NONLINEAR OPTICS COURSE

- **Course objectives**
- **Essential questions addressed by the course**
- **Final learning outcomes**
- **Intermediate learning outcomes**

- **Ressources on eCampus: lectures notes, learning activities, exercises**
- **Evaluation:**
  - **Learning activities on eCampus = Bonus (+2 points)**
  - **Homework (January) = 30%**
  - **Written exam (no document) = 70%**

Nonlinear Optics : Course objectives

- Introduce nonlinear optical interactions that occurs when an optical beam at high intensity propagates through a material medium
- Present useful tools to understand the basic concepts of nonlinear optics
- Derive standard models to describe the mostly used nonlinear interactions (2^{nd} and 3^{rd} orders),
- Evaluate the efficiency and order of magnitudes in specific cases.
- Study a variety of phenomena and applications: generation of 2^{nd}, 3^{rd} harmonic generation, parametric amplification and oscillation with the realization of widely tunable coherent oscillators (OPO), generation of frequency comb, self-phase modulation effects, self-focusing or de-focusing of beams, soliton effects, four-wave mixing...

Nonlinear Optics : Essential Questions

- ***Capability of light matter interactions in modifying light properties***, leading to frequency generation, self-action or cross-actions of light on beam propagation, optical amplification, phase shift, rectification...
- ***Limit of the classical models*** in depicting the origin of the nonlinearities and some nonlinear interactions ➜ ***QUANTUM description***

Nonlinear Optics : Final learning outcomes

By the end of the course, students will be able to

- ***describe*** the origin of the nonlinear optical interactions that lead to the generation of novel optical frequencies
- ***evaluate*** and ***calculate*** 2^{nd} and 3^{rd} order nonlinear interaction performances/efficiencies under approximations that should be specified, explained and justified
- ***design*** and ***optimize*** a 3 or 4 wave mixing configuration to meet given performances. The approach and values shall be justified and presented in a written or oral report.
- ***model*** 2^{nd} and 3^{rd} order nonlinear interactions under assumptions to be specified and ***implement*** related numerical simulations.

intermediate learning outcomes

MEANING…	
Understanding – Students will understand that..	**Essential Questions**
U1 - Nonlinear effects are a key points in the development of many applications in photonics (especially in relation with laser physics) U2 - Understand interplays between linear and nonlinear effects U3 - Nonlinear interactions lead to energy transfer between optical beams, and/or between matter and beams, enabling in some cases the realization of nonlinear optical amplification and/or oscillation. U4 - Nonlinear optics is an essential tool to create novel optical frequencies generated through the interaction of incident beams within nonlinear materials U5 - Nonlinear effects are subject to phase matching conditions	Q1 - Capability of light matter interactions in modifying light properties : frequency generation, self-action or cross-actions of light on beam propagation, optical amplification, phase shift, rectification… Q2 - Use of a perturbative approach in describing and deriving a NON LINEAR problem in physics Q3 - Link between the microscopic and macroscopic terms in Maxwell's equations (induced dipole, macroscopic polarization and fields) Q4 - Link between the frequency relation and the law of energy conservation, the phase matching relation and the law of momentum conservation
ACQUISITIONS…	
Knowledge – Students will know…	**Skill** – Students will be skilled at…
K1 - the constitutive relations of nonlinear optics ($D = \epsilon_0 E + P$ and $P = \epsilon_0 \chi^{(1)} E + \epsilon_0 \chi^{(2)} EE + \epsilon_0 \chi^{(3)} EEE + \cdots$) K2 - the nonlinear effects that arise in a 2nd and 3rd order nonlinear materials K3 - the origin of the nonlinear susceptibilities (classical origin) K4 - the basic properties of nonlinear susceptibility tensors	S1 - Manipulating the nonlinear susceptibility tensor components and, with given incident fields, calculate the components of nonlinear polarisation vector S2 - Determining the phase matching conditions for a given nonlinear interaction and achieving/fulfilling this condition by exploiting birefringence properties of materials and/or QPM technique S3 - Solving the nonlinear equation in parametric situations and derive analytical solutions under the undepleted pump approximation S4 - Calculating nonlinear interaction performances/efficiencies in situations governed by analytical solutions or expressions

Lecture 1/7 : *intermediate* learning outcomes

By the end of this lecture, you will be able to ...

• derive the relation between the macroscopic polarization and the electric field (the so-called constitutive relations of nonlinear optics) (K1)

• cite nonlinear effects that arise in a 2nd and 3rd order nonlinear materials (K2)

• provide a classical description for the origin of the nonlinear susceptibilities (K3)

By the end of this lecture, you will start to understand ...

• the capability of light matter interactions in modifying light properties : frequency generation, optical rectification… (Q1)

• how a perturbative approache enables in describing and deriving a NON LINEAR problem in physics (Q2)

• the link between the microscopic and macroscopic terms in Maxwell's equations (induced dipole, macroscopic polarization and fields) (Q3)