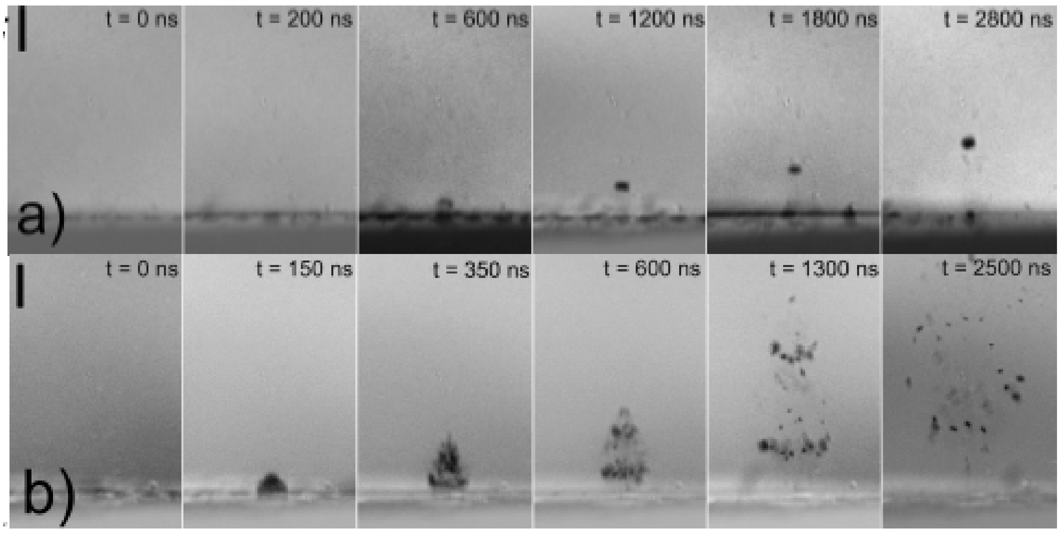
Shadowgraph imaging in femtosecond laser-induced forward transfer of functional materials.

Robert Eason, Matthias Feinaugle,

Optoelectronics Research Centre, University of Southampton, UK.

Laser-induced forward transfer, (LIFT), is a laser-assisted additive direct-write method that is increasingly being used for rapid prototyping of electronic and photonic devices. Lasers with pulse durations in the ns to fs regimes are most generally used for LIFT, although fs laser sources may prove to have greater flexibility due to their much shorter pulse duration compared to ns sources, for the two important reasons of (i) multiphoton absorption within either the donor or the sacrificial release layer used and (ii) a reduced level of interfacial thermal damage.

Another important factor however is to investigate the dynamics and structural integrity of the 'flyer' (the pixel of the donor material) to be LIFT-printed, as the typical pixel size for fs lasers that may only deliver mJ level pulses, will be much smaller than those using more energetic (~100s mJ) ns laser pulses. To investigate the transfer dynamics (threshold incident laser fluence, latency and final flyer velocity) we have used the shadowgraphy set-up available at LP3, to time resolve the flyer behavior for a range of donor thicknesses and laser fluences, and typical results as shown in the figure below.



Sequence of shadowgrams showing transfer of a Bi_2Se_3 flyer for a fluence of (a) ~130mJ/cm^2 and (b) ~400mJ/cm^2. The times at the bottom of the frames indicate the delay times between arrival of the laser pulse and the beginning of image capture by the CCD. (The scale bar in the first frames for a delay time of 0ns in each row is 100μm).

The experiments were carried out with the help of an 800 nm Ti:sapphire laser and a flash-lamp-illuminated shadowgraph imaging system. We observed transfer of flyers in intact state at transfer velocities as low as 34 m/s for ~ 1.1 μm thick donors, and 48 m/s for ~1.8 μm thick lead zirconate titanate. For a ~0.5 μm thick donor of a third alloy we measured a velocity for non-intact transfer of ~ 140 m/s. Contrary to what has been observed so far in time-resolved studies of LIFT, no shock-wave has been observed during the experiments.