HELLENIC REPUBLIC
National and Kapodistrian
University of Athens

Department of Physics
Section of Solid State Physics

Theoretical and Computational Nanophotonics Group

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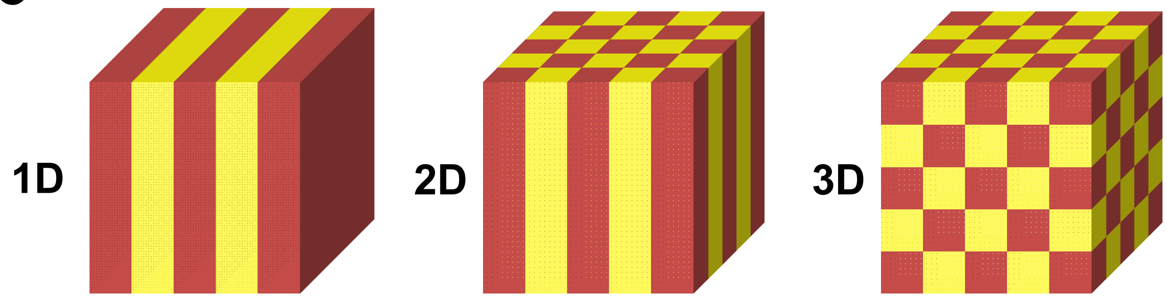
Supported by National Grants

Introduction

Periodicity ➡ important for the determination of material properties

System	Description	Waves	Band gap
Crystalline Solid	Periodic arrangement of atoms ~ 5 Å	Electrons (Ψ) **Schrödinger** Eq.	Absence of **electron** states

Classical waves in **artificial periodic** structures:
Controlling the propagation of **light** and **sound**



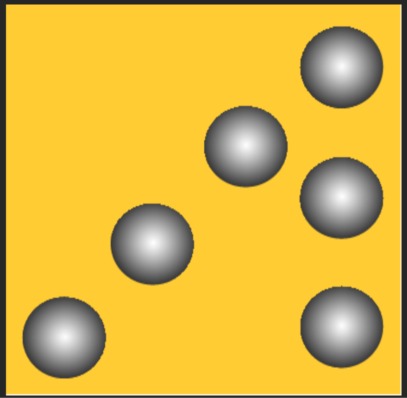
System	Description	Waves	Band gap
Photonic Crystal	Periodic variation of ε, μ on a macroscopic scale	EM (**E B**) **Maxwell** Eq.	Absence of states of the **EM** field
Phononic Crystal	Periodic variation of ρ, λ, μ on a macroscopic scale	Elastic (**U**) **Elasticity** Eq.	Absence of states of the **elastic** field

Research Highlights

Coupled-Cavity Optical Wavequides

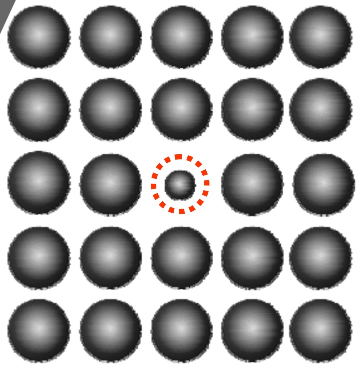
Concept: Transmission through coupled evanescent modes

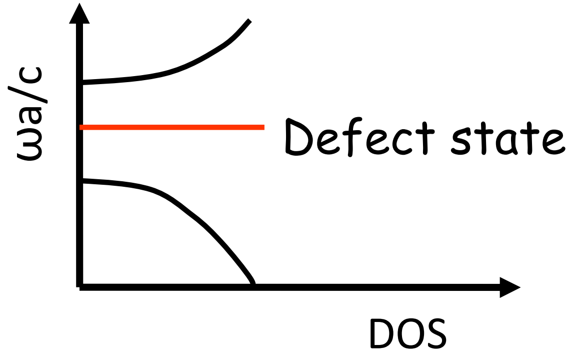
- Weakly coupled defects with localized in-gap states
- Tight-binding description
- Slow light
- Efficient transmission through sharp bends

