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CUTTING APPLICATIONS WITH HIGH BRIGHTNESS LASERS

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ABSTRACT

Laser cutting machines with linear motor drives provide high contour accuracy and high cutting rates. Thus laser beam cutting has become increasingly competitive compared to mechanical precision cutting [1]. Since the several years, new laser beam sources are available for cutting. One of the promising solutions is cutting with fiber lasers. The fiber laser has several advantages such as absorption rate, power efficiency, fiber delivery, better focusing if compared to the CO_2 laser.
During the recent years, the system technology for laser beam cutting was upgraded at Fraunhofer IWS Dresden [2]. In particular, a precision 3D-laser cutting system with linear drives, robotic systems, scanners and several fiber lasers have been installed.
Within the frame of several research projects laser beam cutting with fiber lasers has been investigated in order to compare the cutting quality and cutting performance with the CO_2 laser. Objective of this study was to show the potential of fiber laser remote-cutting. It could be learned that singlemode fiber lasers in the kilowatt range can increase the cutting speed and can thus reduce the cutting time dramatically [3]. This paper describes the gained user experience of Fraunhofer IWS Dresden. Single mode beam sources are evaluated with respect to cutting speed and quality.
Moreover, cutting of thick metal sheets with high brightness lasers will be demonstrated and compared to CO_2 – cutting.

***Key words**: High brightness lasers, Remote cutting,*

1. INTRODUCTION

Fiber lasers as modern versions of solid-state lasers offer the advantageous combination of high beam power with highest beam quality. Important advantages of the fiber laser such as:

- Depth of focus, capability to focus,
- High absorption for metallic materials,
- Possibility to use fiber delivery,
- High electric efficiency,
- Compact design and mobility

are of special interest for laser cutting. However, Fraunhofer IWS Dresden could learn that with the fiber laser the cutting rate for conventional fusion cutting can be increased (Figure 1). This is especially valid for thin sheets. As shown in the chart, it is possible to cut much faster with a 4 kW fiber laser (IPG GmbH) if compared to a 3 kW CO_2 slab laser. When the data of the DC 030 (Rofin Inc.) and the 1 kW fiber laser (IPG GmbH) is evaluated, it is apparent, that the same cutting speed can be achieved with much lower power. The reasons are the better absorption rates for the shorter wave length and the better capability to focus for the solid state laser.

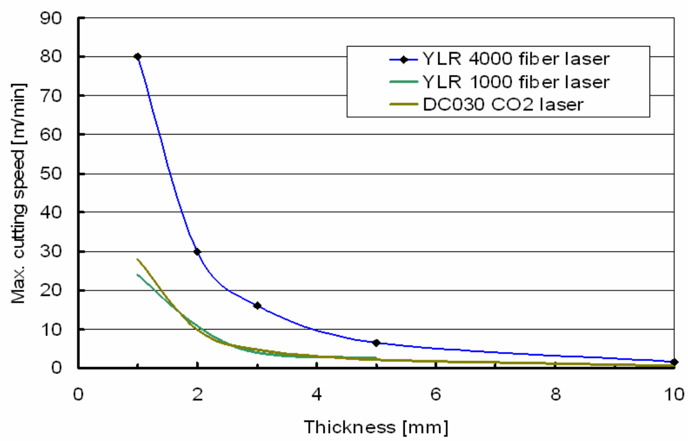

Figure 1 - Cutting of stainless steel 1.4301, Cutting gas N_2, focal length 125 mm [3]

2. APPLICATION "REMOTE CUTTING OF METALS"

2.1 High brightness lasers

For this application two single mode beam sources have been used:

Table 1: Specification of the used equipment

Laser specification YLR 1000 SM	**Laser specification YLR 3000 SM**
Laser power: 1000 W	Laser power: 3000 W
Wave length: 1070 nm	Wave length: 1070 nm
Fiber diameter: 14 µm	Fiber diameter: 30 µm
Fiber length: 5 m	Fiber length: ~ 4 m
BPP < 0,34 mm x mrad	BPP < 0,4 mm x mrad
Electrical efficiency > 25%	Electrical efficiency > 20 %

These lasers can be combined with 2D and 3D handling systems (portals, robots) and processing optics e.g. scanners, as can be seen in
Figure *2*.

