GERMAN WELDING SOCIETY

RESEARCH | TECHNOLOGY | EDUCATION

IN FOCUS

Laser Beam Welding and Allied Processes in the DVS

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The technical-scientific collaboration in the DVS

As a technical-scientific association the DVS is fully committed to joining technology. To that end DVS initiates and supports research activities for example, captures and documents the latest state-of-the-art technology and ensures that training and development programs offered by the DVS meet current requirements. This close network of research, technology and education is the core element of the technical-scientific collaboration work in the DVS. With this interdisciplinary approach, the association guarantees that its diverse work results are always based on current knowledge and are compatible with each other.

An impressive example of this successful work philosophy is the DVS technical code, consisting of more than 500 DVS technical bulletins and guidelines. The DVS technical code also sets high training standards and comparable qualifications in training and ongoing training, creating the basis for the highest level of uniform national and international acceptance and procedures.

The results of the DVS work are reflected in DVS events and are supported by DVS Media GmbH inter for example in specialist magazines, specialist books and other publications and made accessible to the professional world.

The booklet “In Focus” presents specific examples to illustrate the practical results of the scientific and technical community work in the DVS and invites you to participate in the various activities in the DVS. Each booklet is devoted to one topic and shows how the entire business location Germany benefits from the close linking in the DVS of research, technology and education to the respective industry.

Dipl.-Ing. Jens Jerzembeck
Head of Research and Technology

Source: ©aerogondo /Fotolia.com

Contents

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Title image: LZH Hannover (Hannover laser centre)

Laser Beam Welding and Allied Processes

In recent years, the technology involved in the development of laser beam sources has taken huge steps forward. The result is that beam sources with practically any level of performance and beam quality have become available for industrial use. As such, for the non-specialist, the diverse range of beam sources with different wave lengths, levels of performance and price categories is difficult to overlook. These sources have an enormous usage potential in the most diverse sectors of industry.

The reason for this development is that industrial disk laser and fibre laser technology, as well as short pulse laser technology, have been introduced, which constitute a substantial addition to the laser technologies available and also lead to the substitution of established laser technologies. The wide range of laser beam sources available means that lasers are no longer an exotic tool, rather they are used as standard in material processing.

At the same time, sources have become increasingly specialised in recent years. A few years ago, it was usual to find laser beam sources that were employed in different application processes. However, requirements for process quality and efficiency are becoming increasingly more demanding, meaning more and more laser beam sources with specific and highly-specialised properties are being developed.

The dynamic development of new laser beam sources has not yet come to an end. New, optical fibre amplifiers which enable new oscillator-amplifier systems are involved in the development process. The availability of stable short pulse laser systems with higher pulse energies, as well as a drop in their prices, means this kind of system is becoming increasingly more attractive for industrial usage. Fibre-guided diode lasers with constantly increasing levels of performance and a high degree of effectiveness whilst simultaneously having smaller spot diameters are penetrating the market.

However, laser application technology, especially the knowledge of how to optimally apply each different laser beam source, has only partially kept pace with the tremendous speed of the development process. In many cases, the method of getting laser beams and work pieces to interact in an optimal way remains insufficient. In particular, complex micro processing applications, as well as micro and short-time metallurgy processes, remain in basic research stages and the processes involved in their interaction are only just beginning to be understood.

The industry's quality requirements for application processes, regardless of whether it is a matter of drilling, cutting or ablating, have steadily become more stringent. As there are more and more custom-made materials being developed, it has become more challenging to process them and the desired limitations for their applications have been raised in relation to the maximum processing possibility achievable. Furthermore, there is an increasing need for new process developments in some fast-growing sectors of the industry. To date, these have been using laser technologies in a limited fashion, or not used it at all, such as the photovoltaic solar market or nano-technology applications. At the same time, there are sectors of the industry faced with laser application processes that can hardly rely on any experience with traditional welding and cutting processes and besides the introduction of lasers in production processes, these sectors are also confronted with legal, normative, and also unknown to date, specialist issues and new requirements for safety in the workplace.

In order to maintain an competitive edge in German industry by international comparison, it is necessary to make research findings available to small and medium-sized businesses (SMEs), to map out the transfer of knowledge and recommendations for action in a technical codes and to provide up-to-date training, both basic and advanced, for members of staff.

