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Electro-Optic Microscopy (EOM) for cell biology

P. Didier[1], Z. Hayat[1], A. El-Abed[1], J.P. Barbot[2], A. Marty[3], L. Mir[4], C. Lafargue[1,a], B. Le Pioufle[2] and J. Zyss[1]

[1]*Laboratoire de Photonique Quantique et Moléculaire, ENS de Cachan, France*
[2]*SATIE, UMR8029, ENS de Cachan, France*
[3]*UMR 8118, Université Paris-Descartes, Paris, France*
[4]*CNRS UMR 8121, Institut Gustave-Roussy, Villejuif, France*

1. Introduction

We propose to develop a new imaging modality for biology, based on the Pockels effect, providing quantitative physical information of structural and functional nature on cells and tissues. This non-invasive, bio-compatible and low-cost approach is based on nonlinear optical properties that are depending on statistical sub-micrometer organization schemes for an ensemble of molecules or nanoparticles embedded in the sample of interest. This method may allow for instance to study the structure of a cell membrane, at the molecular scale, under the application of an electric field (electro-permeation phenomenon) and thus takes on an important biological and clinical interest. Another domain of application that will be addressed is the all-optical detection of neuronal action potentials.

2. Set-up

The set-up is based on a highly sensitive interferometric scheme allowing to detect the phase shift induced by the Pockels effect at the focal point of the microscope objective. Under the application through the sample of a quasi-static electric field, a quadratically nonlinear material experiences a linear change of its refractive index, known as the Pockels effect. Based on a quadratic response of the electrons in the systems to the combined optical and electrical field, the Pockels effect requires a breaking of centro-symmetry, which is intrinsic to the ferroelectric phase in oxide crystals or to molecular crystals of adequate symmetry [1,2]. This condition can also be satisfied in statistically oriented molecular assemblies, such as biological membranes, which are generating considerable interest in biophysics and life sciences,. The proof of principle of PLEOM microscopy has already been demonstrated experimentally [1-3].

[a] Corresponding author: clement.lafargue@ens-cachan.fr

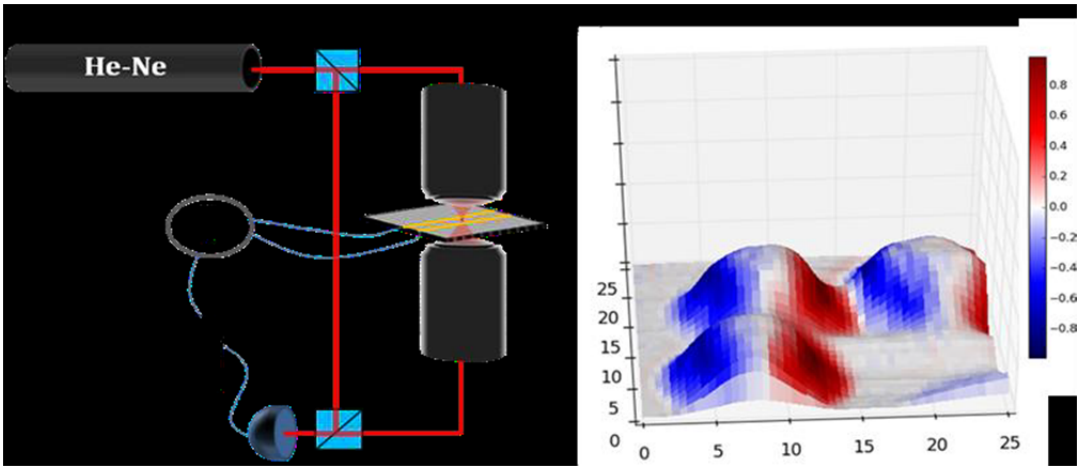

Figure 1. a) schematic principle of the EOM. b) 3D three PC12 cells reconstruction, and EOM signal in colour code. The cell shape is revealed by the EOM signal that depends on the shape's slope along the direction given by the quasi-static electric field.

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