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## Ultrafast Materials Science with the Artemis XUV beamline

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Contemporary materials science is particularly concerned with complex materials that can be understood only via highly specialized and powerful experimental methods. Two such techniques are ultrafast pump-probe spectroscopy, which uses femtosecond laser pulses to study relaxation dynamics after photoexcitation<sup>1</sup>; and angle resolved photoemission spectroscopy (ARPES), which retrieves information on electronic band structure and Fermi surface topology by measuring photoelectrons generated by XUV or soft X-ray irradiation<sup>2</sup>. Recently the *combination* of these techniques – using an ultrafast pulse to photoexcite a material, while monitoring the resulting changes using ARPES with a laser-based UV source – has directly revealed the evolution in electronic structure during an ultrafast photoinduced phase transition<sup>3</sup>.

A new beamline at Artemis, an open-access user facility at the Central Laser Facility in the UK, offers a unique combination of capabilities optimised for this new technique of ultrafast time-resolved ARPES. The pump wavelength is tuneable from mid-IR to near-UV, to drive a wide variety of excitations. For photoemission, Artemis offers high UV photon energies, so that electronic dispersion can be measured over a wide momentum range. Finally, the pump and probe are well-synchronised and carrier-envelope-phase (CEP) stable, with femtosecond time resolution.

The core of the facility is a 14 mJ, 1 kHz, 30 fs laser amplifier with active CEP control. This laser is used to generate all other pulses, so there is always a natural synchronization between pump and probe. A hollow-fibre compressor produces 0.5 mJ, 7 fs pulses, while an OPA system produces 30 fs pulses from 230 nm to 20 microns. Any of these pulses can then either be used to generate XUV, or used directly as pump or probe. XUV pulses are generated by high harmonic generation in a gas jet, and then passed through a time-preserving monochromator which outputs narrow-bandwidth radiation tuneable from 10 eV to 100 eV. This novel monochromator uses a single grating in conical illumination and has high transmission (up to 30%).

To measure the duration of 35.7 eV XUV pulses, we used single-photon absorption to cumulatively pump an excited ion population in krypton. This was probed by tunnel ionization yield in a strong-field IR drive pulse with variable delay. We found that a 28 fs IR pulse produced a 24 fs XUV pulse.

After the monochromator, a toroidal mirror focuses the XUV beam onto the sample, inside a UHV chamber. A high-resolution hemispherical electron analyser measures the distribution of photoelectrons in both energy and angle. UHV manipulators allow sample transfer and cleaving; there is a UV lamp for static ARPES, and a LEED for surface characterization.

This facility should deliver key results on the ultrafast dynamics of complex materials, particularly strongly correlated electron systems. Current experiments are investigating the ultrafast melting of Mott and charge order in layered dichalcogenides, and exploring the relationship between various transient metallic phases in layered manganites, with a particular focus on mid-infrared excitation. We will present preliminary results from these experimental projects.

<sup>1</sup>D Averitt et al, J. Phys.: Condens. Matter **14** R1357 (2002); <sup>2</sup>A Damascelli et al, Rev. Mod. Phys. **75** 473 (2003); <sup>3</sup>L Perfetti et al., PRL **97** 067402 (2006); F Schmitt et al., Science **321** 1649 (2008).