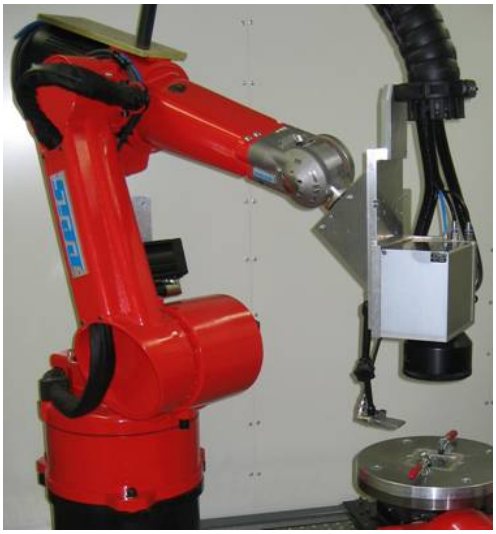

Figure 2 - Remote cutting station holding a high speed scanner

2.2 Cutting process

What differs from conventional cutting is that this process can be described as a "layer-wise ablation process". That means, a single mode fiber laser beam in CW mode is guided with high speed on the material surface. The high brilliance of the beam enables an ablation process of the material. A groove is formed which is shown in Figure 3. However, not the entire volume of the material is evaporated, due to the Gaussian beam shape. Some molten material remains in the groove, which is removed with the next scan.

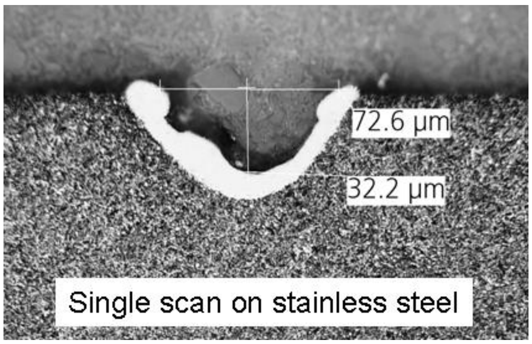

Figure 3 -Cutting groove with remaining melt (white section)

As the image illustrates, a single scan cannot cut material of higher thickness. The depth for one scan is for this optical setup about 32 µm. This layer by layer ablation process is repeated until the complete sheet is cut. Thus the material thickness defines the necessary scans. The cutting kerf width depends on laser spot size and the number of scans. It can be expected in the range of 80 – 200 µm.

2.3 Remote cutting quality

One objective of this investigation was the characterization of the cutting quality. As can been seen from
Figure ***4*** the first cutting results show already good results. It must be mentioned that this process works without cutting gas which usually removes the molten material from the cutting kerf.

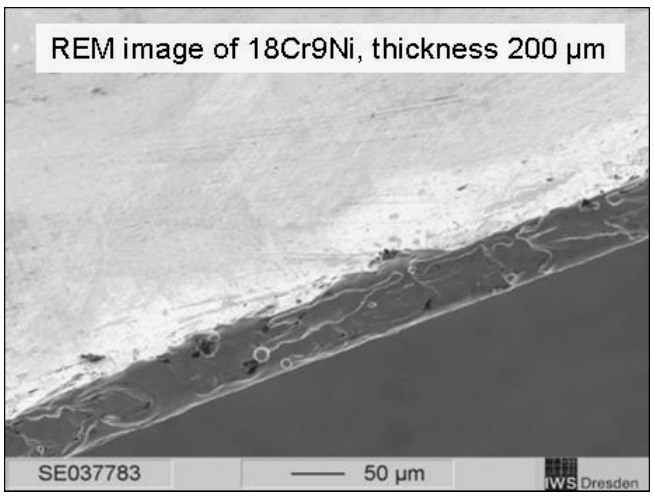

Figure 4 - Cutting surface quality

A typical appearance of such a "remote cutting surface" is given with the REM- image. For these thin foils it was impossible to measure the roughness with standard methods. Therefore it was evaluated for 500 µm thick stainless steel. The values are Ra = 6 µm and Rz = 35 µm.
The burr height was measured as well and the results are shown in Table 2. According to DIN ISO 13715:2000 such edges are defined as "sharp-edged". Which makes this process different from conventional cutting is that the burr appears on top of the material surface.

Table 2: Measured burr height for the 1 kW SM fiber laser cut

Material thickness	**Burr height**
50 µm	< 5 µm
100 µm	5 – 15 µm
200 µm	10 – 20 µm

3. APPLICATION "CUTTING OF THICK METAL SHEETS"

Cutting of thicker materials in the range of several millimeters is only possible with gas support, in other words, this must be done with standard cuttings heads for solid state lasers (see Figure 5). For investigations and developments in laser beam cutting of thicker materials, IWS has several high brightness lasers available, for example:

- 4 kW multi mode fiber laser and
- 5 kW disk laser, linear polarized.

All lasers can be combined with 2D and 3D handling systems (portals, robots) and with control technology. Processing optics with a variety of focal lengths and distance sensors have been purchased for high pressure cutting applications.

