Relativistic Ultrafast Electron Diffraction and Imaging (RUEDI) Future National Facility in the UK

Yoshie Murooka

School of Engineering, University of Liverpool, Liverpool, UK

Efforts to elucidate microscopic fast dynamics using electrons have more than 50 years history. In last 30 years, two-dimensional digital detectors were introduced in electron microscopy and has advanced efficiency and quantification, opening the possibility of time-resolved observation, utilising weak signals [1,2]. In particular, the introduction of stable femtosecond lasers has boosted the progress over the past two decades [3]. While ultrafast electron diffraction and imaging have been developed over the past two decades, its advancement has been often limited by the stroboscopic method, the thickness of a specimen, its environment, its external stimuli, and the time resolution. This makes it difficult to study ultrafast dynamic in biology, chemistry, and that of materials under strong excitations, because those dynamics are often irreversible, in liquid phase and spatially not homogenous in addition to µm thick specimens. To overcome these difficulties, both stroboscopic and single-shot method have been developed using bright pulsed MeV electrons over the past 20 years. While it is limited to diffraction, RUEDI aims to integrate these and expand the range of applications by adding unique MeV imaging for the next 20 years [4].

The facility will provide MeV electrons in two different beamlines [5]. The electron diffraction beamline will reach the shortest possible timescales down to 10 femtoseconds resolution, while the imaging line will enable time-resolved single-shot electron microscopy at nanometre-scale resolution. The diffraction line will be based on a radiofrequency photocathode, combined with a magnetic beamline for bunch compression. The imaging line will be based on a DC electron source, combined with a fast chopper. State-of-art sample environments such as gases, liquids and cryogenic temperatures will be made available. RUEDI will be equipped with rich external stimuli such as lasers, high-frequency electromagnetic fields, and ions, to induce a variety of dynamics. RUEDI is driven by the five scientific themes [6]: (i) Dynamics of chemical change, (ii) Energy generation, conversion & storage, (iii) In vivo bioscience, (iv) Materials in extreme conditions and (v) Quantum materials & Processes with a cross-cutting theme of Artificial Intelligence/Data Science underpinning all activities. RUEDI will provide a unique gateway to new applications and new phenomena for the next 20 years. I will present the current status of RUEDI and discuss the new research areas it opens up.

References:

[1] D. McMullan, et al, Inst. Phys. Conf. Ser. No.98, *EMAG-MICRO* **89** 55 (1989).
[2] Y. Murooka and J. Yuan, Proc. *ICEM 13-PARIS* 751 (1994).
[3] B.J. Siwick, et al., *Science* **302** 1382 (2003).
[4] "University to lead £125M world-first diffraction and imaging electron microscopy facility to drive UK science breakthroughs" (2024).
[5] J. McKenzie, Y. Murooka et al., *Proc. IPAC'24* 1979 (2024).
[6] Y. Murooka, et al., *Micro. & Micro.* **29** 1487 (2023).
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東京大学
次世代電子顕微鏡法
社会連携講座

主催: 「次世代電子顕微鏡法」社会連携講講座
e-mail: ishikawa@sigma.t.u-tokyo.ac.jp