High power Adaptable Laser beams for materials prOcessing

HALO project newsletter #3

March 2014

Welcome to the third HALO project newsletter!

The HALO project is approaching its halfway point, and there will be a major review with the EC, including a demonstration of some of the HALO hardware, in May-2014. This newsletter presents some of the recent results from the project. More information can be found on the project website (www.halo-project.eu), including an overview presentation, which was updated recently.

HALO has released several more conference and journal papers in this period, and the relevance of the project to real industrial requirements is becoming increasingly clear. At the recent Fraunhofer IWS Tailored Joining Symposium (see pg 5), radial polarisation and non-Gaussian beam profiles were discussed as routes to optimisation of welding and cutting processes. HALO is looking for potential demonstration applications, so if adaptable beams could be of interest in your area, please get in touch (see below)!

In this newsletter:

- *TRUMPF reports on using adapted beam profiles and polarisations to optimise metal cutting results*
- *G&H presents its HALO work on adaptable beam components, including segmented waveplates for radial polarisation and annular profile capillaries*
- *ILT describes its high speed videography which is being used to improve modelling.*

Image courtesy of Fraunhofer ILT

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

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End user demonstration applications wanted!

The demonstration phase of the project is scheduled to begin towards the end of 2014. 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. There is significant flexibility in the demonstration activity, and perhaps we could include your material or process. If you are interested in 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

TRUMPF

Sheet metal cutting

Since the first industrial CO_2 laser was developed in the 1980s by TRUMPF, it has become the most important tool for cutting sheet metal, providing both high productivity and excellent quality. In the last few years, solid state lasers have joined the group of industrial laser sources since they offer significant advantages concerning material flexibility, power consumption and productivity. Even in the challenging field of cutting thick sheet stainless steel, solid state lasers no longer have to hide behind the quality level known from CO_2 lasers, see Fig. 1.

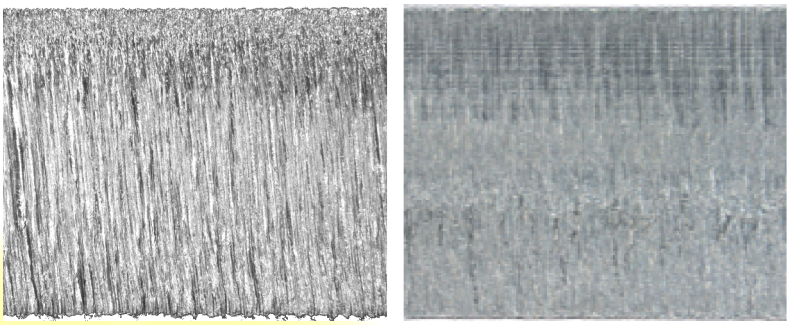

Fig. 1: 12 mm stainless steel. Left: disk laser; right: CO_2 laser.

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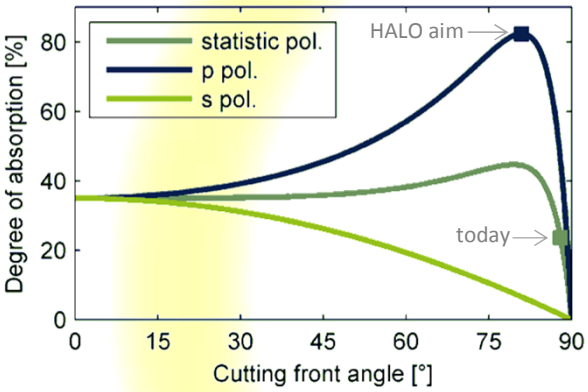

Fig. 2: Absorption diagram for solid state lasers.

However, as can be seen from the absorption diagram for solid state lasers in Fig. 2, the degree of absorption is still far from its theoretical maximum. It is the aim of HALO to take advantage of this unused potential by adapting the following laser beam properties:

1. **Beam profile**
   Adapt the beam profile such that the cutting front angle is decreased to 79° (Brewster angle).
2. **Polarisation**
   Change the polarisation of the laser beam from statistic to p polarisation.