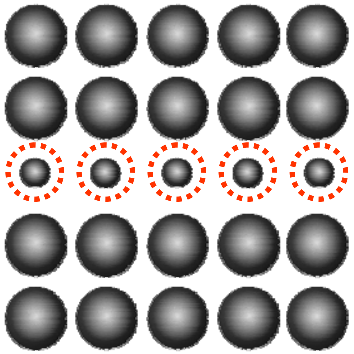


N. Stefanou and A. Modinos, Phys. Rev. B **57**, 12127 (1998)

A. Yariv, Y. Xu, R.K. Lee, and A. Scherer, Opt. Lett. **24**, 711 (1999)







Tunable Hypersonic Bandgaps in Colloidal Crystals

Concept: Engineering tunable hypersonic bandgaps in self-assembled colloidal crystals

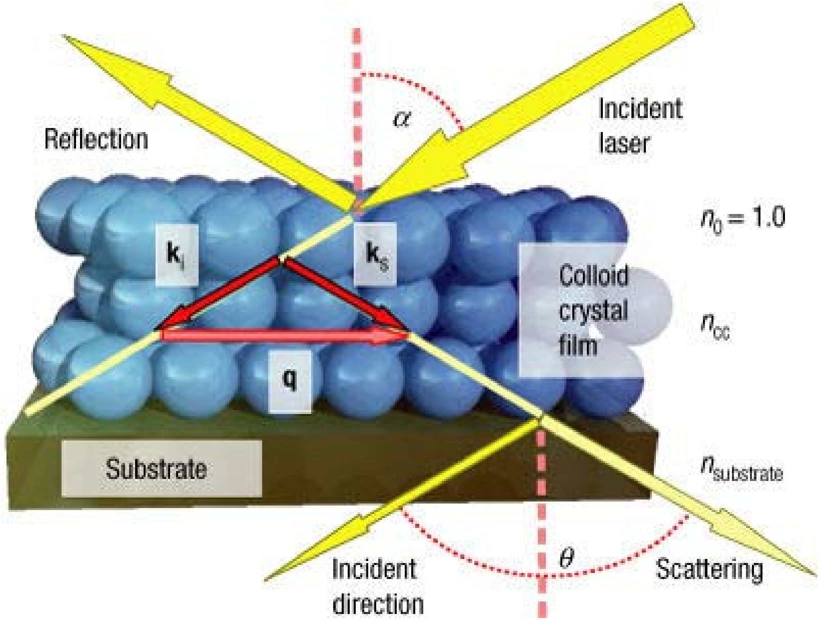
•Molding the flow of hypersound (~10 GHz)

•Probing acoustic wave propagation by Brillouin Light Scattering

W. Cheng, J.J. Wang, U. Jonas, G. Fytas, and N. Stefanou, Nature Materials **5**, 830 (2006)

T. Still, W. Cheng, M. Retsch, R. Sainidou, J. Wang, U. Jonas, N. Stefanou, and G. Fytas, Phys. Rev. Lett. **100**, 194301 (2008)

T. Still, G. Gantzounis, D. Kiefer, G. Hellmann, R. Sainidou, G. Fytas, and N. Stefanou, Phys. Rev. Lett. **106**, 175505 (2011)