The extensive activities covered by the DVS which come under the topic "Laser Beam Welding and Allied Processes" are summarised in this present booklet with focus on research, technology and education.

Prof. Dr. Ing. Ronald Holtz (graduate engineer),
Class 4 Laser Professionals AG, Burgdorf, Switzerland
Chairman of the Expert Committee for "Blasting Procedures" (FA 6) in the Research Association on Welding and Allied Processes e. V. of DVS

Dipl.-Phys. (physics graduate) Jan Hoffmann,
Schweißtechnische Lehr- und Versuchsanstalt Mecklenburg-Vorpommern GmbH, Rostock
Chairman of the Working Group "Laser Beam Welding and Allied Processes" (AG V 9.2) in the DVS

Dipl.-Ing. (FH) Ilka Zajons (graduate engineer from a German university of applied sciences),
LZH Laser Akademie GmbH, Hannover
Chairwoman of the Expert Group "Training for Beam Welding" (FG 4.7) in the DVS

Source: Institute for Welding and Joining Technology (ISF) at the RWTH Aachen

Potential weld cross-sections and weldable materials when being used in a laser beam welding process and placed under a vacuum.

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The DVS technical code

The DVS technical code for "Laser Beam Welding" offers extensive, application-oriented information on procedures, quality assurance, testing, design, training, materials, etc. and also defines the special requirements that are required of skilled workers in the area of Resistance Welding.

The interdisciplinary cooperation between the Research Association on Welding and Allied Processes e. V. of DVS, the Technical Committee (AfT) and the Education Committee (AfB), has resulted in a worldwide established and recognised set of DVS technical code, which represents a self-contained system.

DVS members have free access under: www.dvs-regelwerk.de

Laser beam usage examples

Nowadays, there is a variety of different laser beam sources and procedures which are becoming increasingly specialised for specific applications. Whether it's a matter of gas lasers, such as fast-flow or diffusion-cooled CO_2 lasers, or solid-state lasers, such as traditional Nd:YAG, disk lasers, fibre lasers or diode lasers, there's more to the world of laser radiation than what can be explained in this document. As such, by detailing a few examples, this booklet can provide an overview of some typical applications. You can receive more information by contacting the Expert Groups named in this booklet or by getting in touch with your contact partner.

The principal usage areas for laser beam technology are:

- Sheet metal treatment
- Car and vehicle construction
- Air and spacecraft construction
- Ship construction
- Medicine
- Steel industry
- Machine construction
- Consumer goods industry
- Electronics industry
- Semiconductor industry
- Jewellery industry

Application and construction of the laser beam

There are many factors involved in how a laser beam welding plant is set up: Design of the work piece, welded joint geometry and type of joint, amount of components, extent to which the manufacturing process is automated, procedures and materials – these all play an important role (figure 1).

Figure 1: Laser beam welding of a gearbox component.

Laser cladding

Material is added during the process of laser cladding. Generating procedures are involved and you can differentiate between two application scenarios:

- Material can be applied on a basic form, for example to repair or finish a tool
- A whole component can be built, for example to produce a prototype or functional component

Manual cladding is one of the oldest cladding procedures and in principle, it is similar to fusion welding, but with additional material. The difference: The material added does not act as a filler for a wide joining gap. Rather, a certain form is applied to the surface of the work piece. The additional material reaches the processing location as thin filament. The laser beam fuses the filament. The molten material forms a tight connection to the basis material, which is also molten, and then they both become solid once more. A small protrusion is left behind. Point by point, line by line and layer by layer, the welder applies the desired form. Air is kept out of the process by using an argon gas flow.

Overall, cladding is used when material is lacking due to wear and tear, damage or due to a design change.

Laser beam welding under a vacuum

Laser beam welding under a vacuum combines the advantages of laser beam welding with those of electron beam welding. By using a vacuum during the laser beam welding process, due to diverse effects which are still not completely understood in their entirety and which are the focus of intensive work performed by research organisations, it is possible to achieve welding joints qualitatively similar to those created during an electron beam welding process. However, the requirements for the vacuum needed are not as high as those for its sister procedure electron beam welding. Furthermore, components do not have to be demagnetised. Almost all common metal materials can be welded to the highest quality using this process, either well or very well. It is possible to process construction steel, stainless steel, nickel-base alloys, titanium, niobium and aluminium alloys and copper.

