Houston, February 10, 2006

Report: The LWS Flexcell Cladding System

General Background Information

Today the multi-kilowatt laser application and processing market is dominated by CO_2 and Nd:YAG lasers which combine to a total of more than **90% of all installed laser systems**. Since the late 1980's when more than 80% of all installed multi-kilowatt lasers were CO_2 lasers the Nd:YAG lasers have constantly **grown** their market share which is now more than 50%. Today with both systems being equally reliable the focus shifts to the end user to pick the right system to address all of their customer requirements in respect to **part quality** and **manufacturing cost**.

Why is LWS using a Nd:YAG laser?

LWS is a new company but with a high laser experience and know-how level present through its employees who have worked with laser systems in industry and research for more than 20 years.

Picture 1: 3000 Watt Nd:YAG Laser

Picture 2: 8,000 Watt CO_2 Laser

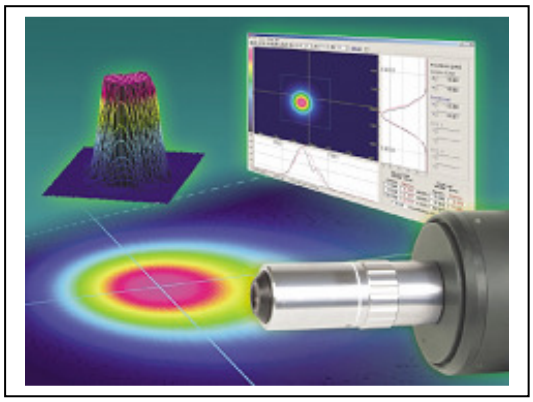
The Nd:YAG laser offers significant advantages over CO_2 lasers for the cladding of oil field drilling components which makes it the natural choice for every new and modern production system:

1. Wavelength
   The wavelength of the Nd:YAG laser is **1.06 µm** versus 10.6 µm of the CO_2 laser. As a result the absorption, or the **efficiency** with which the laser energy is utilized for the cladding process is approx. 3x higher using a Nd:YAG laser.

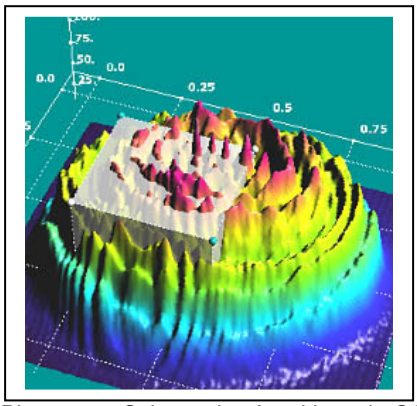
Why is this important for the customer?
The better absorption leads to a more effective energy incoupling into the part. The laser energy is thus more effectively used for the process which overall reduces the heat-input into the part, causes less dilution of the clad layer (and subsequently a harder clad layer) and a process which can be easier and better controlled.

2. Shape of the Laser Beam and Energy Distribution Profile
The laser beam of the Nd:YAG laser is delivered through a **glass fiber cable** from the generator to the weld head. The glass fiber cable homogenizes the beam and as a result the shape at the work piece is **perfectly round**. A cross section of the energy distribution shows a so called **Top Hat** profile with no disturbing hot spots or local energy deficiencies.

A CO_2 laser usually has a slightly oval spot shape and the energy distribution is a multi-mode structure with energy peaks and valleys.

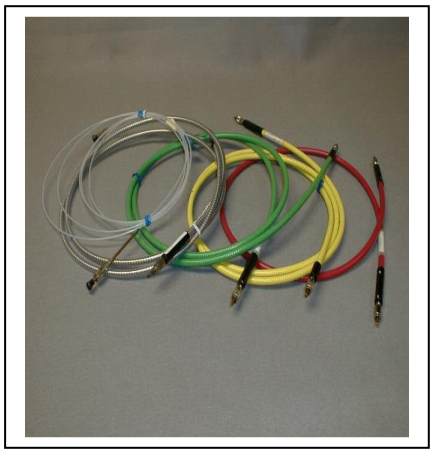


Picture 3: Schematic of Nd:YAG beam profile



Picture 4: Schematic of multi-mode CO_2 beam profile

Why is this important to the customer?
The perfectly round shape and the Top-Hat energy distribution of the Nd:YAG will deliver completely **identical weld layers** with consistent and superior quality **independent of the weld direction** on the work piece. **Hot spots** and other irregularities in the energy distribution of the CO_2 laser can easily generate local **overheating** on the part if not traveled in the direction preferred by the laser. The weld bead looks differently if the welding direction changes from x to y. Customers will have to specify a “preferred only” weld direction to get consistent quality on the part.



