High power Adaptable Laser beams for materials prOcessing

HALO project newsletter #4

September 2014

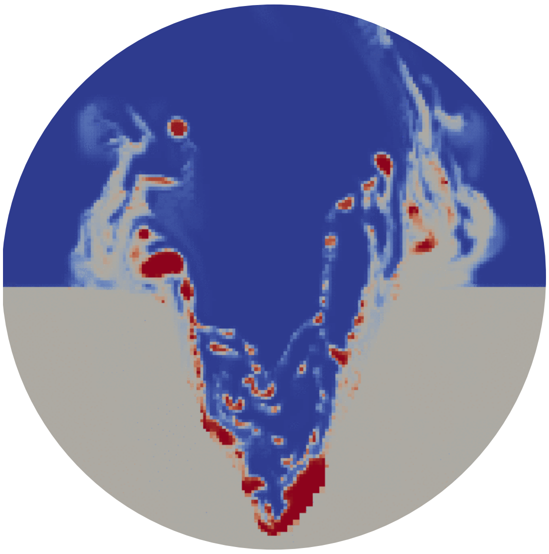
Welcome to the fourth HALO project newsletter!

The HALO project has successfully completed its mid-term review and is entering the demonstration phase. This newsletter presents some of the recent results from the project. More information can be found on the project website (www.halo-project.eu) which is kept up-to-date with the latest news and project outputs.

HALO has been involved in a number of international events over the summer, and published several more conference and journal papers. As part of the demonstration activity, HALO is seeking real industrial applications which could be used to assess the new processes and components developed in the project. If adaptable beams could be of interest in your area of activity, please get in touch (see below)!

In this newsletter:

- *Synova reports on the latest results using liquid jet cutting to process sapphire*
- *ORC Southampton presents ground-breaking new wave-plates manufactured using nano-grating technology.*
- *LTU describes high speed imaging of steel cutting to aid the understanding of dynamic laser cutting phenomena*
- *Review of some upcoming HALO outputs.*



HALO is supported by the European Commission through the Seventh Framework Programme (FP7), project number 314410.

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Image courtesy of Fraunhofer ILT

End user demonstration applications still required!

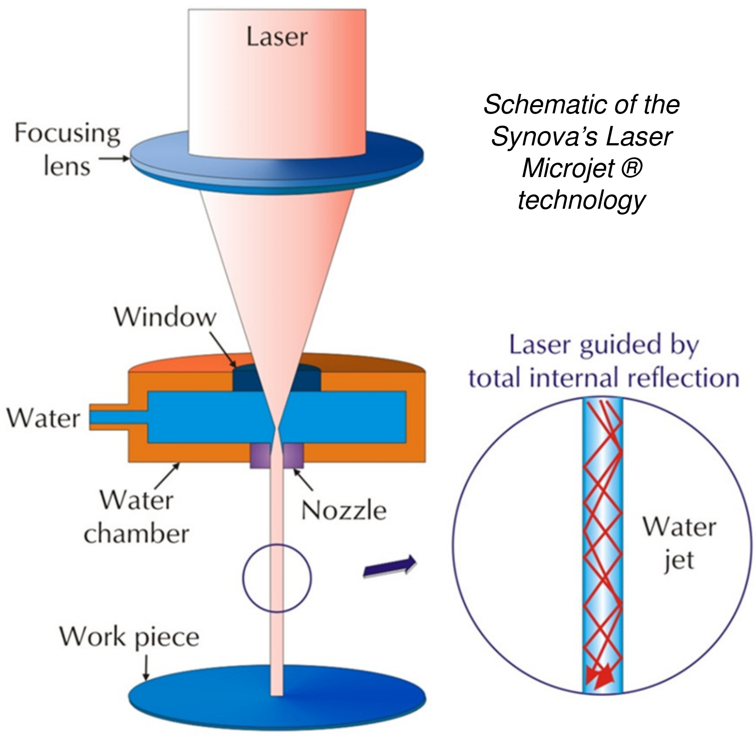
The demonstration phase of the project is now underway, but it is not too late to get involved. HALO is an industrially-driven project (funded under the "Factories of the Future" initiative) and the consortium is keen to ensure that the chosen applications reflect real industrial requirements. The project covers a very broad range of materials including: metals, glasses, plastics, ceramics and sapphire. If you are interested in testing adaptable laser beam technology for a particular application, please contact Tom Legg or Bruce Napier on the emails given above.

