PEP 18
PHOTOTHERMAL EFFECTS IN PLASMONICS
Special focus on Biology

SUMMER SCHOOL
JUNE 24-29 2018
in Porquerolles (France)

Detailed topics

Emmanuel Bossy, *Université Grenoble Alpes (France)*

Photoacoustic Imaging **(2 hours)**

A first part of the course will introduce the field of photoacoustic imaging and a second part will more focused on the photoacoustic generation from gold nanoparticles.

Luis Carlos, *Universidade de Aveiro (Portugal)*

Luminescence thermometry as a new thermal technique **(1 hour)**

After a general historical perspective of the work done on ratiometric luminescent nanothermometers since the explosion of the field at one decade ago, and a discussion on the pros and cons of the technique relatively to other thermal microscopy tools suited for plasmonics. The lecture will be focused on recent examples of heater-thermometer nanoplatforms capable of measuring the magnetic- and plasmonic-induced local temperature increase of nanoheaters and its applications.

Upconversion thermometry in nanofluids **(1 hour)**

This course will be focused on recent examples illustrating how powerful is the technique to unveil the thermometers' local surrounding properties as, for instance, the measurement of the instantaneous ballistic velocity of Brownian nanocrystals suspended in both aqueous and organic solvents.

Benoit Charlot, *Institut d'Electronique et des Systèmes, Montpellier (France)*

Thermodynamics and thermal stimulation of neurons **(1 hour)**

Neurons are the cells that process information in the brain but some of them, called sensory neurons, convert physical stimulations into action potentials toward the central nervous system. These sensory neurons are called mechanosensitive or thermosensitives, it means that they react to temperature and temperature transients with biophysical mechanisms. This lecture will introduce basic concepts in neuron electrophysiology, generation of action potentials and the role of membrane proteins in the propagation of electric signal in neurons. We will then expose some consideration on the thermodynamics of the ion exchange processes to explore what is the role of temperature in the biophysics of neurons. Finally we will present some techniques to initiate or to inhibit action potentials with temperature stimulations that are generated by infrared laser shots. these thermal stimulation techniques are able to control a neuron activity at distance and with no contact.

***Anton Plech**, Karlsruhe Institute of Technology (Germany)*

Pulsed excitation of nanoparticles
Bubble formation and particle reshaping **(1.5 hour)**

Metallic (plasmonic) nanoparticles are promising nano-sensing and nano-manipulating tools for a vast number of applications. At the same time, they also serve as prototypic systems for understanding fundamental aspects of nanoscale material as well as light-matter interaction.

Pulsed photoexcitation leads to a deep non-equilibrium process, which in many cases, allows for watching the associated phenomena enrolling consecutively as a film. A quantitative description is in need of learning as much on structure and energetics as possible. This, however poses a several problem of direct structural access and at the same time high temporal resolution. We have approached this problem by employing time-resolved light spectroscopy and X-ray scattering. The very general aspects of nanoparticle photodynamics can thus be addressed. The lecture will discuss fundamentals of thermal kinetics, lifetimes and secondary caloric effects, such as phase transitions in the particles as well as the environment. At the same time non-reversible effects that can be utile or detrimental, will occur with strong enough excitation and need to be characterized. Nanoscale bubble formation and particle destruction or resphaping ar the most prominent effects seen.

***Romain Quidant**, ICFO, Castelldefels-Barcelona (Spain)*

Putting thermoplasmonics to work **(1 hour)**

After more than 10 years of active research, the field of thermoplasmonics has developed an extensive toolbox to control and monitor heat at the nanometer scale. In this talk, we present some of our recent efforts towards the application of nanoscale heat delivery to different fields including biomedicine, cosmetics and reconfigurable optics.

***Alois Würger**, LOMA, Bordeaux (France)*

Mechanisms of thermophoresis **(1.5 hour)**

The motion of macromolecules and particles along a temperature gradient, or thermophoresis, is a non-equilibrium phenomenon that arises from osmosis of heat or molecular solutes. Here we discuss the well understood mechanisms driving DNA and colloidal particles, and as a major open question, the thermophoresis of proteins.

***Jean-Luc Tapié**, Coherent, Paris (France)*

Lasers — current state of the art **(1 hour)**

We will review some history of the most currently used laser technologies and their applications. The presentation will span from gas lasers to solid state lasers, and from ultra-short pulses to continuous operation.

***Daniel Jacque**, Universidad Autonoma de Madrid (Spain)*

New generation of thermal-based therapies and diagnosis

(1.5 hour)

Temperature is one of the most important parameters determining the behaviour of biological systems. Temperature is also one of the most sensitive indicator of the appearance of malfunctions and diseases. In this work we will give a general overview of the actual diagnosis tools based on thermal measurements that are, indeed, already being used at the clinical level.

Over the last few years, the scientific community has witnessed a remarkable advance in the design, synthesis, and implementation of luminescent nanoparticles for bio-imaging and bio-sensing applications. Some of the old, unrealizable dreams have become possible thanks to the appearance into scene of novel advanced materials with never before imagined properties. This is the case of luminescent nanothermometers, nanoparticles capable of providing contactless thermal reading through their light emission properties. Luminescent nanothermometers have made possible the measurment of temperature inside a living cell or, even, inside a cancer tumor in animal models. In this talk we will discuss about the latest results achieved at the in vivo level by using luminescent naothermometeres as diagnosis probes and controlling agents during thermal therapies. It will be shown the potential of luminescent nanothermometers as multifunctional thermal probes that will be the base of new diagnosis and therapies. Advantages and limitations of these new techniques in respect to the "conventional" ones will be discussed.