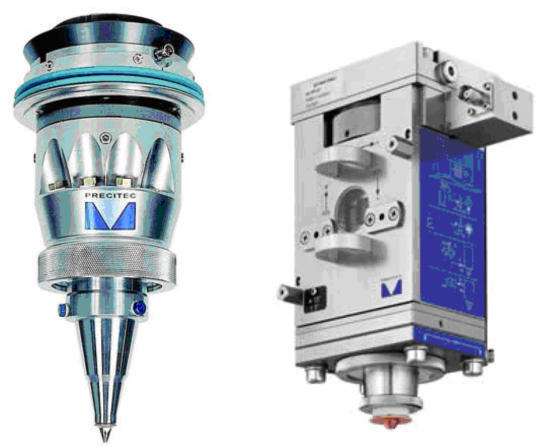

Figure 5 - Cutting heads YK 52 and right HP 1.5" [4]

After the development of basic cutting parameters for an acceptable cutting surface quality, the feed rates were determined. The tested material was stainless steel 1.4301.
The following table shows parameters were a good cutting quality can be achieved. Table 3 depicts the obtained speeds for a thickness range between 10 and 20 mm for the 4 kW multimode fiber laser. In comparison the range up to 10 mm for stainless steel 1.4301 can be seen in Figure 1. If comparing these cutting rates with CO_2 cuts, it can be found that the fiber laser outperforms the CO_2 laser for thick materials as well.

Cutting edge quality
The following pictures present the physical observations of the cutting surfaces for the thick material. The structure looks different as known from CO_2 - cuts. The striation pattern can be separated in two regions, one with relatively low surface roughness and one with higher roughness. One explanation is the more complicated melt eject mechanism for the thicker materials, since the cutting kerf is very small and very deep. Here, it is necessary to improve the melt flow by developing new cutting parameters.

Table 3: Cutting parameters for cutting stainless steel with Nitrogen

Material thickness [mm]	**10 mm**	**12 mm**	**15 mm**	**20 mm**
Power [W]	3000	4000	4000	4000
Focus length [mm]	190	254	254	254
Speed [m/min]	1.2	1.2	0,7	0,35
Gas pressure [bar]	18	20	20	22
Nozzle diameter [mm]	2,5	2,5	3	3

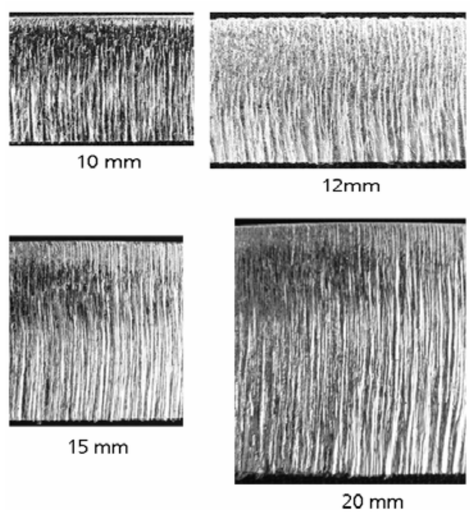

Figure 6 - Cutting surface structures for YLR 4000 fiber laser cuts

The roughness was measured with a Perthometer and the values are given with Figure 7. The cutting parameters are similar to the values in Table 3.
When comparing the obtained quality (Figure 7) with typical CO_2 qualities it is obviously that the CO_2 cutting surface is smoother than the fiber laser surface. However, it should be considered that the cutting speed for the fiber laser is higher.

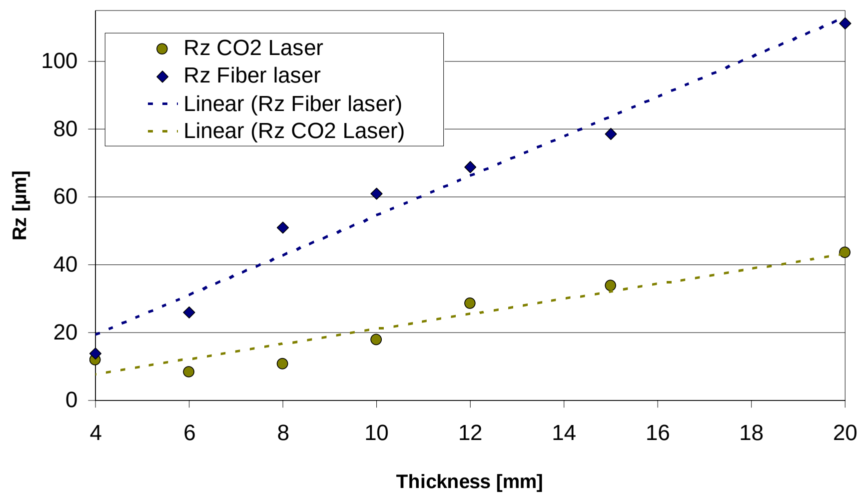

Figure 7 - Edge quality values for stainless steel (1.4301)

4. CONCLUSION AND OUTLOOK

Fraunhofer IWS Dresden, Germany has developed a new technique called “laser remote cutting”. The process takes advantage of new developments in solid state laser technology which has enabled the use of oscillating optics to rapidly scan a highly focussed laser beam across a work-piece at extremely high speeds.

