EXTATIC

Extreme-ultraviolet and X-ray Training in Advanced Technologies for Interdisciplinary Cooperation

EXTATIC Project Proposal 2016

Project Title	Coherent Diffracting Imaging at the Nanoscale
Home University	Dublin City University
Home University Supervisor	Dr. Lampros Nikolopoulos and Prof. John Costello
Host University	University of Southampton
Host University Supervisor	Dr. Bill Brocklesby
Third University	
Third Supervisor	
Associated Partner(s)	European XFEL GmbH
Associated Partner Supervisor(s)	Dr. Michael Meyer
Project Outline (max 250 words)	UV and X-ray Free-electron laser (FEL) radiation possesses unique properties such as coherence, high brilliance and ultrashort duration [1]. FLASH at DESY and LCLS at Stanford are the first facilities in the world offering FEL radiation in the regime of X-ray wavelength. They have recently been joined by SACLA in Japan and FERMI@Elettra in Italy with others under construction in Germany, Switzerland, Korea and China. In addition, short wavelength radiation based on the high-harmonic generation (HHG) from intense femtosecond lasers is produced routinely, thus offering an alternative (table-top size) source with different temporal profile than the FEL radiation for the study of ultrashort processes [2]. The subject of the present project is the study of the influence of the dynamics of the systems of nanoscale size (in the gas or solid phase) on the coherent diffraction imaging (CDI) pattern of UV or soft X-ray single radiation scattered from these nanometre scale entities [3]. In contrast to traditional X-ray crystallography patterns, where a repetitive structure (multiple identical copies of the same object, known as a crystal) is imaged, in the present case, CDI images of a single ultrasmall scale object are made. To date, CDI has applied to various structures such as nanocrystals, yeast cell and even to a human chromosome. An important drawback of this single-object technique is that the X-ray energy deposited into the target causes what is known as radiation damage. In the case of X-ray FEL radiation, this is inevitable consequence ot the X-ray irradiation can be counterbalanced by the use of extremely short pulses which yield the CDI pattern before the molecule, nanoparticle, etc. breaks up. For example, one case that can be considered as ideal objects for the present objective is atomic clusters. In the present proposal we'll formulate the relevant theory and calculate the dynamical response of an atomic cluster by studying the CDI pattern at different times of interaction [4]. Part of the proposal (6 months to 1 year) will be completed to the group of Dr Bill Brocklesby, Univ. Of Southampton where relevant algorithmic techniques have been developed recently [4]. On the experimental side, in principle, the same information can be obtained by

	the use of the pump-probe laser technique, widely spreaded for time-resolved experiments. An opportunity to observe, and maybe even participate in such experiments, will be afforded to the candidate so that his/her theoretical data may be used in context. The present proposal requires a strong interest on novel diffraction techniques, computational and mathematics skills and a solid quantum mechanics background.
Relevant Reference(s)	**Non-linear processes in the interaction of atoms and molecules with intense EUV and X-ray fields from SASE free electron lasers (FELs),** N. Berrah, J. Bozek, J. T. Costello, et al., J. Mod. Opt 57, 1015-1040, (2010). **Extreme-ultraviolet pump-probe studies of one-femtosecond-scale electron dynamics.** P. Tzallas, E. Skantzakis, L.AA. Nikolopoulos, GD Tdsakiris and D. Charalambidis., Nature Physics, 7, 781-784, (2011). **Femtosecond diffractive imaging with a soft-X-ray free-electron laser,** Henry Chapman et al, Nature Physics, 2:839, (2006). **Temporal Coherence Effects on Coherent Diffractive Imaging of a Binary Sample by a High Harmonic Source,** A.D. Parsons, R.T. Chapman, B. Mills, S. Bajt, J.G. Frey and W.S. Brocklesby**,** EPJ Web of Conferences, **41**, 12015, (2013). **Two-Photon Excitation & Relaxation of the 3d-4d Resonance in Atomic Kr,** M. Meyer et al Phys. Rev. Lett 104 213001 (2010)
Lead University Profile	**DCU:** URL: www.physics.dcu.ie/~jtc We have 6 laboratory areas focussed on pulsed laser matter interactions with lasers produced GW to TW pulses of duration 30fs – 30 ns (http://www.physics.dcu.ie/~jtc/expfacil.html). We also have international collaborations with the Free Electron Laser Facilties in Europe (FLASH-Hamburg) and LCLS (Stanford). *The DCU group currently comprises:* Principal Investigators (6): John T. Costello, Eugene T. Kennedy (Emeritus), Jean-Paul Mosnier, Lampros Nikolopoulos (T) and Paul van Kampen and Patrick Hayden. The group also comprises 9 PhD students and 3 Postdoctoral Fellows. **Southampton:** URL: http://www.orc.soton.ac.uk/xray.html Bill Brocklesby leads a group working on generation and applications of coherent VUV and EUV light by high harmonic generation. The work ranges from development of high intensity, high average power pulsed fibre lasers, through simulation and development of capillary-based XUV HHG sources, to the use of HHG sources in coherent imaging, and spectroscopy in time and frequency domains. The group is multidisciplinary, with members from Physics, Optoelectronics, Chemistry, and Life Sciences. The Southampton group comprises 3 academic faculty and 5 research students. **XFEL GmbH: URL:** http://www.xfel.eu/organization/staff/meyer_michael XFEL GmbH is charged with the construction, commissioning and operation of the €1B European X-ray Free Electron Laser at DESY, Hamburg. Dr. Michael Meyer is 'Leading Scientist' responsible for Small Quantum Systems experiments at XFEL. His group comprises 3 postdocs and postgrads. He is currently designing and building the most comprehensive endstation for the study of the excitation and fragmentation of atoms, molecules and clusters conceived to date.