Lasers weld,

In Ditzingen near Stuttgart, the Trumpf Group organised its Technology Day on February 24 last. The day comprised demonstrations of many Trumpf laser welding and cutting machines, whose names without exception start with the prefix Tru. For example, it was shown how immense sheet metal parts for the automotive industry can be cut and welded on huge TruLaser Cell machines, with TruPulse, TruDisk and TruDiode as versatile laser sources. Also optical systems were shown that distribute laser energy to machining cells: precision technology on a large scale. On a smaller scale, Trumpf engineers showed how precision products that used to be milled from solid, can be realized at much lower prices in sheet metal.

• *Frans Zuurveen* •

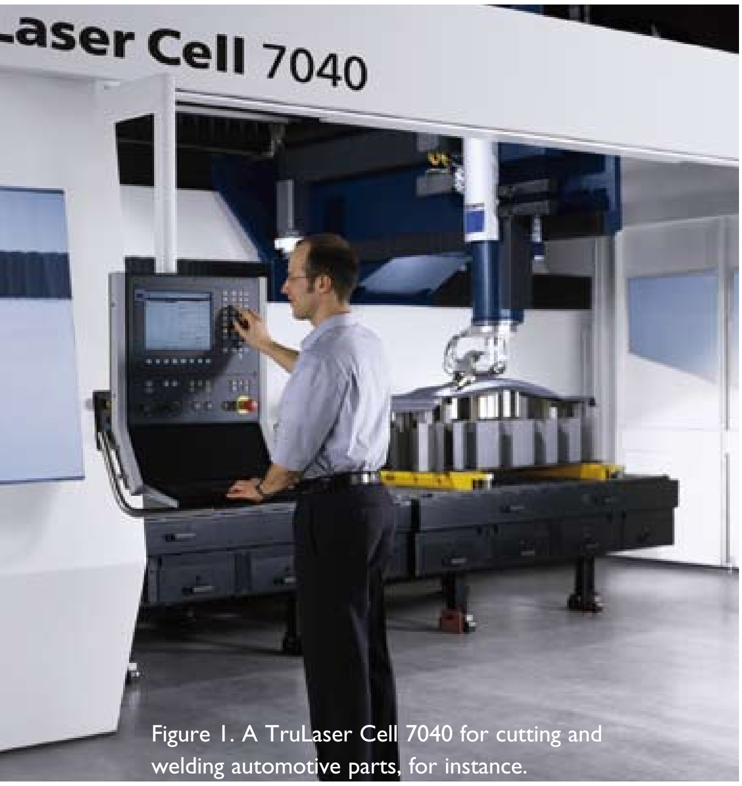


Figure 1. A TruLaser Cell 7040 for cutting and welding automotive parts, for instance.

Albert Einstein seems to have used the term “stimulated emission” in connection with his quantum theory to explain radiation of light. Not much later, in 1923, Christian Trumpf started a mechanical workshop that gradually specialised in the production of machines for sheet metal processing: punching and nibbling.

In 1960, Theodore Maiman constructed the first laser: Light Amplification by Stimulated Emission of Radiation. This invention stimulated the Haas Company in Schramberg to investigate the application of a laser spot for

Figure 2. An example of a laser cut and welded product from sheet steel that replaces a much more expensive piece milled from solid.

cut and deposit

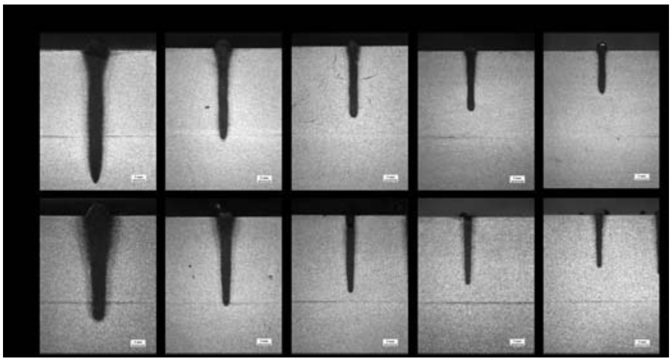


Figure 3. Cross sections that show welding penetration at different speeds (from left to right 2, 4, 6, 8 and 12 m/min) for gas laser TruFlow (upper row) and solid-state laser TruDisk (lower row).