In this way, the maximum absorption of the laser beam may be achieved, which is expected to drastically increase cutting quality and productivity, particularly in case of thick sheets. For a systematic adaption of the laser beam's properties, extra cavity beam converters will be developed and tested under real conditions. In more detail, the following approaches are taken:

1. **Adapted beam profile**
   Depending on sheet thickness, the diameter of the laser beam is adjusted in such a way that the resulting cutting front is inclined at the Brewster angle. To avoid widening the cutting kerf for productivity reasons, an elliptic focus will be used, see Fig. 3.
2. **Adapted polarisation**
   To realise an electric field of the incoming beam which is parallel to each particular plane of incidence, segmented waveplates for tailored polarisation will be developed and tested (see page 4).

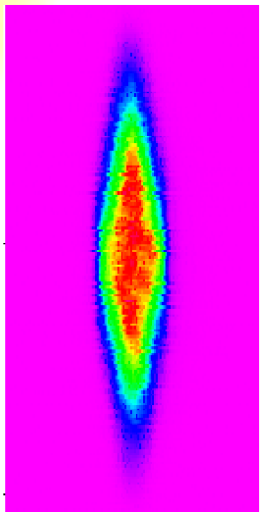

Fig. 3: Elliptic focus.

Finally, for maximum improvement both approaches will be combined.

Components for doughnut modes

Gooch & Housego

Fused components

Within HALO, Gooch & Housego is developing novel fused fibre devices such as the tapered capillary fibre, which is to be used in the HALO demonstration laser to generate a "doughnut" pump profile. This pump profile is required to directly excite the LG_{01} mode in an end-pumped holmium rod laser. This fused component connects a standard 105/125 µm 0.22 NA multimode fibre to a 200 µm (OD)/ 105 µm (ID) capillary with excellent transmission (>98%).

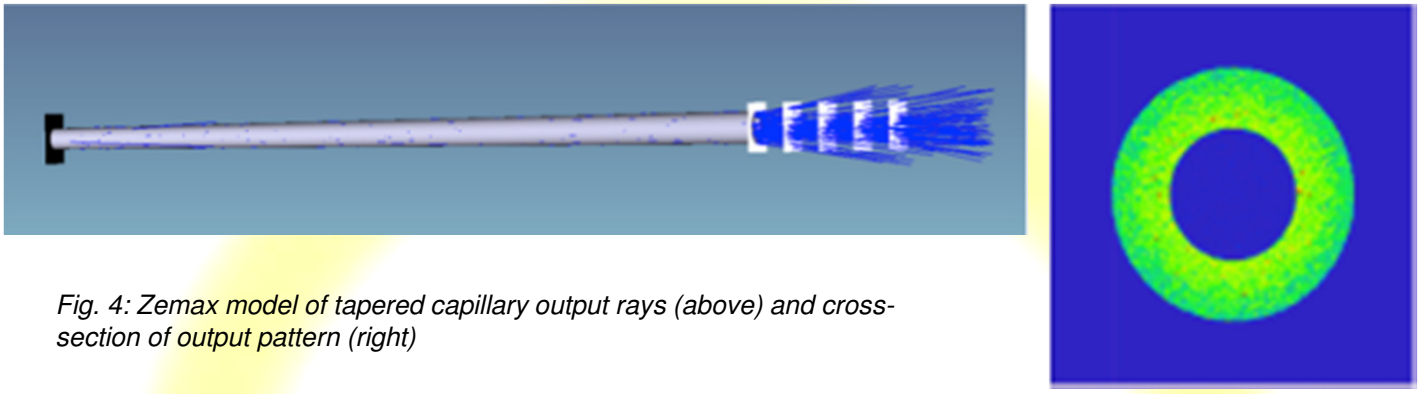

Fig. 4: Zemax model of tapered capillary output rays (above) and cross-section of output pattern (right)

Analysis of the near-field beam shape and intensity profile from the output of prototype capillaries shows a very uniform output with 99.9% of the output contained within the doughnut. Thermal analysis of the packaged fused tapered capillary reveals that the package should be capable of transmitting in excess of 500 W power.