Gooch & Housego | LULEÅ UNIVERSITY OF TECHNOLOGY WORLD-CLASS RESEARCH AND EDUCATION | VIVID COMPONENTS | TRUMPF | Laser Expertise Ltd. | UNIVERSITY OF Southampton Optoelectronics Research Centre | SYNOVA | Fraunhofer ILT

Liquid jet laser cutting: Microjet®: A revolution in micro-machining

SYNOVA

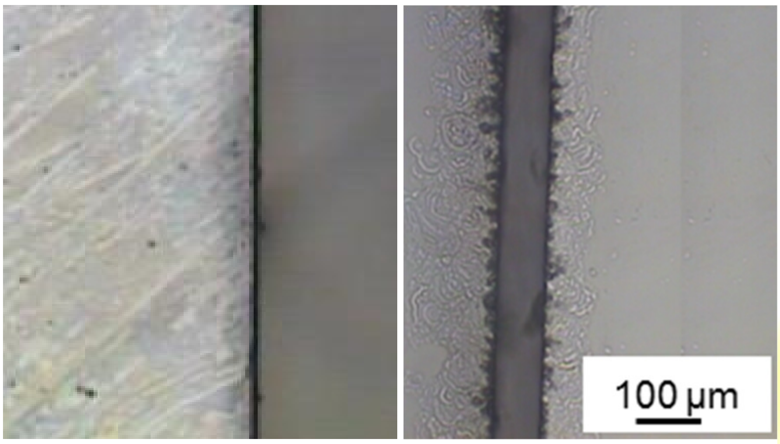
Laser MicroJet® technology from Synova uses a laser beam which is guided by a water jet. The length of this water jet is usually 1000 times larger than the nozzle diameter, usually between 30 µm and 150 µm, which allows high aspect ratios during cutting. With the water-coupled laser parallel cutting kerfs may be achieved. Additionally the water jet cools the workpiece while removing the ablated material from the cut and avoiding contamination.



Schematic of the Synova's Laser Microjet ® technology

In the HALO project, for the first time, an effective liquid jet cutting process for sapphire has been developed. Due to HALO systematic process developments, sapphire of up to 3 mm thickness can now be cut, with a kerf roughness R_a of *c.* 0.3 µm. The front side of the cut has excellent quality and the chipping on the backside is <20 µm. The cutting speed for a 1 mm thick piece is *c.* 0.2 mm/s.

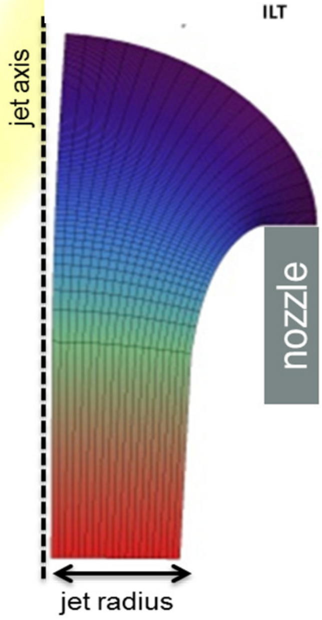
High peak intensities are needed to achieve reasonable ablation rates and the nozzles need to withstand the extremely harsh environment required during the cutting process. Consequently, within HALO, Synova is investigating the topic of nozzle damage to improve nozzle lifetime during the cutting process by adapting the optical system and nozzle designs.



(Left) Front side quality and (right) rear-side of a 1 mm sapphire cut, which has been made possible for the first time by the HALO project. [Images courtesy of Synova.]

Fraunhofer ILT

These designs have led to smaller jet sizes because of a reduced contraction ratio, which is also likely to reduce nozzle damage. An example of simulated water velocity distribution in a standard nozzle is shown on the right. This ongoing modelling work is being undertaken by Fraunhofer ILT in close collaboration with their colleagues at Synova.



Above right: Schematic of water velocity distribution from a standard nozzle. [Image courtesy of Fraunhofer ILT.]

