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## PhD position

### Structural precursors and elastic coupling during ultrafast photo-induced phase transitions

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Institut de Physique de Rennes, University of Rennes 1, France

(starting October 1st 2020, net salary ~1.4 k€)

**Scientific Background:** Over the last few years unprecedented opportunities have emerged to modify the macroscopic properties of materials of different sorts with a femtosecond (fs) laser pulse. Literature has been steadily filling up with examples of changing electronic and / or structural orders following excitation, and so the material's functionality. This project is a take on the photoinduced phase transitions, whereby crystal deformations triggered by a laser pulse will be primarily investigated. We will focus in particular on the non-equilibrium variations of crystal volume occurring on the so-called "acoustic" time scale, determined by the material dimensions and its speed of sound. This acoustic process is therefore slower than electronic transitions, but remains ultra-fast in the case of nanomaterials [Bertoni2016]. Our studies are have two main objectives: (1) establish whether purported elastic mechanisms are universally valid in photo-induced phase transitions (2) attain non-volatile transitions beyond the transient states. Following on the earlier studies of molecular materials undergoing spin transition, our target material for this project undergoes the insulating-metal transition. It is another class of isostructural transitions associated with large volume jumps, originating from coupling between the change of volume and the change of electronic state. Revealing exceptional bistability in the nano-crystalline form (~ 10 nm),  $\text{Ti}_3\text{O}_5$  has already offered the opportunity to bring the study a step further (collaboration with the University of Tokyo). The initial electronic excitation induces a coherent oscillation movement of the titanium dimers. This oscillation can be observed with IR reflectivity close to the gap of the insulating phase (time-resolved experiments in collaboration with the University of Poznan in Poland). Such initial deformation triggers a sequence of structural rearrangements that amplified during the macroscopic volume dilation. Thanks to our recent experiments at the ESRF and the SwissFEL (synchrotron and free electron laser), we were able to establish the growth of the metallic phase with the sonic propagation of different deformations such as compression, shear, volume [Mariette2020].

**PhD project :** This project build on a very recent experience by the group, and will enhance the quantitative structural analysis, as well as enlarge the range of investigated morphologies. It also will tackle the so far eluding aspects relating propagation direction and efficiency. The project will focus in particular on the importance of morphology and elastic coupling forces in different classes of materials, metal oxides and organic conductors. The project will involve strong collaboration with the University of Tokyo (LIA IM-LED), and the Institut des Matériaux Jean Rouxel in Nantes,

for material engineering. Most experiments will be carried out at large scale facilities (synchrotron and X-FEL free electron laser, [Mariette2017, Azzolina2019, Mariette2020]). Development of analytical techniques adapted to these unconventional experiences will also be central part of the PhD project ([Thomsen1986, Schick2014, Mariette2020]). The time-resolved XRD measurements will be complemented by ultrafast optical spectroscopy, as well as steady state laboratory XRD measurements.

**Références :**

*Thomsen1986* C. Thomsen, et al., Surface generation and detection of phonons by picosecond light pulses, *Phys. Rev. B* 34, 6 (1986).

*Schick2014* D. Schick et al., Ultrafast lattice response of photoexcited thin films studied by X-ray diffraction, *Structural Dynamics* 1, 064501 (2014)

*Bertoni2016* R. Bertoni, et al., Elastically driven cooperative response of a molecular material impacted by a laser pulse, *Nature Materials* 15, 606–610, (2016).

*Cammarata2017* M. Cammarata, H. Lemke et al. <https://www.psi.ch/swissfel/first-pilot-experiment>, (2017).

*Mariette2017* C. Mariette et al., Formation of local spin-state concentration waves during the relaxation from a photoinduced state in a spin-crossover polymer, *Acta Cryst. B* 73, 660–668 (2017)

*Mariette2019* G. Azzolina, E. Collet, C. Mariette et al., Single Laser Shot Photoinduced Phase Transition of Rubidium Manganese Hexacyanoferrate Investigated by X-ray Diffraction, *Eur. J. Inorg. Chem.* 3142–3147 (2019).

*Mariette2020* C. Mariette, M. Lorenc et al., arXiv:2002.08152v2 (2020)

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**Context :** The successful candidate will work in the Materials and Light laboratory at the Institute of Physics of University of Rennes I. Our team is young and dynamic, a third being foreign, English is the working language. The scholarships include full social security coverage and a net salary of ~1.4 k€. Students have no teaching obligations. If interested, successful candidate can apply to a teaching assistant position during the first or second year of PhD. The University offers French courses for foreigners and hosts an international Erasmus Mundus program. The student should obtain their PhD degree within the 3 years of the financial support (before Oct2023).

Rennes is a medium size French city less 1.5 hour train ride from Paris, offering a relaxing lifestyle with many cultural and sport activities.

**Candidate (s):** The candidate should have a Msc. Degree in Physics and an excellent background in solid state physics. A strong interest in experiment is required. Skills in programming (Python language) will be essential for data analysis and model simulations.

Interested candidates are encouraged to contact (before end of may):

Dr Céline Mariette ([celine.mariette@univ-rennes1.fr](mailto:celine.mariette@univ-rennes1.fr))

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Curriculum Vitae, motivation letter, university marks and manuscripts (master thesis, experimental reports, etc) might be joined to the email

**Further information:**

<https://ipr.univ-rennes1.fr/en/materials-and-light-departement>