Femtosecond multiphoton nonlinear-optical spectroscopy and applications

Summary

This interdisciplinary experimental project lies on the intersections between photophysics, physical chemistry, nonlinear- and quantum optics and studies multi-photon optical absorption and -emission by organic and metalloorganic fluorophores with the aim of improved understanding of the fundamental relation between chromophore's structure and the efficiency of multiphoton processes with the ultimate objective of elucidating the nature of light particles - photons. The experiments will address key physical aspects such as ground-state symmetry, quantum state degeneracy, interaction between chromophore's electronic- and vibrational motion, nonlinear saturation of absorption as well as two-photon stimulated emission. The experiments will be conducted using state-of-the-art femtosecond nonlinear-optical spectroscopy instrumentation developed at the National Institute for Chemical Physics and Biophysics. These investigations will facilitate novel and augmented applications in biological microscopy, 3D nano-printing, photocatalysis and quantum information. Qualifications for this position include master's level physics, physical chemistry or equivalent. Candidates should exhibit enthusiasm towards practical laboratory work including femtosecond lasers. This interdisciplinary experimental project lies on the intersections between photophysics, physical chemistry, nonlinear- and quantum optics and studies multi-photon optical absorption and -emission by organic and metalloorganic fluorophores with the aim of improved understanding of the fundamental relation between chromophore's structure and the efficiency of multiphoton processes with the ultimate objective of elucidating the nature of light particles - photons. The experiments will address key physical aspects such as ground-state symmetry, quantum state degeneracy, interaction between chromophore's electronic- and vibrational motion, nonlinear saturation of absorption as well as two-photon stimulated emission. The experiments will be conducted using state-of-the-art femtosecond nonlinear-optical spectroscopy instrumentation developed at the National Institute for Chemical Physics and Biophysics. These investigations will facilitate novel and augmented applications in biological microscopy, 3D nano-printing, photocatalysis and quantum information. Qualifications for this position include master's level physics, physical chemistry or equivalent. Candidates should exhibit enthusiasm towards practical laboratory work including femtosecond lasers.

Research field:	Applied physics and mathematics
Supervisors:	Aleksander Rebane Charles Stark
Availability:	This position is available.
Offered by:	School of Science National Institute Of Chemical Physics And Biophysics
Application deadline:	Applications are accepted between June 01, 2024 00:00 and June 30, 2024 23:59 (Europe/Zurich)

Description

Principal aim of this project consists in experimental studies of multi-photon optical absorption and -emission properties of organic and metalloorganic fluorophores. Currently there exist numerous established as well as emerging new photonics technologies that rely on chromophores that absorb two or more photons simultaneously. While the efficiency of multiphoton processes is a function of chromophores' structure, many key fundamental physical aspects such as ground-state symmetry, quantum state degeneracy and interaction between chromophore's electronic- and vibrational motion are still inadequately understood, hindering sustained technological advancement. This project will address the named fundamental broad problems using state-of-the-art femtosecond nonlinear-optical spectroscopy instrumentation developed at the National Institute for Chemical Physics and Biophysics (NICPB).

The prospective student will be able to conduct experiments with novel symmetry-agile materials, including multi-branched and nanosheet-forming systems, where chromophore symmetry can be switched in a controlled manner between multiple forms while preserving underlying atomic arrangement, and thus actively controlling of manipulating the multiphoton response of the material. Another potential experiment will develop a new method to determine simultaneously the molar extinction and the concentration of an unknown species using precision measurement of

saturation of linear absorption under femtosecond pulse excitation. A further option includes experimental study of stimulated emission of simultaneously two-photons by an organic fluorophore. In addition to resolving long-standing fundamental issues, these investigations will facilitate novel and augmented applications in biological microscopy, 3D nano-printing, photocatalysis and quantum information.

The thesis should address the following questions: 1) How are externally-induced alterations of the molecular structure/symmetry e.g. though protonation affect properties of single- and multiphoton transitions? 2) How to optimize the efficiency of multiphoton absorption transitions in view of practical applications such as microscopy, materials processing and data storage? 3) Is it possible to observe multiphoton stimulated emission using both classical laser light as well as quantum-correlated light and how is the latter relate to properties of the photon (or photons)?

Responsibilities and (foreseen) tasks

- Participate in all stages of conducting experiments using wavelength-tunable femtosecond lasers
- Maintain the lasers system and associated experimental equipment/instruments
- Prepare the research samples including handling of certain solvents and related chemicals
- Evaluate and analyze the collected data
- Contribute to the preparation of publications
- Contribute to the organization of research and practitioner workshops where project findings are presented

Applicants should fulfil the following requirements:

- a master's degree in physics, physical chemistry or equivalent
- interest towards practical laboratory work including femtosecond lasers
- excellent command of English
- strong and demonstrable writing and analytical skills
- capacity to work both as an independent researcher and as part of an international team
- capacity and willingness to provide assistance in organizational tasks relevant to the project

(The following experience is beneficial:)

- Experimental optical spectroscopy
- Programming in LabView, Mathematica or equivalent
- Working knowledge of optics, nonlinear optics, quantum optics
- Working knowledge of organic and/or metallorganic chemistry
- Working with lasers, optical spectrometers etc.

The candidate should submit a CV, personal letter of motivation and names of three references.

We offer:

- 4-year PhD position in one of the premier multidisciplinary basic research institutions in Estonia and in the Baltic states.
- The chance to do high-level research and collaborate with world leading experts in broad areas of spectroscopy, materials science and theoretical quantum chemistry.
- Opportunities for conference visits, research stays and networking with globally leading universities and research centers in the fields of optical physics and materials science.

About the department

NICPB is an independent multidisciplinary research institution offering and excellent learning- and work environment with 80 PhD researchers in broad areas of optical, terahertz and NMR spectroscopy, materials science, energy- and biotechnology and elementary particles physics. The Institute has close ties with Tallinn University of Technology and is located a short walking distance from the TalTech campus. The multiphoton experimental spectroscopy group at NICPB consists currently of 3 PhD researchers and one technical engineer. In addition, 2 PhD researcher work on the quantum-chemical calculations and modelling that support our experimental efforts. The laboratory has also close contacts with the National Metrology Institute Metrosert.

(Additional information)

For further information, please contact Prof. Aleks Rebane arebane@montana.edu or Dr. Charles Stark charstark@gmail.com or visit the web page Chemical Physics | KBFI KBFI

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