Phoxonic Nanostructures

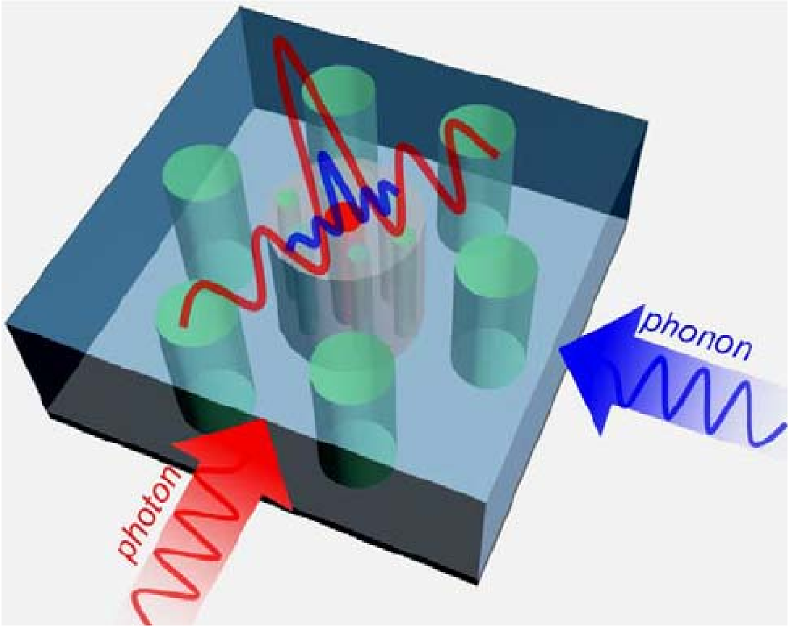
Concept: Enhancing the photon-phonon interaction in appropriately designed cavity structures which support resonant modes of both the acoustic and the EM field, localized in the same subwavelength region.

- Strong modulation of EM waves with acoustic waves
- Strong optomechanical interaction
- Nonlinear effects (multi-phonon exchange processes)

E. Psarobas, N. Papanikolaou, N. Stefanou, B. Djafari-Rouhani, B. Bonello, and V. Laude, Phys. Rev. B **82**, 174303 (2010)

G. Gantzounis, N. Papanikolaou, and N. Stefanou, Phys. Rev. B **84**, 104303 (2011)

E. Almpanis, N. Papanikolaou, and N. Stefanou, Opt. Express **22**, 31595 (2014)

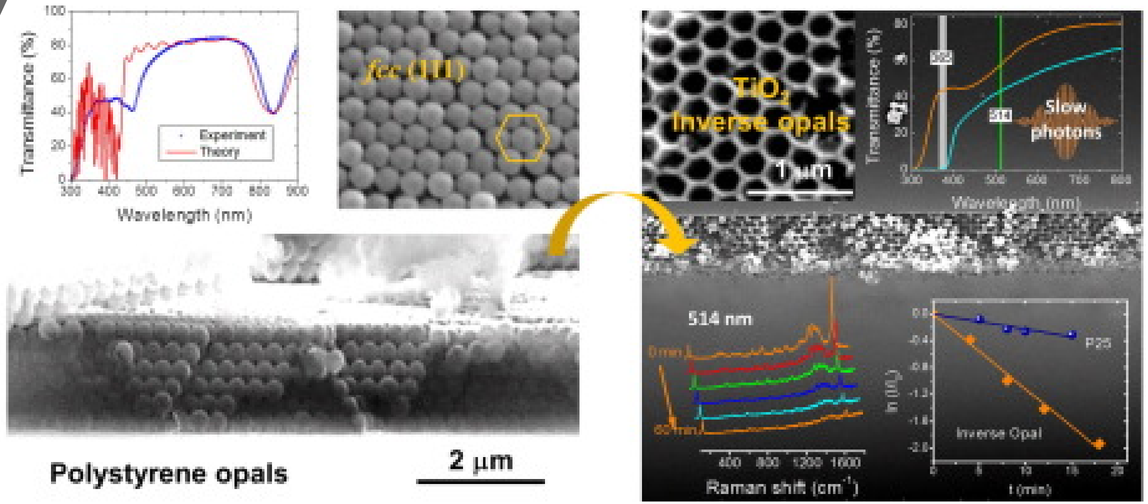


In-house-developed Multiple-Scattering Computational Method

- Fast and accurate numerical calculations (two orders of magnitude faster than commercial packages)
- MULTEM code is used by many groups >700 citations
- Recent application: Slow-photon enhanced photocatalysis (Collaboration with V. Likodimos group, 2017)