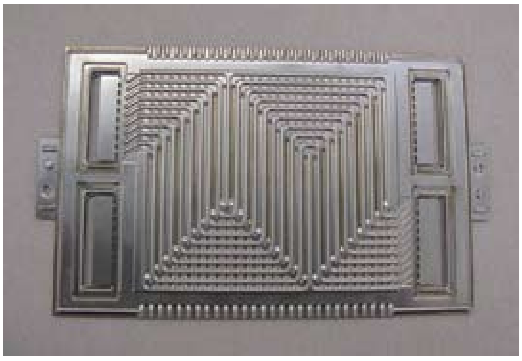


Figure 4. Example of precision welding a 200 μm thick foil with a TruFiber 400 laser.

solving the difficult problem of fastening coiled springs for the German and Swiss watch industry. This resulted in the development of Haas's first solid-state laser in 1970. The renamed Haas Laser GmbH started a co-operation with Trumpf and the latter decided to concentrate on gas lasers, which at that time were able to generate more radiation power. So, in 1985 Trumpf succeeded in developing a 1kW CO_2-laser, in 1989 followed by a high-power folded CO_2-laser. In 1992, Haas Laser became part of the Trumpf Group and today it has been fully integrated.

In the nineties, gas and solid-state lasers competed in power. In that competition disk-lasers succeeded in multiplying the power of diode-pumped solid-state lasers: today disk-lasers have almost the same power as gas lasers, 16 kW for the TruDisk 16003 and 20 kW for the TruFlow 20000.

This article – drawing from the interesting lectures that Trumpf specialists gave during their Technology Day – aims to explain how Trumpf applies lasers in practice for welding and cutting sheet metal, for the deposition of material and for product marking.

Laser selection

Many laser types and many applications do not make it easy to choose a laser. Customer requirements that determine the type of laser include strength, material, quality and visual appearance of products. Process parameters are laser power, welding speed, focus diameter and process gas (N_2 or Ar to prevent oxidation).

For welding it is interesting to compare a TruDisk solid-state laser with a TruFlow gas laser concerning speed and penetration depth. Figure 3 shows that for large penetration and small welding speed a TruFlow has to be preferred, whereas a TruDisk wins for large welding speeds at small penetration. A real precision product is a 0.2 mm thick foil for fuel cells, welded with a TruFiber 400 laser at 25 m/min, see Figure 4.

For laser cutting it is important to convert as much laser light into heat as possible. The relative quantity depends on the light's wavelength and on the light's incident angle, which is small for small sheet thickness and large for larger sheet thickness, see Figure 5. This means that for small thickness the TruDisk laser is preferable concerning speed and quality, because of its larger absorption at small incident angles. On the other hand, a TruFlow laser can achieve a better quality and larger speed for larger sheet thickness because of its larger absorption at large incident angles.

These examples show that it is necessary to use different laser sources to fulfil the requirements of the various applications, and to consider the complete system from laser source to handling machine.

Remote laser systems

In TruLaser Cell machines the workpiece moves on guided slides. In a TruLaser Robot the optic system moves by using a robot arm. In both cases the laser light is guided to the cell

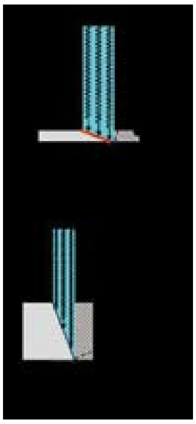


Figure 5. Cutting sheet metal with a small thickness gives a smaller incident angle than when cutting sheets with a larger thickness.

by a glass fibre cable. That cable transports the light from a modular housing that accommodates the beam generator (solid-state or gas laser), the beam guidance system, power supply, cooling and laser control. Some laser modules are provided with mirror systems to divide the laser energy across several machining cells. The distance between cells and laser module may amount to as much as 100 m.