However, this process is a complete departure from conventional laser cutting, which relies on full penetration of the laser beam through the work-piece and assist gas to eject the molten material through the cut kerf. The remote process uses the interaction of the rapidly scanned laser beam to achieve partial sublimation or evaporation of the cutting kerf and, thus, the cut area is continuously ablated until it is completely separated.

One major advantage of this technique is the high processing speed, which cannot be matched even by the latest high speed linear drive cutting machines due to their inherent mass inertia issues.

With scanning optics it is possible to cut a hole matrix (100 circles with a diameter of 6.5 mm) from a 100 µm thick stainless steel sheet in less than 2 seconds. Compared to conventional machines with linear drives, that means a gain in efficiency of nearly 1000%. For sheets, which are 50 µm thick, the cut time is reduced to just 1.2 seconds.

As Fraunhofer IWS Dresden continues to develop this technology further, this revolutionary new remote cutting technique could be applied to a wide range of industrial applications from cutting of automotive gaskets to electrical sheets. As the maximum achievable thickness increases (Figure 8), the application areas will open up further, for example cutting of steel filter screens and mesh materials.

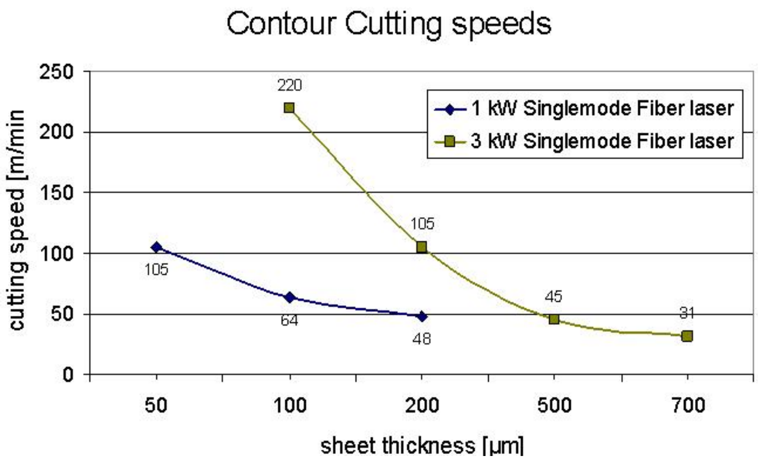

Figure 8 - Achieved cutting speeds on the contour for two different beam sources

The laser remote technique can easily cope with complicated contours. The possible material spectrum is wide and the heat affected zone is lower than with conventional cutting, due to the higher cutting speed. Compared to conventional punching, the advantages of the remote technique are clearly lower costs for the tool making and the finish-grind and the lower noise level.
Cutting of thick metal sheets with brilliant beam sources is possible as well, however this cutting process must be investigated more deeply to improve the cutting quality.

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SEČENJE SA LASEROM VISOKE SVETLOSNE MOĆI

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REZIME

Mašine za sečenje laserom sa lineranim pogonskim motorom omogućavaju postizanje konture visoke tečnosti uz visoku produktivnost. Ovaj način sečenja postao je veoma konkurentan u poređenju sa mehaničkim preciznim sečenjem. Od pre nekoliko godina na raspolaganju su laseri sa novim tipovima zraka. Jedno od obećavajućih rešenja je i sečenje sa fiberskim laserom. Takav laser ima niz prednosti u odnosu na CO2 laser, nivo apsorpcije, dobro iskorišćenje energije, bolja mogućnost fokusiranja i dr.
Na Fraunhofer IWS Institutu u Drezdenu (Nemačka) u poslednjih desetak godina intenzivno se radi na usavršavanju i poboljšavanju procesa sečenja laserskim zrakom. Između ostalog, u Institut je instalirano postrojenje za precizn 3D sečenje sa linearnim pogonom i sistemom robota. U pogonu je nekoliko skenera i filter-lasera.
U okviru ostalih istraživačkih projekata, istraživanje i razvoj na polju sečenja fiber laserom bilo je sprovedeno sa ciljem da se ovaj postupak uporedi sa sečenjem pomoću CO2 lasera i to sa stanovišta kvaliteta i ostalih relevantnih karakteristika. Cilj istraživanja je bio da se pokažu potencijalne mogućnosti ovog postupka. Pri tome je dokazano da fiber laser nivoa kilovata može značajno povećati brzinu, tj. skratiti vreme sečenja.

***Ključne reči**: Laser visoke svetlosne moći, Daljinsko sečenje*