N. Stefanou, V. Yannopapas, and A. Modinos, Computer Phys. Commun. **113**, 49 (1998); ibid. **132**, 189 (2000)

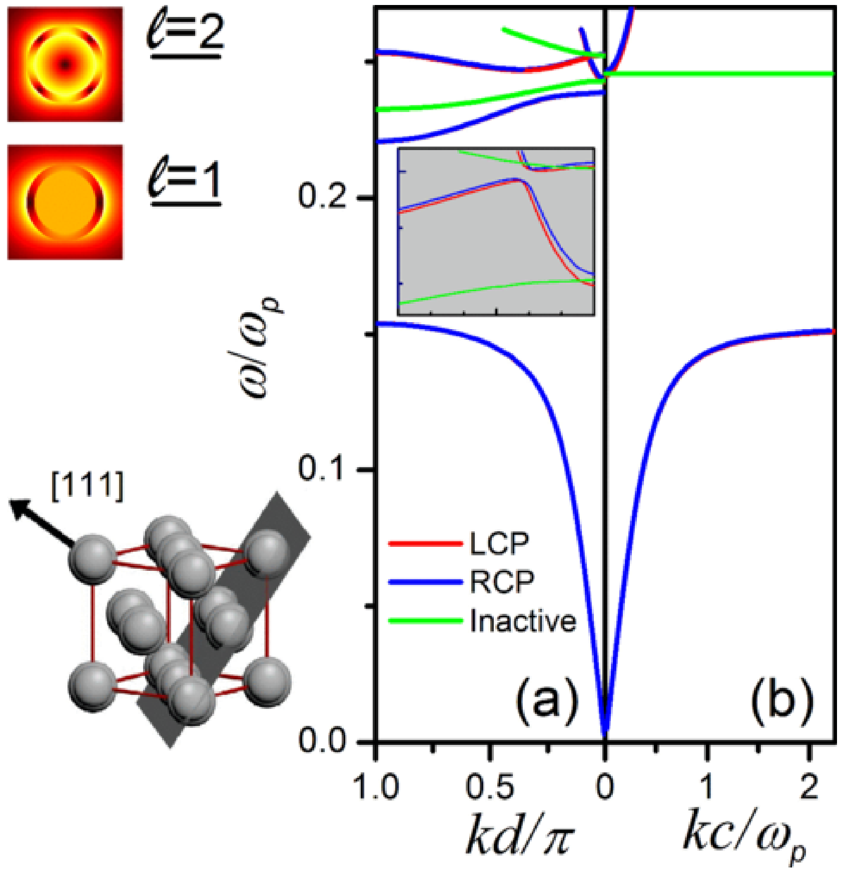
A. Toumazatou, M.K. Arfanis, P.A. Pantazopoulos, A.G. Kontos, P. Falaras, N. Stefanou, and V. Likodimos, Mater. Lett. **197**, 123 (2017)



Crystals of core-shell Magnetoplasmonic Nanoparticles

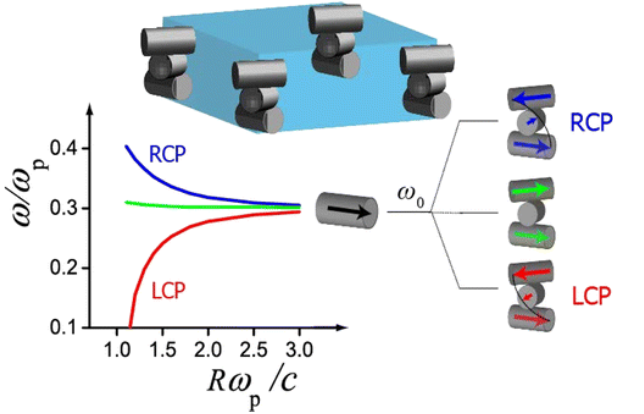
P. Varytis, P.A. Pantazopoulos, and N. Stefanou, Phys. Rev. B **93**, 214423 (2016)