A disadvantage of workpiece or robot movement systems is the unproductive time when travelling from one welding or cutting position to another. In remote laser systems this unproductive time has been nearly eliminated by the introduction of two light-weighted rotatable deflection mirrors. They allow the laser focus point to scan the workpiece, see Figure 6. A work distance of up to 500 mm avoids contamination of the mirrors. A real sophistication is the addition of a camera with image recognition having a resolution better than 30 μm.

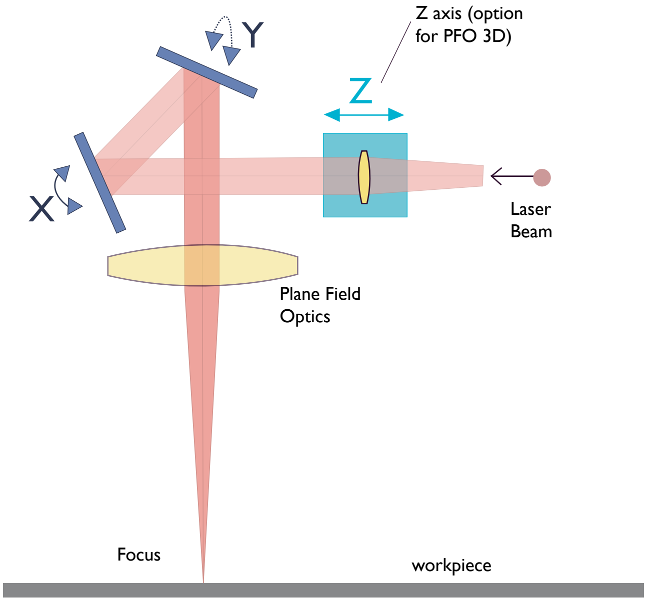


Figure 6. In a remote laser machining system two rotatable deflection mirrors allow the laser focus point to scan the workpiece.

Figure 7. A remote laser system with a PFO 3D (PFO: Programmable Focusing Optics) mounted on a robot for welding a car door. After rough positioning by the robot the PFO focuses the laser spot accurately.

Remote laser systems find more and more applications in the automotive industry, for highly efficient replacement of conventional resistance spot welding. In such systems the combination of a robot and a remote laser system, see Figure 7, provides a very flexible welding system that can yield a process time reduction of a factor three compared with conventional spot resistance welding.

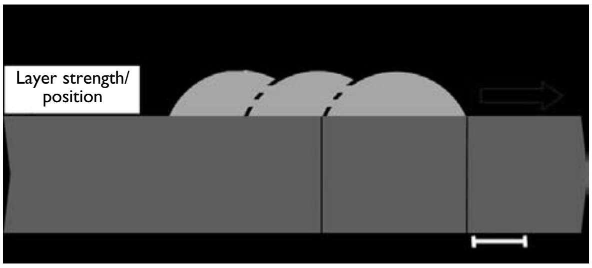
Highly dynamic 3D processing

TruLaser Cell series 7000 are large machines for 3D welding, cutting and metal deposition, both with solid-state or gas lasers. Off-line programming makes their use more comfortable, also thanks to the user-friendly TruTops Cell Basic software programme package. Maximum working ranges x,y,z are 4,000 x 2,000 x 750 mm^3. A gas-laser system is a bit more versatile, as compared to the solid-state laser, and it is able to cut thicker sheet metal.

Workpiece improvement

Laser deposition welding can be applied to improve surface characteristics of products or to repair them. A laser beam is used to create a melt pool wherein coating material and substrate mix and form a metallurgical bonding in the solid state. The coating material is deposited by spraying powder particles onto the substrate surface.

