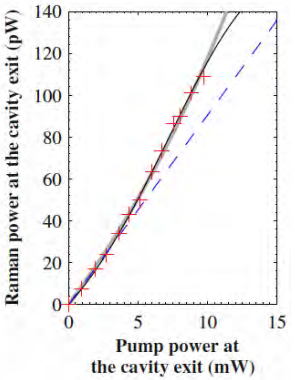
Hole shifts ABC are 9, 6 and 3 nm.

PRA (2010), PRB(R) (2010)

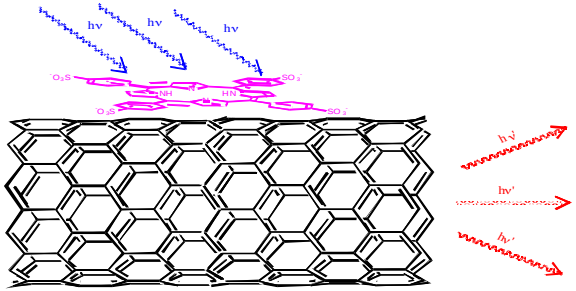


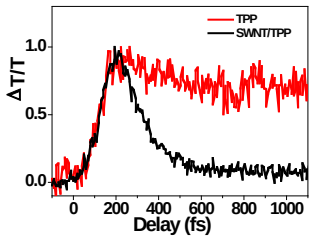


Germanium microwires with Si_3N_4 stressor



- Carbon nanotubes (LPQM)
  - Excitation transfer
    - With porphyrines molecules
  - Non-covalent functionalization
    - Single object studies
    - Transfer mechanisms





Nature Materials (2010)

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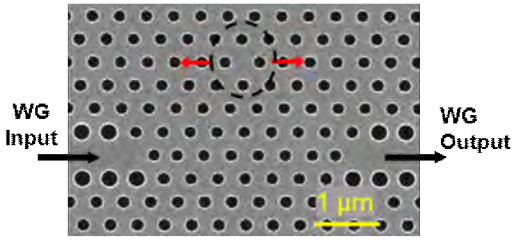
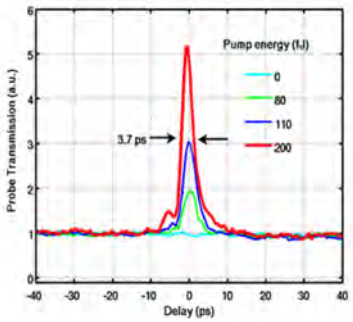
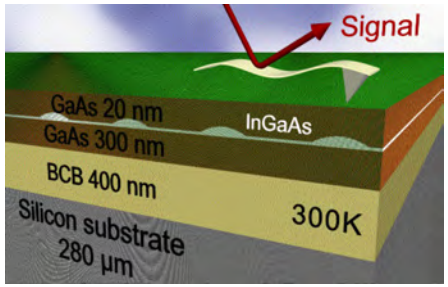
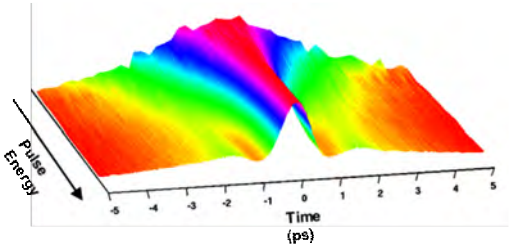
new functionalities

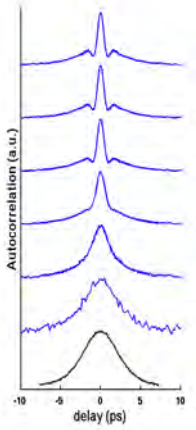




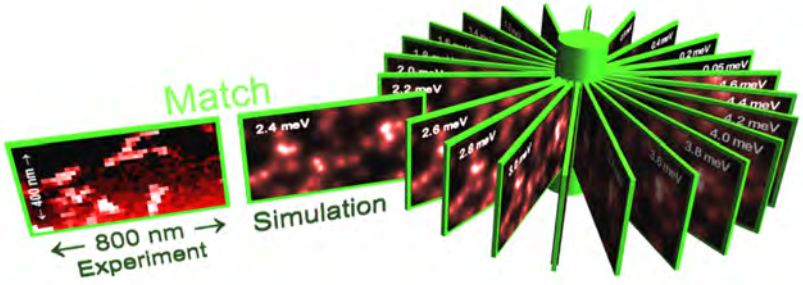
- 3.7 ps On/Off
- Energy 200fJ







Nature Photonics (2010)