***Sylvie Marguet**, IRAMIS/NIMBE, CEA Saclay (France)*

Synthesis and assembly of gold nanoparticles of various morphologies **(45 min)**

This lecture will focus on the synthesis and assembly of high quality gold nanoparticles of various sizes and shapes to provide suitable materials for research in the fields of plasmonics, plasmon-driven chemistry, sensing and medicine The properties of these nanostructures are studied in collaboration with various teams of experts in order to discover unexpected properties.

We synthesize monodisperse gold NPs which are produced only in a few laboratories: spheres, ultra-small rods and wires, cubes, stars, octahedra and nano-micro-plates (hexagon, disk, prism). Some of them are very interesting, for example: 1) Spheres and cubes on top of an Au- film are used for different types of microscopy within the gap, 2) Triangular-plates are sensitive biosensors and promising for photoacoustic imaging, 3) Plates can spontaneously self-assemble in ordered 1D-columnar aggregates or 2D-metasurfaces. The large atomically flat facets of microplates are promising for (F.I.B.) fabrication of monocrystalline pattern, not otherwise accessible. Hot-spots are prepared in our lab through spontaneous self-assembly. 3D-assembly is obtained by simply evaporating concentrated solutions on non-patterned substrates. We are currently working on 2D assembly. In the future, we are eager to widen the application of these NPs to biomedical through new collaborations. As a first step towards this objective, we have the possibility to produce Au@SiO2 core-shell with a thin silica coating .

***Jochen Feldmann**, Photonics and Optoelectronics Group, LMU, Munich (Germany)*

Optical and thermophoretic forces on plasmonic particles

(45 min)

I will present our results on utilizing optical, optothermal and thermophoretic effects on plasmonic nanoparticles. Examples range from the controlled melting of DNA double strands via nanoparticle printing with nanoscale precision to optically driven elevation of Janus particles. Life science applications will be discussed such as optothermally driven PCR, thermophoretically controlled force measurements on single biomolecules and thermally controlled injection of DNA-loaded nano-pens into living cells.

***Michel Meunier**, Polytechnique Montreal (Canada)*

Plasmonics Enhanced Ultrafast Laser Nanosurgery of Living Cells **(1.5 hour)**

A new technique was recently introduced to perform nanosurgery in living cells using a laser multi-nanoscapel. Irradiating plasmonics nanostructures by an ultrafast laser beam produces highly localised processes on the nanoscale in the biological surrounding medium, yielding to the nanosurgery of cells. These nanoparticles could be functionalised to target specific biological entities, thus performing multiple targeted surgeries on the nanoscale. As an example, the laser multi-nanoscapel was employed to perform gene transfection in living cell with an optoporation efficiency as high as 80%. Complete physical model was developed to determine the basic mechanism underlying this new nanosurgery process. Our laser multi-nanoscapel shows promises as an innovative tool for fundamental research in biology and medicine as well as an efficient alternative nanosurgery technology that could be adapted to therapeutic tools in the clinic. It is now being developed in close collaboration with researchers in hospital for applications in cancer treatment, ophthalmology, cardiology and neurology. A provisional patent has been recently filed for the application of this new technology in ophthalmology. In this invited lecture, I will cover the fundamentals aspects of the technique as well as its applications in nanomedecine.

***Hervé Guillou**, Institut Néel, Grenoble (France)*

Self assembly driven by DNA thermodynamics **(1 hour)**

DNA molecules are becoming a construction material that can be use to self-assemble and form a scaffold to organize nanoparticules at the nanoscale promising interesting applications in photonics and medicine. We will introduce the basics of DNA hybridation thermodynamics and demonstrate how to use it as a new assembly materials.

***Franck Cichos**, Universität Leipzig (Germany)*

Thermophoresis with feedback controlled temperature fields

(1 hour)

The use of plasmonic heat sources such as gold nanoparticles and thin gold films allows to control temperature and temperature gradients at the nanoscale. The temperature gradients result in thermophoretic drifts, which can be used to manipulate nano-objects and even single molecules. In the first part of this lecture, we describe applications of thermophoresis for the manipulation and trapping of single colloids and biomolecules.

We show, how feedback controlled temperature fields may create virtual potential landscapes for nano-objects in solution.

In a second part we refer to active particles which are driven by self-generated temperature gradients. These active particles are simple micro machines and model systems for motile living objects.

With the help of feedback control active particles allow access to information based interactions known e.g. from flocks of birds for example. These information based interactions can be used for the design of new active structures to explore the interplay of different feedback timescales in the living worlds. In addition the control of active particles provides an interface between active matter and machine learning.thermal imaging and local heating of living cells or nanoparticle detection.

Fundamentals of Photothermal Microscopy **(1 hour)**

When nano-objects are absorbing light but not emitting radiation in form of fluorescence, they commonly produce heat in condensed matter environments.

This heat generation and the connected local temperature changes are behind photothermal microscopy, an microscopy scheme providing optical contrast for non-fluorescent nanoparticles and even molecules.

In this lecture, we describe the fundamental principles of photothermal microscopy of single nano-particles from various perspectives of optics. We show that the interaction of light with the local heated environment resembles a scattering of photons reminiscent of Coulomb scattering.

Various applications of this technique for the study of dynamical processes or heat propagation in liquids or biological environments are presented.

***Benoit Watterlier**, Phasics SA, Saint Aubin (France)*

Quantitative phase imaging **(1 hour)**

In this lecture, we will first discuss the different technologies commonly used to produce quantitative phase images (QPI) in microscopy: digital holography, SLIM, wave front sensing. We will then study several applications of QPI in biology and physics, in particular using quadriwave lateral shearing wave front sensors as QPI cameras. We will finally focus on the use of QPI for nanoscale thermal imaging and local heating of living cells or nanoparticle detection.

And more to come...