High power Adaptable Laser beams for materials prOcessing

HALO project newsletter #5

June 2015

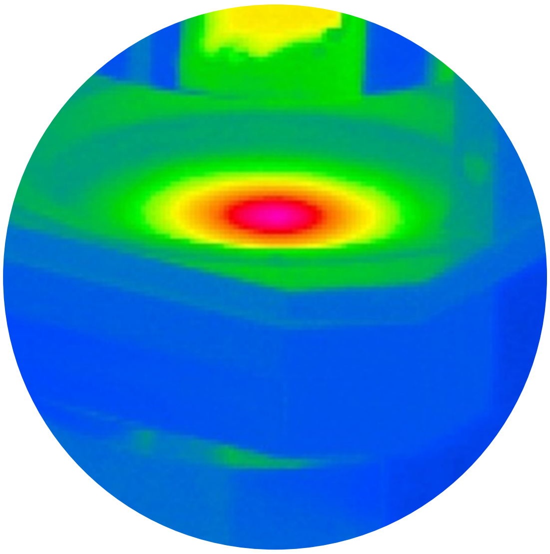
Welcome to the fifth HALO project newsletter!

The HALO project has been extended by eight months in order to ensure the full completion of the project targets. 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 continues to be involved at key important international conferences and events, and has published several more conference and journal papers. The call for companies interested in participating in the industrial demonstration activity remains open. Some (free-of-charge!) materials processing work has already been carried for an important European manufacturer, with excellent results and discussions are ongoing with several others. If adaptable beams could be of interest in your company, please get in touch (see below)!

In this newsletter:

- *Trumpf Laser reports on the use of adaptable beams to cut brittle materials*
- *Fraunhofer ILT describes the development of multi-dimensional metamodels to optimise laser cutting*
- *Laser Expertise and LTU present some conclusions on steel cutting with CO_2 and fibre lasers*
- *Review HALO activities at Laser World of Photonics.*



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

Coordinator
tlegg@goochandhousego.com

Admin
bruce@vividcomponents.co.uk

Image showing thermographical diagnostics of optical systems; courtesy of Fraunhofer ILT

Project extension gives more time for end user demonstrations!

The demonstration phase of the project is going well, and the eight month project extension means that there will be more time for end users to get involved. The project offers to try out some of the developments in adaptable beam laser cutting on end user processes. This could be for a range of material types 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.

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SEVENTH FRAMEWORK PROGRAMME

TRUMPF

Cutting of brittle materials

Glass is of ever-increasing importance in industrial markets, especially in display or cover glass applications for consumer electronics, which is a rapidly growing sector. However, precision cutting of brittle materials is a demanding process. High quality industrial glass sheets with high bending stability require minimal micro-cracks, particularly on the cut edges.

Cutting with ultrafast lasers with picosecond pulse durations has high potential for processing brittle materials efficiently without time consuming post-processing operations. There are various methods for cutting transparent materials with ultrashort pulsed (USP) lasers. The ablation process is well suited for complex geometries and inner contours in particular. However damage can occur during the ablation of transparent materials under certain conditions (Figs 1.1 & 1.2), the processed edges are angled (Fig. 1.3) and the processing speed is slow compared with other processes.

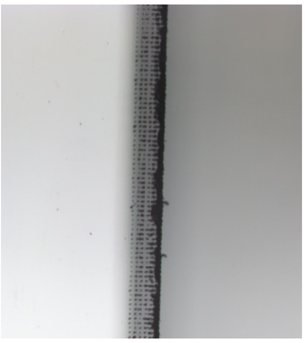

Fig 1.1 Damage at the rear side of the glass workpiece.

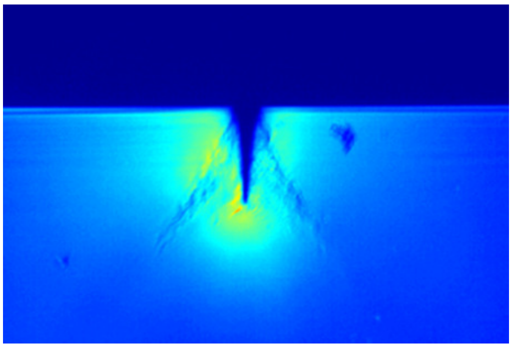

Fig.1.2 Polarisation contrast image of cross-section cutting kerf showing damage & tension.