For more information please contact
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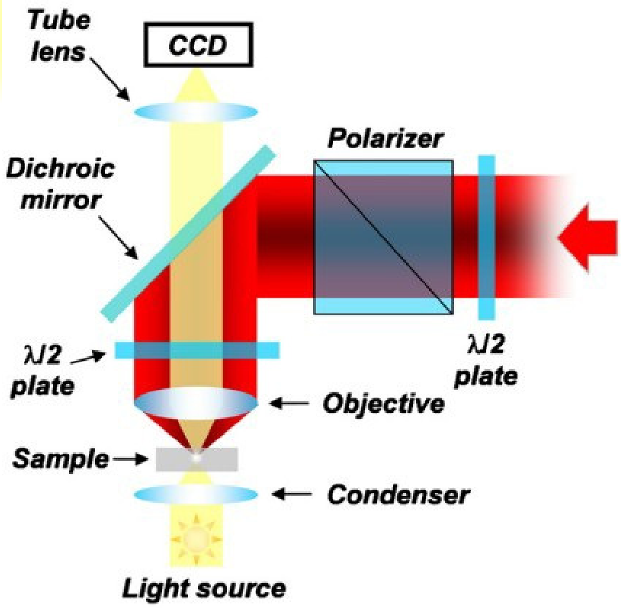
Efficient conversion to radial polarisation

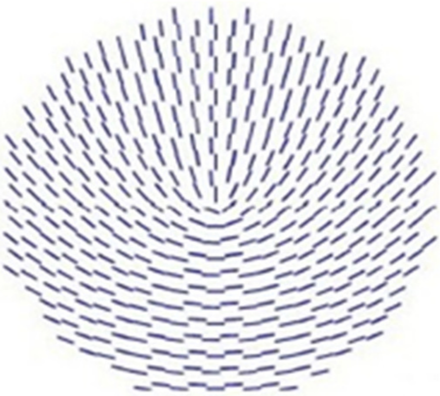
UNIVERSITY OF Southampton
Optoelectronics Research Centre

Radially polarised beams are attracting growing interest for use in a variety of laser processing applications due to their unique optical properties. However, generating these beams in an efficient manner and with high polarisation purity is a challenging task. The ORC has recently developed a continuously space-variant half-wave plate (S-waveplate) that allows a linearly-polarised laser beam in the two-micron wavelength band to be converted into a radially-polarised (or azimuthally-polarised) doughnut mode with both high efficiency and very high polarisation purity.

The S-waveplate was fabricated using a femtosecond laser to write nano-structure gratings in a silica glass window. The grating structures induce birefringence with slow and fast axes aligned parallel and perpendicular to the grating direction respectively, allowing the construction of a two-dimensional array of microscopic half-wave plates aligned in a manner designed to produce the required position-dependent polarisation rotation. These S-waveplates provide dramatically improved polarisation purity compared with, *e.g.* segmented retardation plates.

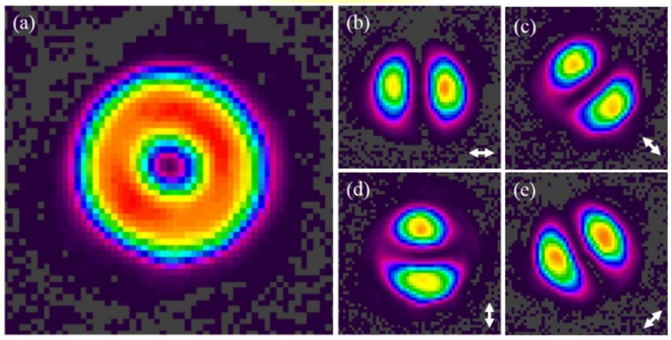


Above: Schematic showing femtosecond laser S-waveplate writing set-up at ORC.



Left: A schematic showing the orientation of nano-gratings in the ORC S-waveplate. The device offers greatly improved polarisation purity compared with traditional waveplates.

Below: (a) Intensity profile of radially polarised beam (a) without and (b-e) with an analyser polariser.



The S-waveplate was tested with a tunable thulium fibre laser yielding a doughnut-shaped radially-polarised (or azimuthally-polarised) beam with a polarisation extinction ratio (PER) of 18 dB and with a very low scattering loss of only 7%. The beam propagation factor (M^2) was measured to be ~2.15 and hence in close agreement with the theory. Optimisation of the S-waveplate design and fabrication procedure is expected to yield further improvements in performance in terms of loss, power handling and polarisation purity.