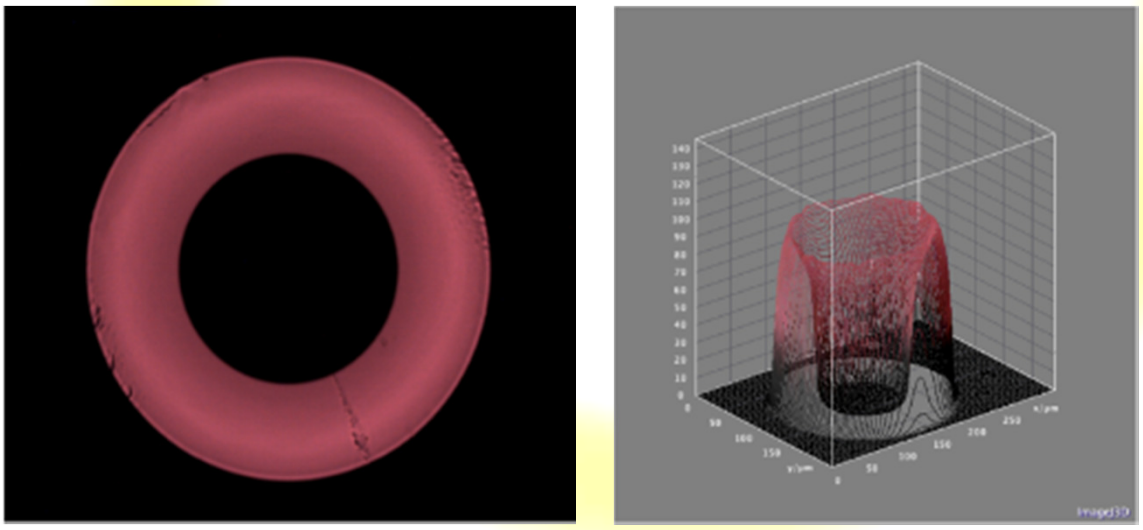

Fig. 5: Near field beam shape (left) and intensity profile (right)

A (6+1)×1 fused pump combiner with a double clad 10/200 µm passive fibre output is also being developed. The output of this combiner is matched to the gain fibre required for the Tm fibre pump lasers proposed by the ORC.

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Gooch & Housego

Optical isolators

A high power optical isolator to operate with radially and azimuthally polarised LG beams is also being developed by G&H. The design of this isolator needs to be polarisation independent because Faraday materials work by rotating the angle of linearly polarised light. At a polarisation beamsplitter the radially or azimuthally polarised LG_{01} mode will decompose into equal intensity HG_{01} and HG_{10} modes with orthogonal linear polarisations. In order to recombine these into a "pure" radially or azimuthally polarised LG_{01} beam, one requires control of not only the polarisation through the Faraday isolator but also the phase (path length) of the two modes.

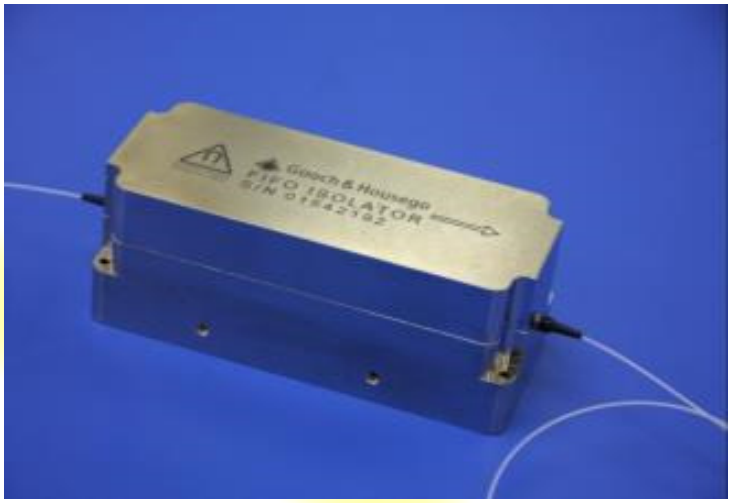

Fig. 6: G&H fibre-in fibre-out (FIFO) isolator

A preliminary demonstration with a linearly polarised LG beam has demonstrated isolation >23dB across all input polarisation angles. This was demonstrated with a free space beam; the intention is to extend this capability to fibre-coupled devices with LG producing elements.

Acousto-optic deflector

G&H has been working on the development of a fibre-coupled acousto-optic deflector designed to switch the pump laser light for the holmium laser between a standard pump fibre producing a Gaussian pump profile and the capillary tapered fibre to produce a doughnut shaped pump. This will allow the output mode of the holmium laser to be actively selected by pump shaping to match the required mode within the laser.