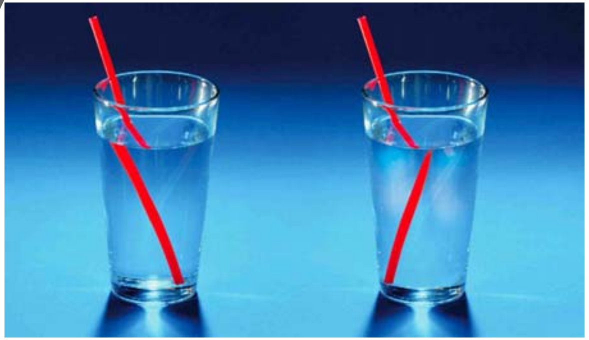
- Engineering cavity- and particle-like plasmon modes
- Plasmon-enhanced magneto-optical effects
- Giant Faraday rotation for miniaturized optical isolators
- Strong circular dichroism

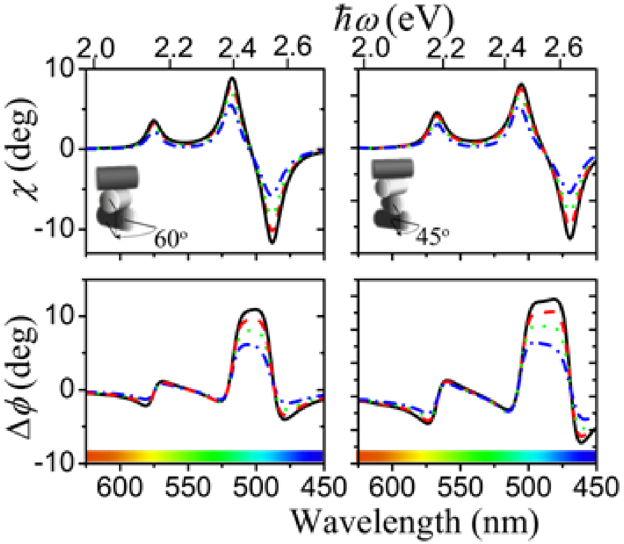


Chiral Optical Metamaterials

Christofi, N. Stefanou, G. Gantzounis, and N. Papanikolaou, Phys. Rev. B **84**, 125109 (2011); J. Phys. Chem. C **116**, 16674 (2012)







- Giant optical activity
- Negative refraction
- Superlensing

Magneto-chiral structures

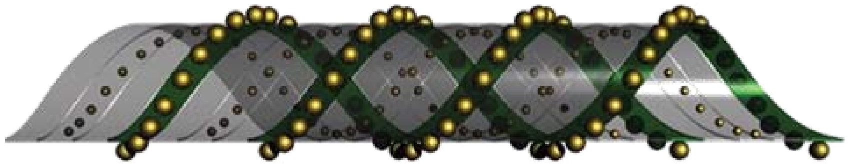
Concept: Lack of time-reversal and space-inversion symmetries can lead to spectral nonreciprocity (applications to optical communication and computing technologies)

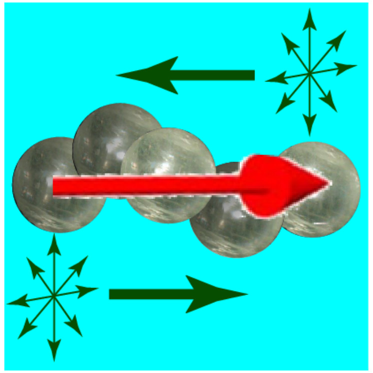
Realization: Helical structures of magnetic garnet particles

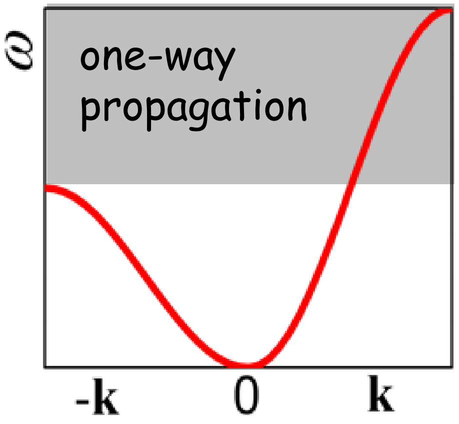
- Giant polarization rotation
- Nonreciprocal response
- Strong magnetochiral dichroism