An abrasion-resistant layer can be created by laying parallel tracks onto a surface with a minimum width of 0.3 mm, a minimum thickness of 0.1 mm and a smallest



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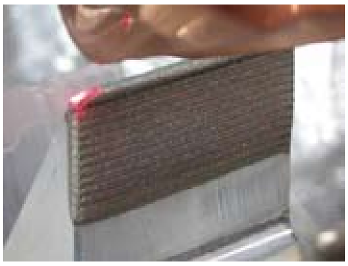
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Figure 8. Applications of laser deposition welding.
(a) The laying of surface-improving tracks.
(b) A laser coated saw tooth.

overlap of 0.15 mm, see Figure 8. Coating materials for improving resistance against corrosion are nickel alloys (NiCr, NiCrMo) and austenitic steels. Cobalt alloys (satellite) and carbides in a metal matrix (WC, TiC) improve resistance against wear.

The laser deposition process is highly valuable for repairing products like turbine blades and pistons (piston ring grooves). A quite new application is the filling of large gaps, for joining profiles for example.

Fine-contour processing

Fine 2D cutting with lasers competes with wire eroding and stamping, but laser cutting neither needs a starting hole nor expensive tools and is very flexible when producing pre-series. 3D cutting with lasers is often used for medical technology and for contouring pressed or forced sheet metal parts.

Good examples of products created by 3D laser precision machining (cutting, welding, marking and polishing) are medical transplants, see Figure 9. The only way to design and manufacture such sophisticated products is the application of laser technology.

TruLaser Cell series 3000 machines are applied for 2D and 3D precision cutting and welding, together with TruPulse, TruFiber, TruDiode or TruDisk solid-state lasers. Figure 10 shows how the frequency of pulses from a TruPulse laser can be controlled in curves: fixed pulse frequency or fixed pulse overlap.

Efficient production

Laser welding of sheet metal parts helps to expand functionality at constant costs, or to reduce costs at constant functionality. Laser welds can be narrow, have a minimal heat-affected zone, are highly reproducible with little distortion, require no filler material and are made without contacting the material.

Welding sheet metal products nearly always requires fixtures. Turnkey systems can be successfully expanded with a TruLaser Robot 5020 with one of the solid-state lasers. A robot positioning accuracy of ± 0.10 mm can be realized at a maximum workpiece weight of 30 kg within a workspace of 2,000 x 1,000 x 700 mm^3. For example, savings in time (90%) and cost price (80%) can be achieved by building up a switching frame from two laser cut sheets and laser welding them together, instead of milling it from solid material. Mind that the holes and slots are also realized by laser cutting.

Laser marking

A CNC-controlled laser in a TruMark machine provides a very flexible and accurate product marking system. Figure 11 shows how marking speed and quality depend on the degree of overlap of successive spots.

Figure 9. A 3D laser cut, welded, polished and marked medical transplant.

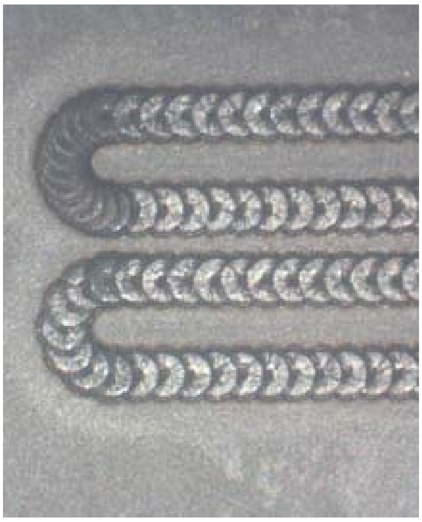

Figure 10. Frequency control of a TruPulse laser in curves. Upper track with fixed pulse frequency, lower track with fixed pulse overlap.

