Relativistic plasma control using two-colour fields

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The interaction of a sufficiently intense laser pulse with an initially solid target can result in the formation of a plasma in which surface electrons are accelerated to relativistic speeds on time scales shorter than a laser cycle. These electrons can form dense bunches and emit radiation that is upshifted in frequency relative to that of the incident laser pulse, reaching up to extreme-ultraviolet (XUV) or even X-ray photon energies [1,2]. As this process repeats periodically with the laser, this upshifted radiation is emitted in the form of high harmonics of the laser frequency. Here, we show clear experimental data demonstrating that this process can be controlled by converting part of the incident laser energy into its second harmonic before it is incident on the target surface. Fine tuning of the sub-cycle timing of this second harmonic pulse can significantly alter the shape of the incident waveform, which modifies the trajectories of the electrons, and can lead to a dramatic increase of the efficiency at which energy is converted into XUV radiation [3]. As well as providing insights into the relativistic dynamics of surface electrons in these interactions, this has the potential to lead to new laser based, coherent XUV sources with unprecedented pulse energies and even attosecond scale pulse durations.

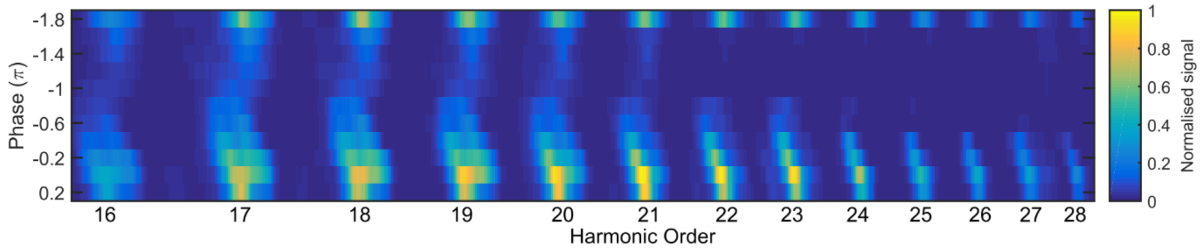

Figure 1. Experimentally observed high harmonic signal for different phases of the 2nd harmonic relative to the fundamental laser pulse. Tuning the phase controls the harmonic generation efficiency and the highest order observed which is directly linked to the dynamics of the relativistic electrons in the target.

References

[1] R. Lichters *et al.*, Phys. Plasmas, 3, 3425 (1996)
[2] B. Dromey *et al.*, Nature Physics, 2, 456 (2006)
[3] M. Yeung *et al.*, Nature Photon. 11, 32 (2016)