A. Christofi and N. Stefanou, Phys. Rev. B **87**, 115125 (2013); Opt. Lett. **38**, 4629 (2013)

A. Christofi, N. Stefanou, and N. Papanikolaou, Phys. Rev. B **89**, 214410 (2014)







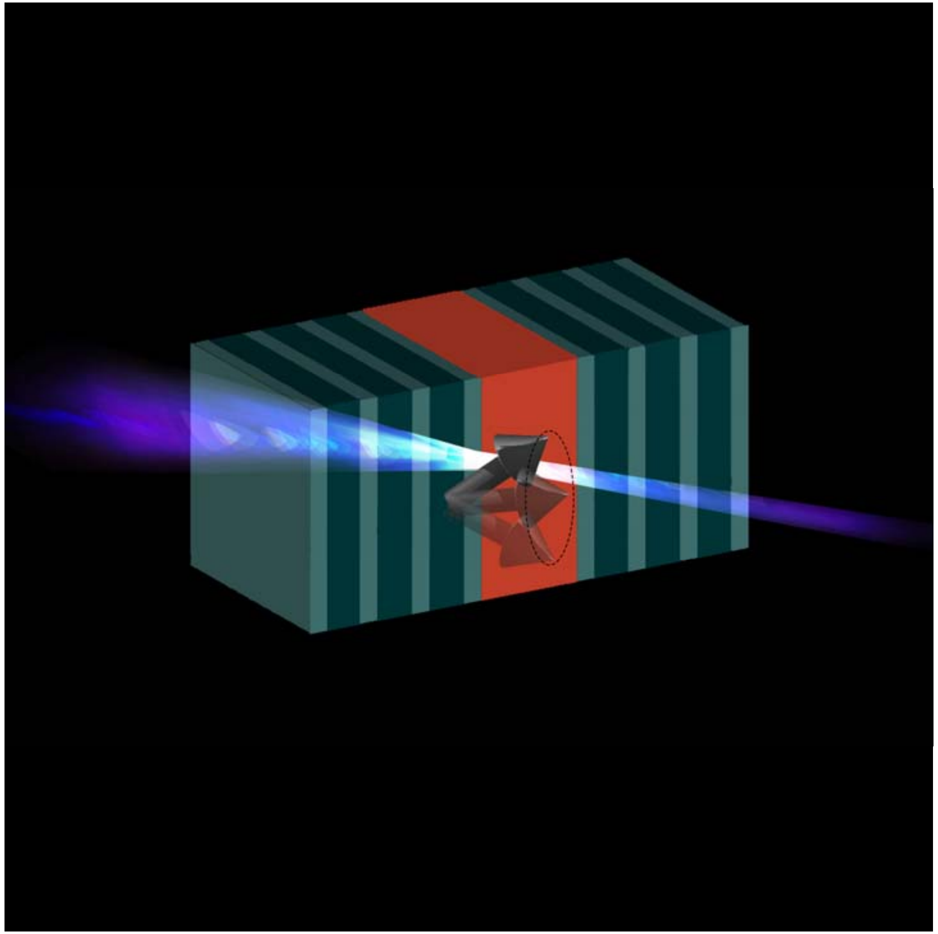
Optomagnonic Nanostructures

P.A. Pantazopoulos, N. Stefanou, E. Almpanis, and N. Papanikolaou, Phys. Rev. B **96**, 104425 (2017)

The interaction of visible/infrared light with magnetization waves is of utmost importance for the development of contemporary, fast and energy-efficient, magnetic recording and information processing nanotechnologies.

Concept: Strengthen this inherently weak interaction in judiciously designed, so-called opto-magnonic, nanostructures, which force photons to spend much of their time together with magnons in the same ultra-small region.

Applications: Novel devices in the era of quantum computation and communication, including magneto-optical devices for optical signal processing and for probing with high sensitivity magnetic properties of bulk or micro-/nano-structured materials.



Thank you

for your attention