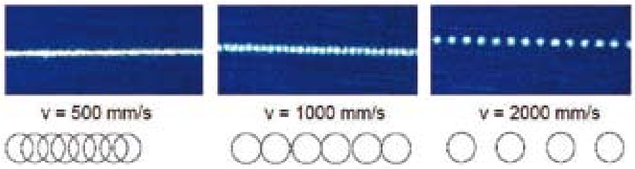

Figure 11. Marking speed and quality depend on the degree of overlap of successive spots.

Various physical phenomena can be applied when marking a product. Most popular is engraving, where surface material (besides metal also some duroplasts or epoxies) is ablated by melting and evaporation, see Figures 12 and 13. Contrast may be increased by oxides in the engraving. Another process is annealing: the material (steels, titanium) is locally heated and changes its structure. Layers of oxide determine contrast and colour. Ablating a coating is a third option, i.e. for marking anodized aluminium or coated surfaces, see Figure 14. The different colours of base material and coating determine the contrast.

Carbonization and foaming are the last processes to be mentioned. Bright thermoplastics can be marked by carbonization, where dark carbon contrasts against the base material. Dark thermoplastics can be marked by foaming, see Figure 15. In this process the marks are bright and contrast against a darker background. Often carbonization and foaming are combined for marking plastics.

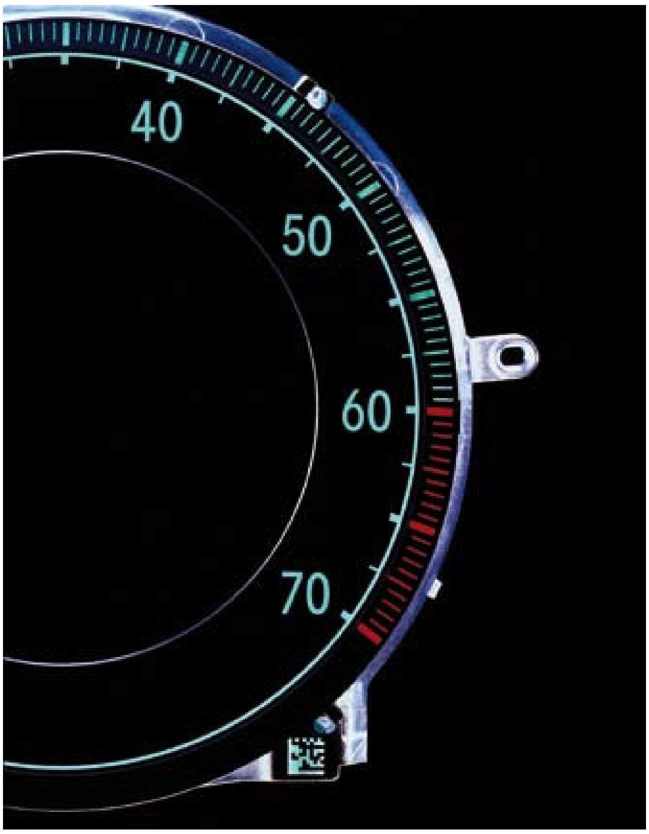

Figure 14. A torque meter as an ablation marking example.

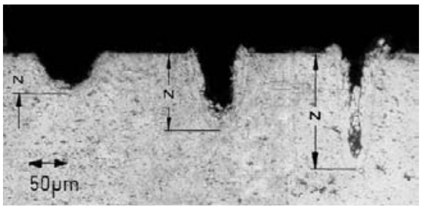

Figure 12. Cross-section of engraved steel.

Figure 13. An engraving example: a punch tool.

To conclude

The Trumpf Technology Day impressed in two ways. On one hand, laser welding, cutting and deposition machines were shown that combine flexibility with high precision. On the other hand, it was an eye-opener to see how a respected and long-established manufacturer of sheet metal machines has turned its mission into a new direction: innovative laser technology. Nevertheless, to ease the mind of sheet metal workers: the oldest Trumpf branch still flourishes.

Author's note

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Information

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Figure 15. An automotive reflector housing marked by foaming.