Ultrashort laser pulses processing optimisation for challenging applications

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Recent years have seen significant improvements in experimental methods for optimising ultrashort pulse laser processing. Such techniques find applications for example to make detectors for high energy physics [1, 2] or battery electrodes for electric vehicles. Laser pulse length, wavelength or intensity distribution can be tailored to each specific application. For example, one method uses spatially structured light, shaped into a radial geometry which, when focused with a high Numerical Aperture (NA) microscope objective, induce highly localised longitudinal electric fields [3]. Other methods use of tailored laser-material coupling to optimise selective removal of materials in multi-layer electrodes.

In this research, example applications using ultrashort pulse lasers are demonstrated, including in processing electrode materials, and radiation hard materials for high energy dosimeters. Case studies are shown, exploring the processing of challenging electrode materials under various experimental conditions. One example uses high purity longitudinal fields, produced by focusing a radially polarised femtosecond laser beam with a 0.95NA objective lens. The experiments aimed to characterise the longitudinal fields and understand how they interact with materials. High aspect ratio nano structures were produced in the far field by single pulse ablation. The duration of laser-material coupling interactions was far shorter than electron-phonon coupling, leading to the removal of deep, high aspect ratio channels with a very high resolution.

[1] Lopez Paz I, Allegre O, Li Z, Oh A, Porter A, Whitehead D 2019 Study of electrode fabrication in diamond with a femto‐second laser Physica status solidi (a) 216 (21), 1900236
[2] Ghosal A, Allegre O J, Liu Z, Jones G 2021 Surface engineering with structured femtosecond laser vector fields Results in Optics 5, 100179
[3] Li Z, Allegre O, Li L 2022 Realising high aspect ratio 10 nm feature size in laser materials processing in air at 800 nm wavelength in the far-field by creating a high purity longitudinal light field at focus Light: Science & Applications 11 (1), 339