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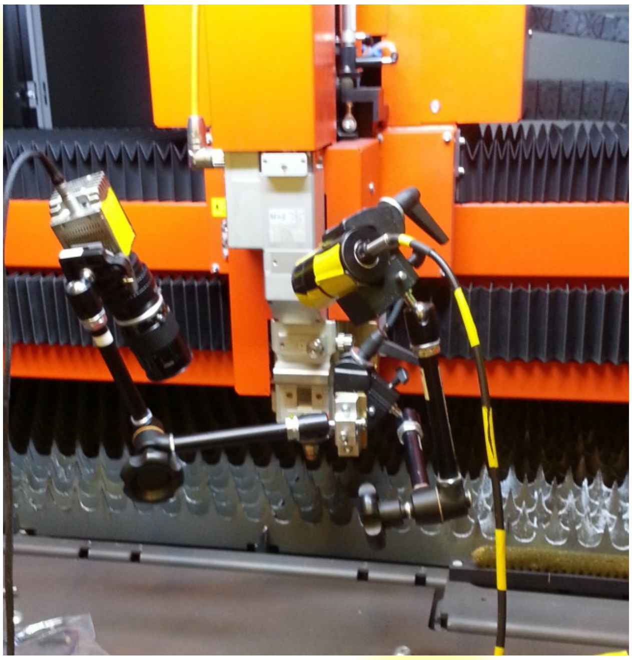
High speed imaging of laser cutting of steel

LULEÅ UNIVERSITY OF TECHNOLOGY WORLD-CLASS RESEARCH AND EDUCATION

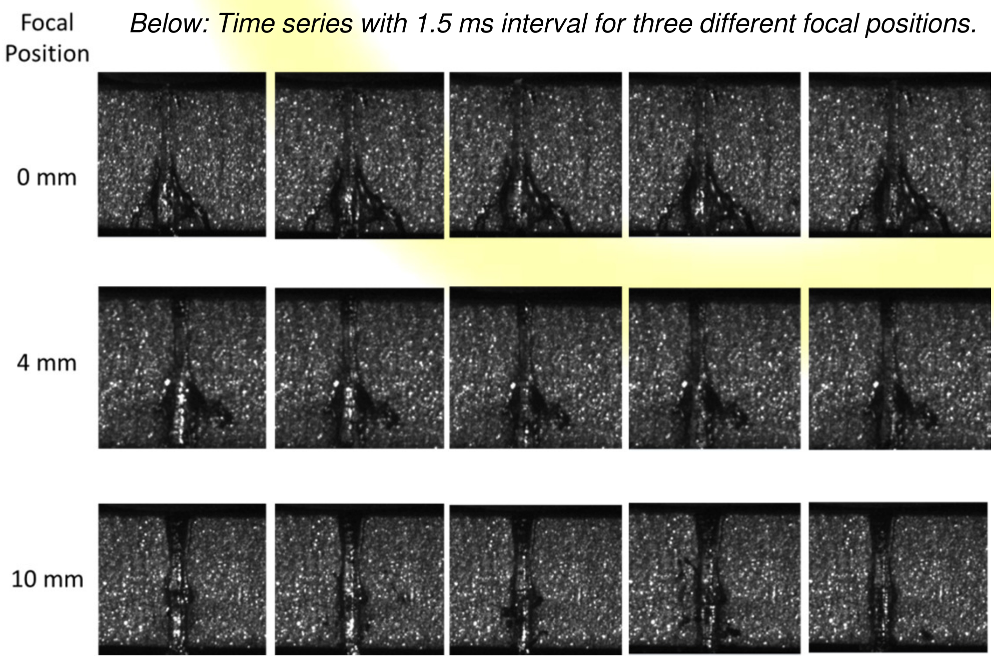
One important HALO task being performed at Luleå University of Technology (LTU) is to develop and apply a high speed imaging (HSI) methodology for the validation of simulations and meta-models that have been developed by Fraunhofer ILT. This includes HSI of drop ejection, dross formation and cutting front melt where different analysis methods are applied, particularly for understanding of dynamic phenomena.

A first series of cutting experiments including HSI to capture the cutting front melt behaviour under industrial state-of-the-art conditions was performed on site at a workshop and demo centre at the beginning of the summer. In this experiment the cutting of 6 mm and 10 mm stainless steel was carried out using a 1 µm fibre laser at powers between 2 kW and 4 kW, with cutting speed up to 4 m/min and nitrogen as the cutting gas. The melt behaviour on the cutting front was monitored with laser-illuminated HSI equipment mounted perpendicular to the cutting front. The images were taken by a Photron SA1 (San Diego, California) high-speed camera, at 4000 to 6500 frames per second. A fibre-guided pulsed diode laser (Cavitar, peak power 500 W) with a wavelength of 808 nm was used to illuminate the cutting front. The experimental arrangement with HSI camera is shown opposite.