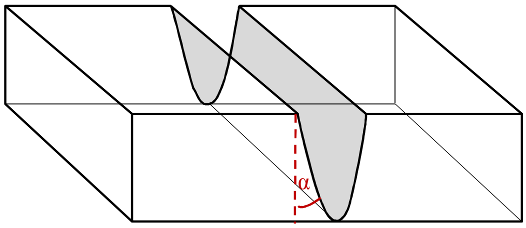

Fig. 1.3 Sketch of the glass sample, where the taper angle (α) is marked.

To meet these challenges TRUMPF is investigating the influence of beam shape and pulse duration on the cutting speed and quality. The spatial beam shape is responsible for the ablation geometry and therefore also influences the level of damage involved. Concerning temporal effects; the high intensities of the ultrashort laser pulses initiate non-linear absorption. A steep temporal increase in the pulse intensity is required to minimise the amount of energy propagating through the material which causes damage at the rear side (Fig 1.1).

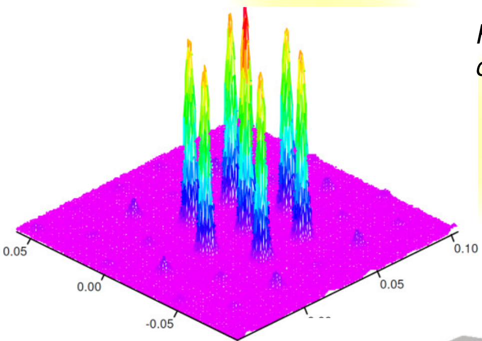

Fig 2.1 Intensity distribution of a multi-spot beam.

For more info please contact:
Lara.Bauer@de.TRUMPF.com

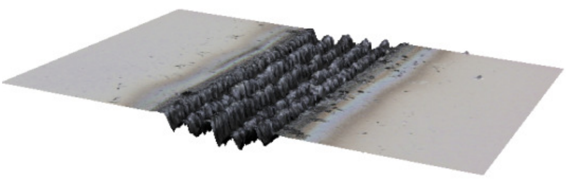

Fig. 2.2 Ablation on glass using multi-spot beam.

Within HALO, TRUMPF is testing various beam-shaping elements e.g. diffractive optical elements (DOEs) for multi-spot generation (Fig. 2.1) and segmented waveplates, and also investigating the effect of strong focussing. A key aspect is to reduce the taper angle and enhance the cutting speed whilst maintaining the cutting quality. The influence of pulse length is studied by comparing processes using laser pulse durations of 1-6 ps. The effect on the ablation threshold and cutting efficiency are explored.

Metamodelling of steel cutting using elliptical beams

Fraunhofer ILT

Metamodelling enables the derivation of rules for the design of optical components to enable high quality sheet metal cutting with fibre-guided radiation. As is well-known from recent publications, the most prominent measure to improve cut quality is to increase the angle of incidence of the laser radiation at the cutting front. A straight-forward design rule for an appropriate optical component is to choose an elliptical beam instead of a circular one, in order to increase the angle of inclination while maintaining a small kerf width. However, simple application of this plausible rule fails, since its applicability is restricted to a bounded region of parameter settings. In HALO, tailored metamodelling approaches are developed and applied to accomplish the request for determination of applicability regions for successful design thinking. (See "Meta-Modelling Techniques Towards Virtual Production Intelligence," W. Schulz & T. Al Khawli; in: "Advances in Production Technology, Lecture Notes in Production Engineering 2015," pg. 69-84, DOI 10.1007/978-3-319-12304-2_6)

HALO design thinking has four steps: "understand," "observe," "concept," and "iterative design." Understanding is achieved by going beyond identification of interaction chains and describing them by mathematical models. Observation beyond experimental evidence is improved by comprehensive numerical simulations including high-dimensional process maps. Concept generation is based on visual exploration of process maps and iterative design by experimental testing.