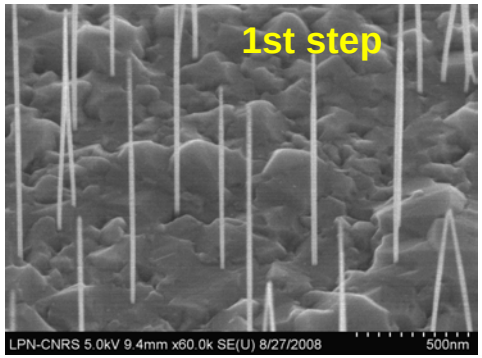
PRB (2011)

- Ultralow power fJ
  Ultrafast commutation ps (Thales)
  - III-V Photonic crystals
- On chip soliton propagation
- All Optical Circuits
  - Low consumption
  - Telecom, Datacom, Hyperfrequency

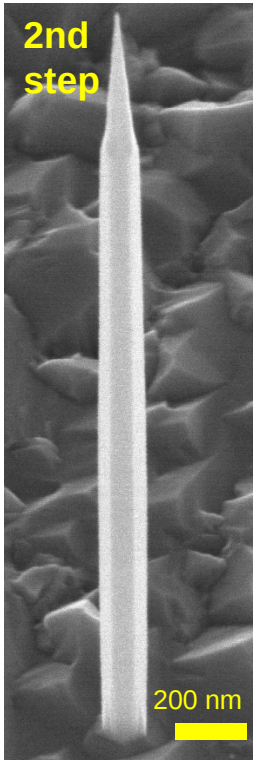
- Ultimate nano-optical imagery (IEF)
  - Semiconductor quantum dots
  - Strong electron-phonon coupling
  - Ultrasmall absorption (10^{-9})
  - Sub-wavelength resolution $\lambda/500$
- Phonon nanosources
  - Thermal, acoustical response
  - Towards a quantum dot THz saser

nanofils

croissance VLS catalysée par une micro-bille d'or



initialisation de la croissance d'un nanofil d'InP contenant une inclusion (boîte quantique) d'InAsP



changement des conditions et croissance latérale d'une coquille d'InP

grande souplesse dans le choix des matériaux et des structures

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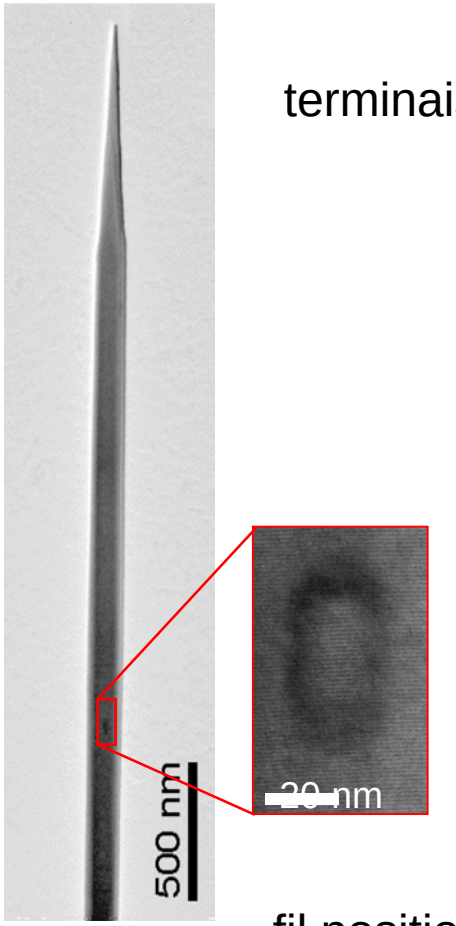
résolution par la croissance de problèmes ardus !



terminaison conique formant adaptateur modal (taper)

boîte quantique parfaitement centrée

fil positionné de façon déterministe grâce à la micro-bille d'or

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