Beam-shaping components

Custom polarising and mode converting ("beam shaping") elements composed of a number of segmented waveplates with varying orientations are also in development. Mode overlap calculations for the simplest design show that for an eight segment plate around 95% of an incident linearly polarised beam can be converted into radial polarisation (assuming negligible diffraction at the waveplate boundaries).

Fig. 7: G&H segmented waveplate prototypes

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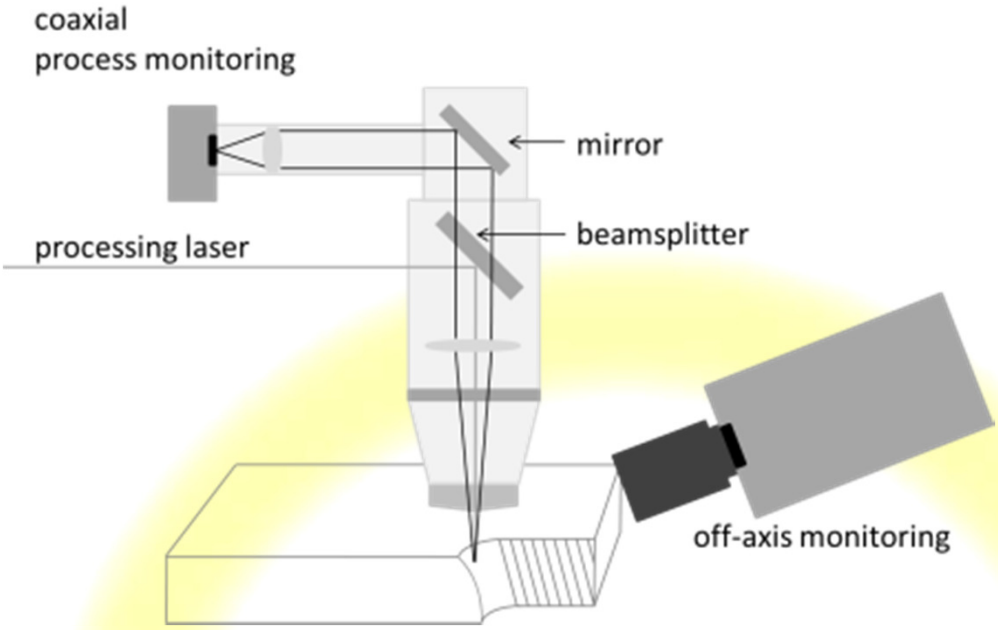
High speed videography

Fraunhofer ILT



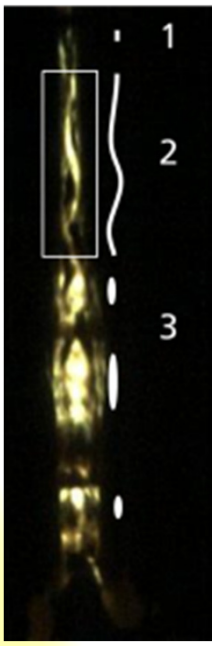


Fig. 8: Schematic of the experimental set-up for high-speed-videography for the laser cutting process (left), and exemplary freeze image of the resulting high-speed-videos (right), in which different structures on the cutting front can be observed.

HALO researchers at ILT are using high speed videography to image laser cutting processes. The set up is sketched in Fig. 8. This technique is helping to advance the modelling work in several areas:

- The high-speed videos reveal details of the phenomena involved in laser metal cutting
- Direct comparison with numerical cutting models is possible
- The impact of adapted optics on the cutting process may be simulated.

HALO events

Fraunhofer IWS

Laser & Tailored Joining Symposium… Just gone!
27-28 Feb-2014; Dresden, Germany
HALO had a joint booth with the ISLA project at this major industrial event organised by Fraunhofer IWS. Topics included a wide range of laser technologies for industrial applications and HALO was very well received.

Photonics Europe 2014… Coming up!
14-17 Apr-2014; Brussels, Belgium
HALO will have a booth at this important European event! With over 1500 presentations and eighteen conferences, Photonics Europe covers a wide range of photonic technology including highly integrated and functional components, advances in laser and amplifier technologies and photonics in industrial applications.

SPIE Photonics Europe