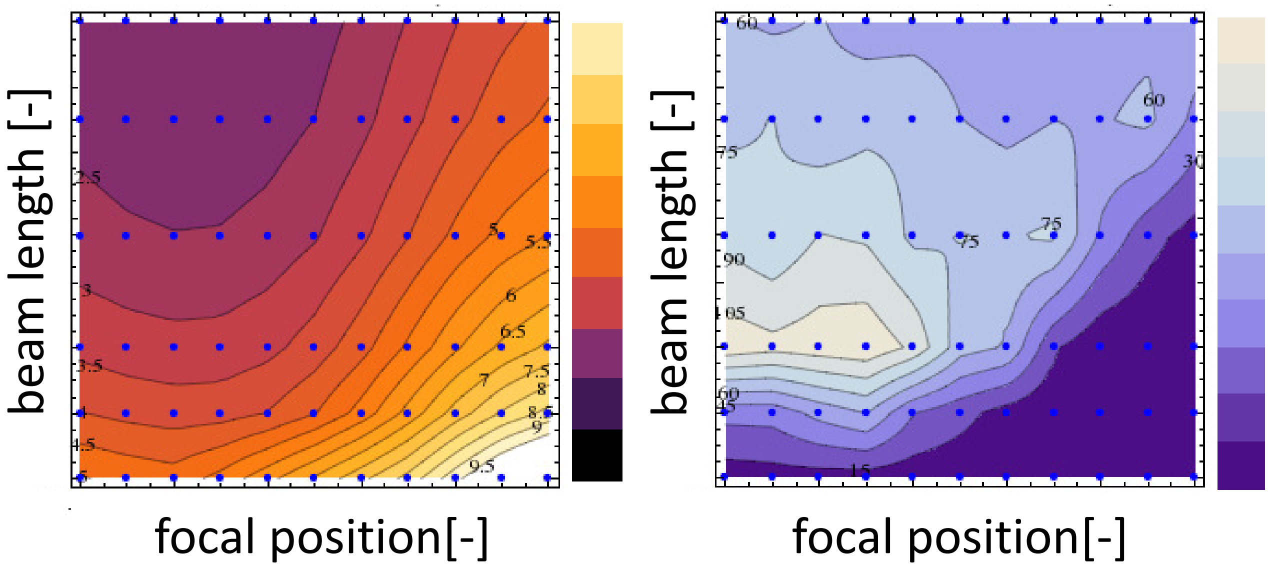

Fig.3: Inclination (left, 0-10°) of the cutting front and roughness (right, 0-150 µm) of the resulting cut surface as functions of beam length at focus parallel to the cutting direction and its focal position. By visual exploration of the Process Maps generated by the Meta-Model of sheet metal cutting the concept of elliptical beam shaping is refined.

The region for successful application of the design rule of elliptical beam shaping is an example of additional relevant information extracted with the metamodelling approach. By visual exploration of the process maps generated by the metamodel of sheet metal cutting, the general concept of elliptical beam shaping is refined, namely, the monotone relation between front inclination and roughness is not general, but holds only within a bounded region of parameter combinations (Fig. 3).

For more info please contact: **Prof. Wolfgang Schulz** wolfgang.schulz@ilt.fraunhofer.de

Laser Expertise Ltd.

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Efficiency of laser cutting of steel

Laser cutting is a multi-billion euro industry, which is dominated by CO_2 and fibre laser cutting machines. Research by the HALO team has investigated the efficiency of the cutting process when cutting stainless and mild steels with different lasers from the point of view of one question:

→ *"How much cut edge is produced for each kilojoule of laser energy?"*

The following summarises the key conclusions of the HALO investigations. For more detail see: J.K. Pocorni, D. Petring, J. Powell, E. Deichsel, and A.F.H. Kaplan, "Differences in cutting efficiency between CO_2 and fibre lasers when cutting mild and stainless steels," Proc. ICALEO 2014 (LMP9, 905).

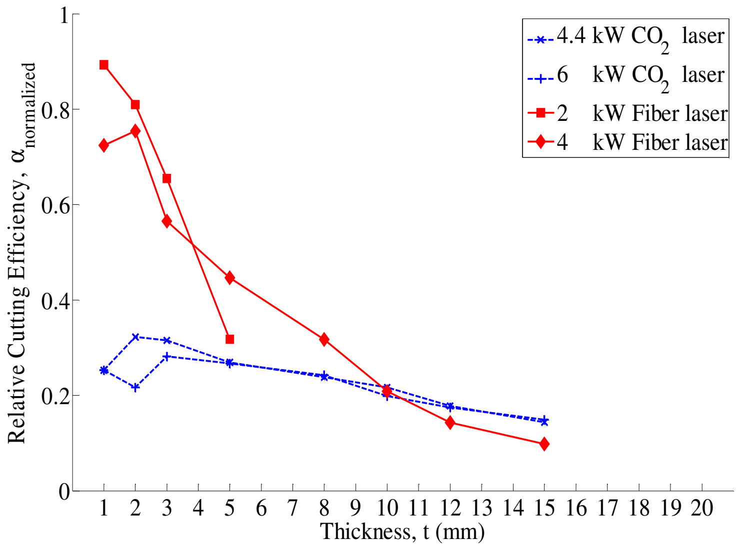

Fig.4 Relative cutting efficiency results for stainless steel (nitrogen cutting gas)