Above: The experimental set-up of the HSI camera and illumination laser, before alignment, in the laser cutting workstation.

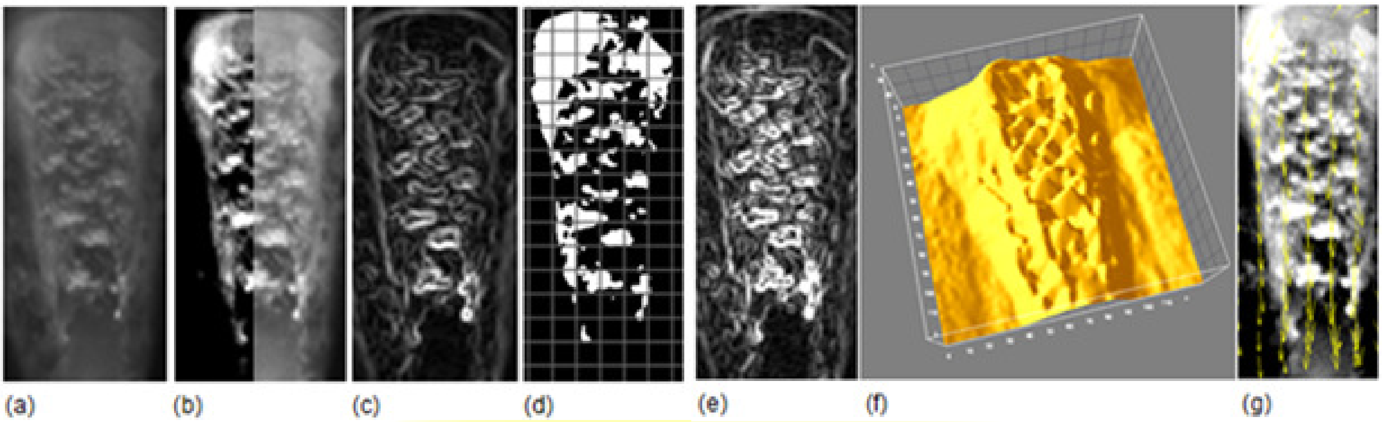
Below: Time series with 1.5 ms interval for three different focal positions.



The figure on the left shows a time series with 1.5 ms interval between each image, from one of the cutting experiments that was performed. This sample thickness was 6 mm, and three focal positions were evaluated:

- 0 mm (on the surface)
- 4 mm (2 mm above base)
- 10 mm (4 mm below base)

The objective was, among other things, to capture the relations between the focal positions and the cutting front melt behaviour.



Above: Examples of image analysis tools; (a) original greyscale; (b) different levels of enhanced contrast and brightness; (c),(e) 'finding edge' function; (d) black-white extreme of contrast, to clearly measure and define shapes; (f) 3D visualisation of the greyscale measured; (g) PIV (Particle Image Velocimetry).

The next phase in the experimental work is to further refine the HSI methods to better and more clearly capture the cutting front melt phenomena. These experiments will be performed in the laser laboratory at LTU and will include the use of different image analysis tools. These tools make it for example possible to identify different melt patterns, melt flow directions and velocity which will facilitate a better understanding of the melt dynamics. Results from these experiments will be reported in the next issue of the HALO newsletter.

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Upcoming HALO outputs

Second HALO video

A new video reporting on the progress made in the project will be recorded shortly and go online later in the autumn. Topics will include segmented waveplates from G&H, the meta-model development by Fraunhofer ILT and how the components and simulation have helped to improve processes at Trumpf and Synova. [And if you haven't already, please view the current video at the HALO website!]

ICALEO

ICALEO 2014

19-23 Oct-2014; San Diego, USA

Several HALO members will be at this important industry event, presenting two papers:

- "Differences in cutting efficiency between CO_2 and fiber lasers when cutting mild and stainless steels," covering work from LTU, Laser Expertise and Fraunhofer ILT.
- "Laser Microjet© cutting of up to 3 mm thick sapphire," will describe further details of the Synova work.

ORC Optics Letters paper http://dx.doi.org/10.1364/OL.39.005359

A paper describing some of the progress at ORC relating to radially polarised output lasers has just been published: "Cladding-pumped ytterbium-doped fiber laser with radially polarized output" Optics Letters **39**, 18, p. 5359 (2014).