Frontier Science at FERMI

Claudio Masciovecchio
Elettra – Sincrotrone Trieste SCpA, Trieste, 34149, ITALY

email: claudio.masciovecchio@elettra.eu

The scientific interest in pushing our knowledge of dynamic phenomena in physics, chemistry and biology towards shorter and shorter time and length-scales draws back more than a century. The great challenge comes from the fact that the systems are generally very complex with a free-energy landscape that encompasses multiple energy, length and time scales. Femtosecond (fs) to picosecond (ps) timescales characterize the typical lifetime of transient states involved in most physical, chemical and bio-chemical processes. Although having different origin in their essence the processes in physics, chemistry and biology have a lot in common, because in their fundaments they all involve motions of electrons, atoms, molecules and nanostructures that are the building blocks of types of matter. In fact, a large number of fs-ps phenomena are arising in complex systems driven far from equilibrium, such as nanoscale electronic and magnetic dynamics, photoinduced chemical and bio-chemical reactions and phase transitions, non-thermal melting etc. For example, the dynamics of chemical bonding is determined by the electron density that evolves in space. The charge re-distribution during the chemical reactions, involving bond breaking and formation, occurs at fs time scales, while the lifetime of the non-equilibrium transition states, that mediate the conversion of the system from one to another chemical state, is within the ps range. It is more than a century that the scientists have been anxious to observe the processes described in the previous section is real time. Generally, the scientific grand-challenge is to visualize the evolution of matter at its shortest time and space scales in order to reach the frontier of ultrafast fs and sub-fs electron motion around the atoms, the spatial scale of the interatomic distances and the energy scale of the chemical bonds, distinguishing not only different atoms but also their chemical states. Once crossed these borders, one can get the very essence of biology, chemistry and condensed matter physics. Undoubtedly, shedding light on the properties of matter arising from complex correlations of its atomic or electronic constituents will have a very strong impact on the development of future technologies as well. However, the experimental control and theoretical understanding of physical, chemical and biochemical processes in complex systems on the fundamental time and length scales of their building blocks need continuous development of advanced tools that should overcome the limitation of the existing ones. We will discuss how the advances in the performance of the FELs, with respect to multi-color pulse production, may push the development of original experimental strategies to study behaviour of matter at the femtosecond–nanometer time–length scales. This would have a tremendous impact as an experimental tool to investigate a large array of phenomena ranging from nano dynamics in complex materials to phenomena that are at the heart of conversion of light into other forms of energy [1,2].

References:

[1] F. Bencivenga, R. Cucini, F. Capotondi, A. Battistoni, R. Mincigrucci, E. Giangrisostomi, A. Gessini, M. Manfredda, I. P. Nikolov, E. Pedersoli, E. Principi, C. Svetina, P. Parisse, F. Casolari, M. B. Danailov, M. Kiskinova & C. Masciovecchio, Nature **520**, 205 (2015).

[2] – F. Bencivenga, F. Capotondi, E. Principi, M. Kiskinova & C. Masciovecchio, Adv. in Phys. **63**, 327 (2015).