



## **EUROPHOTONICS MASTER COURSE**

### **PROPOSAL FOR A MASTER THESIS**

**Dates : april 1<sup>st</sup>, 2014 – september 31<sup>th</sup>, 2015**

**Laboratory : Attosecond & Ultrafast Optics (AUO)**

**City, Country : Barcelona, Spain**

**Title of the master thesis : Investigation of nonlinear properties of optically patterned semi-conductors for broadband mid-IR sources**

**Name of the tutor of the master thesis : Michaël Hemmer/Jens Biegert**

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#### **Summary of the subject (maximum 1 page) :**

The mid-IR spectral range ( $3 < \lambda < 12 \mu\text{m}$ ) is a frequency band of particular interest for a wide range of applications extending from strong-field physics to medicine, spectroscopy and countermeasure systems.

Nonlinear frequency down-conversion techniques driven by mature near-IR laser systems are typically used to reach the mid-IR spectral range. These nonlinear techniques critically rely on the availability of nonlinear crystals with favourable optical, thermal and mechanical properties. The recent emergence of engineered semi-conductor materials as nonlinear crystals exhibiting high nonlinear coefficients, excellent thermal properties and transparency extending deep into the IR has started to open new opportunities in the mid-IR. Optically patterned Gallium Phosphite (OP-GaP) is a promising material and has recently been grown with acceptable quality to envision implementation in optical setups.

The proposed project aims at investigating the potential of OP-GaP for the generation and amplification of few-cycle optical pulses in the mid-IR spectral region. The successful candidate will (i) familiarize himself/herself with basic properties of GaP, (ii) build a numerical model for accurately reproducing experimental results published using OP-GaAs and (iii) modify this model to predict the potential of OP-GaP and its suitability for the generation and amplification of few-cycle pulses in the 3-7  $\mu\text{m}$  spectral range. This is high profile project, extremely timely within the community and can lead to a publication.

The AUO group at the Institute of Photonic Sciences (ICFO) is a dynamic research group composed of 13 researchers. Over the past few years, the group has built a strong expertise

and is at the forefront of developments in mid-IR technology. We are looking for a motivated and dedicated candidate to join our team to investigate the next generation of mid-IR light engines.

**Keywords : nonlinear optics, mid-IR**

**Additional information :**

\* Required skills : Matlab programming, basics of nonlinear optics

\* Miscellaneous : high level of motivation and a good level of English are required

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### PROPOSAL FOR A MASTER THESIS

Dates : April 1<sup>st</sup>, 2014 – September 31<sup>th</sup>, 2015

**Laboratory : Attosecond and ultrafast optics**  
**City, Country : Barcelona, Spain**

**Title of the master thesis: Determining molecular structure and dynamics using laser induced electron diffraction**

**Name of the tutor of the master thesis: Dr Michael Pullen//Jens Biegert**

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#### **Summary of the subject (maximum 1 page) :**

The attosecond and ultrafast optics (AUO) laboratory of Prof. Dr. Jens Biegert is looking for an enthusiastic master student who wishes to advance their career in the promising and rapidly advancing field of molecular determination using laser induced electron diffraction (LIED).

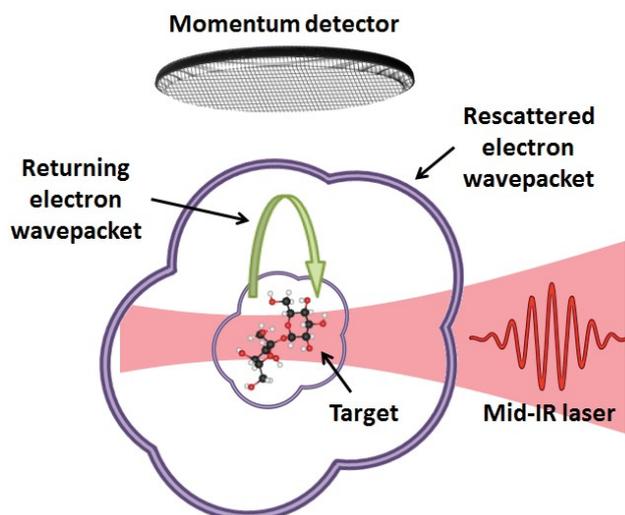


Figure 1: The mechanism of laser induced electron diffraction for molecular structure determination.

Imaging of many types of matter is an extremely important research topic with applications in all sciences. Knowledge of something function requires a detailed understanding of how its internal structure changes with time. Imaging the dynamics of fundamental systems such as a

molecule requires spatial and temporal resolutions on the sub-ångström and femtosecond scales. Traditional techniques such as conventional electron diffraction and X-ray diffraction are able to extract detailed spatial information yet are limited temporally. Up until now, no measurement method is able to achieve the required spatial and temporal resolutions simultaneously. LIED is an exciting new technique that promises to address this limitation by ionising the molecular sample with a mid-IR laser and then using the ionised electron wavepacket to re-scatter (diffract) off of its parent ion as presented in Fig. 1. Structural information can then be extracted from the resultant diffraction pattern using the concepts of the quantitative re-scattering (QRS) theory and conventional electron diffraction. This method is extremely promising as recent results have shown the O<sub>2</sub> bond length change by 0.08 ångström over an interval of five femtoseconds.

The AUO group has developed a state of the art optical parametric chirped pulse amplification (OPCPA) laser system that provides intense laser pulses at a centre wavelength of 3.1 µm at a repetition rate of 160 kHz. This is the ideal laser system for LIED experiments as the long wavelength causes the electron to experience large momentum transfers during diffraction and the high repetition rate ensures a high data collection rate. Combined with the laser system is a reaction microscope that collects all particles created during the interaction so that a complete picture of the process can be obtained.

The applicant will be under the direct supervision of Prof. Dr. Jens Biegert and Dr. Michael Pullen and will be involved in the ongoing experimental endeavours to determine the structure and dynamics of molecules. They should be hard working and have good communication skills as the research will be performed in an open team environment. Preferably they will have a physics degree with experience in utilising laser systems and vacuum apparatuses.

**Keywords : Laser induced electron diffraction, ultrashort lasers, optical tunnelling, atomic and molecular imaging, molecular structure determination, OPCPA, reaction microscope, COLTRIMS**

**Additional information :**

\* Required skills : physics undergraduate degree, laser and vacuum experience preferable, good communication skills

\* Miscellaneous :