Picture 5: Nd:YAG fiber cables

Picture 6: Example of CO2 beam delivery system

3. Laser Beam Delivery System

As previously mentioned, the laser beam of the Nd:YAG laser is delivered via a **glass fiber cable** to the weld head versus the beam of a CO_2 laser which is reflected by **copper mirrors** in a fixed mounted **pipe system**. Exiting the CO_2 laser the beam is not perfectly collimated, meaning it will expand and/or contract slightly while in the pipe system. If the weld head is moved during the welding process, the beam diameter on the focusing lens will **vary** and this will **affect** the spot size on the workpiece.

This is why today CO_2 lasers are usually used only in systems with the weld head in a stationary position and with all motions performed by the workpiece e.g. automotive transmission welding.

Why is this important to the customer?

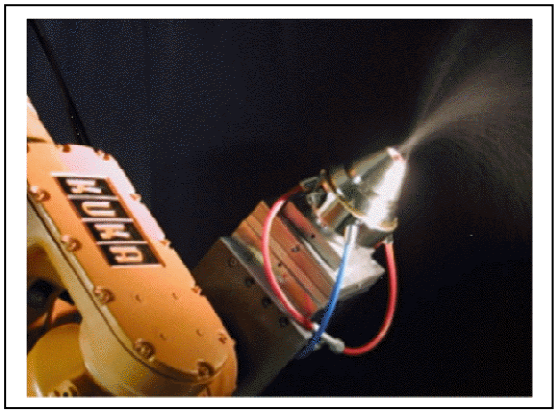
If parts are processed with a total cladd layer length of a foot or less and the weld head is moved along the center line of the part the fluctuation in the CO_2 beam diameter can be disregarded. However, if longer parts are processed or a gantry style system is used with multiple workstations, the **weld bead dimension** and **part quality** will be **notably different**. The customer will have to accept that parts might not look the same (fluctuating layer thickness) and that as a result the **performance downhole** might vary.

These issues are completely unknown to a Nd:YAG laser. Changes in the beam dimension can only occur, if the glass fiber cable is not handled according to the manufacturer specifications (stretched or bend excessively). In the LWS Flexcell the glass fiber is hung in slopes from the ceiling to avoid any complications.

4. Motion Systems

CO_2 and gantry style motion system do not harmonize very well due to the characteristics of the beam delivery and the fact that the weld head is not stationary. Consequently a lot of effort has to be put into getting descent and homogenous cladding results everywhere within the work envelope of the gantry. In addition a gantry style machine is an enormous investment which is reflected in high hourly machine rates.

Nd:YAG lasers are widely used in the automotive and aerospace industry in conjunction with high accuracy robotic motion system. The integration of Nd:YAG laser and robot is simple and requires almost no maintenance. In addition the use of a robotic motion system is more cost efficient.



Picture 7: Modern coaxial cladding head for robots

The reason robot systems have not been used for cladding in the past is related to the older coaxial powder nozzle designs which did not work effectively on a robot. LWS is using a powder nozzle which was designed and developed in collaboration with Toyota and is used today in production for robotic laser cladding of cylinder heads, in automotive tool & die shops and by turbine blade repair companies.

Why is this important to the customer?

The robot combines good accuracy with a large work envelope and outstanding flexibility at a lower cost compared to linear axis machines. It will be able to handle all parts up to 30 ft. and can easily be expended to handle even longer parts if required. The quality of the overlay will be consistent at every point within the work envelope of the system.

Summary
After analyzing all aspects of the laser cladding process, LWS decided to pursue a “total customer satisfaction” approach which addresses the relevant cost and quality issues in respect to oil drilling tools and components. It was the objective to identify and engineer the best possible system solution in respect to:

- Superior And Consistent Overlay Quality
- Less Heat Input into the Tool
- Lower Cost to the Customer
- Faster Turnaround Time

These objectives could only be achieved by investing in more modern and innovative technology than currently used for overlaying oil drilling tools. The result is the combination of a 3,000 Watt Nd:YAG laser and a high accuracy robotic motion system which clearly outperforms any 8,000 Watt CO_2 laser and linear axis machine on almost every level.

Our customers will be able to benchmark this performance as we are able to offer better quality at a lower cost over their complete part spectrum.

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Laser Welding Solutions