• As material thickness increases the cutting efficiency decreases. For all thermal cutting processes, an increase in material thickness results in a decrease in cutting speed. This increases the laser-material interaction time in a given area along the cut line which allows a greater proportion of the heat to be carried away by conduction. This increase in conductive losses per unit length of cut results in a decrease in process efficiency. Other possible reasons for the decrease in efficiency with thickness are reduced absorptivity, and the creation of wider kerfs. (Cuts which have wider kerfs require more energy because a greater volume of melt is created per mm^2 of cut edge.)

• For thinner sections fibre lasers cut more efficiently than CO_2 lasers. This situation is reversed for thicker sections. Again, the influence of kerf width and absorptivity are the main candidates to explain this result.

• In the thin section regime the higher power lasers of both wavelengths tend to have slightly lower efficiencies than the lower power machines. Higher vaporization losses at higher speeds as well as practical, speed limiting considerations of industrial systems are potential explanations.

• The lower power fibre laser cutting efficiency falls off faster than the higher powered machine as material thickness increases.

• At the thinnest sections, when cutting with nitrogen, the cutting efficiency may be reduced by (energetically wasteful) boiling of the melt.

• Kerf widths tend to increase as material thickness is increased. This is primarily for two reasons:

a.) For thicker sections the beam is often focused deep into the material (and therefore presents a larger diameter beam at the kerf entrance).

b.) At lower speeds associated with thicker sections the lower intensity edges of the beam can contribute to the melting process.

• The efficiency of the cutting process has to be distinguished from the cutting volume efficiency (the amount of material ejected from the cut zone per kJ of laser power), as the latter value directly profits from wider kerfs.

• In the case of CO_2 lasers the cutting volume efficiency remains fairly steady over the thickness range. This relative invariance is possible because there is a balance between two opposing effects:

a.) As thickness increases, the cut front approaches the Brewster angle and absorptivity is improved up to a certain thickness (increasing the energy available for material melting); but,

b.) As thicknesses increase the conduction of energy away from the cut zone increases (reducing the energy available for melting).

• In the case of fibre lasers the cutting volume efficiency decreases as material thickness increases. This is because the Brewster angle for fibre lasers favours thin section cutting, i.e. glancing angles above 10°. If the material thickness is increased, the absorptivity of the beam in its initial contact with the material decreases and direct beam impingement and absorption can only feed the upper part of the cutting front. This leads to the dominance of multiple reflections especially further down the kerf with stepwise increasing glancing angle; increasing absorption and the effective contribution of the reflected 1 µm radiation.

• The strong role played by multiple reflections in the case of fibre lasers (particularly for thick sections) facilitates cutting efficiency but can promote instabilities and limit cut quality.

For more information please contact: **Jetro Pocorni** jetro.pocorni@ltu.se

HALO at Munich World of Photonics

WORLD OF PHOTONICS CONGRESS
JUNE 21 – 25, 2015 | MESSE MÜNCHEN

21-25 Jun-2015; Munich, Germany
HALO will have a strong presence at the event, with exhibits from G&H and Trumpf in the exhibition. There will be several HALO presentations at the Congress, including:

- Influence of pulse duration on the glass cutting process (Trumpf Laser in LiM 2015)
- High aspect ratio capillary pumping of rod lasers (ORC in CLEO Europe 2015)
- S-waveplate for 2 µm radial modes (ORC in CLEO Europe 2015).

HALO will also participate in the “European Research on Laser Based Technologies” Forum, organised by Ulrich Thombansen from Fraunhofer ILT, the coordinator of the LASHARE project to share laser-based equipment between European companies.
Hall A2, Stand 250; 2015: 25-Jun-2015; 09:30.
Prof. Wolfgang Schulz (Fraunhofer ILT) has a slot at 13:00 to present “HALO–Real Time Adjustment of Laserbeam Properties for Optimum Process Results.”

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