The Working Group V 9.2 is currently producing a technical bulletin for laser beam welding under a vacuum. The Expert Committee (FA) 6 "Blasting Procedures" are currently working and have worked on several projects on this topic.

Remote welding

Lasers are not beamed with a processing optic close to the work piece, but rather they are beamed from a great distance using a scanner optic (figure 2). A scanner optic contains one or two adjustable mirrors which position the laser beam in an instant. This means more performance can be gained from the beam source, as the positioning time between two welded joints during which the laser beam has to be turned off is virtually reduced to zero. The advantage of having a long working distance of one to two metres is the fact that the working space becomes larger. In remote welding stations, it is possible to weld entire doors and bodyworks.

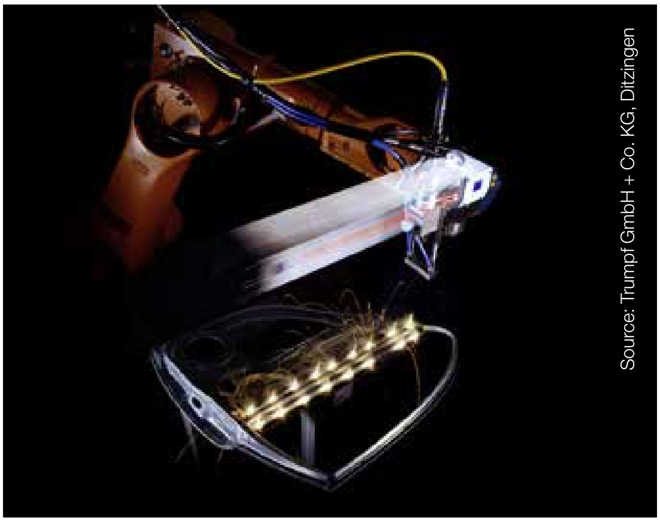


Figure 2: Scanner welding of a car door with a programmable focusing optic.

Laser drilling

For laser drilling, it is mainly pulsed solid-state lasers that are used as they can generate high power densities and short pulses. That is the case for solid-state lasers with increased pulse rates and a Q-switch in particular. For micro processing, solid-state lasers with short and ultra-short pulses in the pico and femtosecond range are used, as well as excimer lasers. CO_2 lasers can also be used to drill. This is mainly done at laser beam cutting plants. At these plants, starting holes for laser beam cutting are drilled this way. The following materials can be drilled with a laser: metals and sintered metals, semiconductors such as silicon and synthetic materials and carbon (figures 3 and 4). Precious stones, such as rubies and diamonds, are also drilled using a laser. Laser beams can also make holes in paper. One such usage example is cigarette paper which is pierced with 500,000 holes per second.

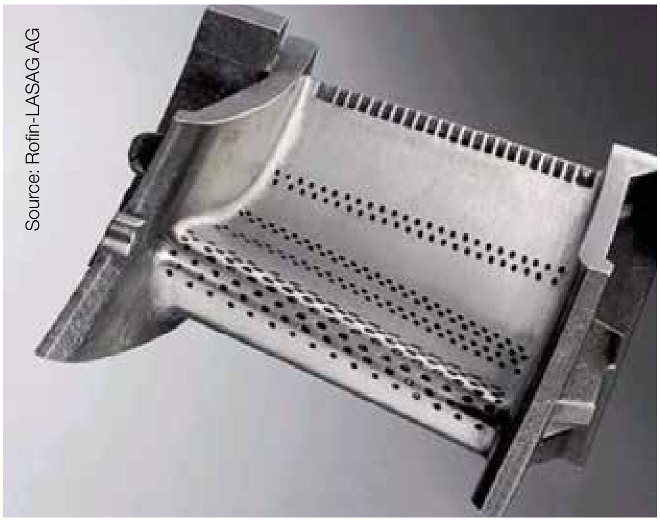


Figure 3: Laser drilling in a guide vane for an aircraft turbine.

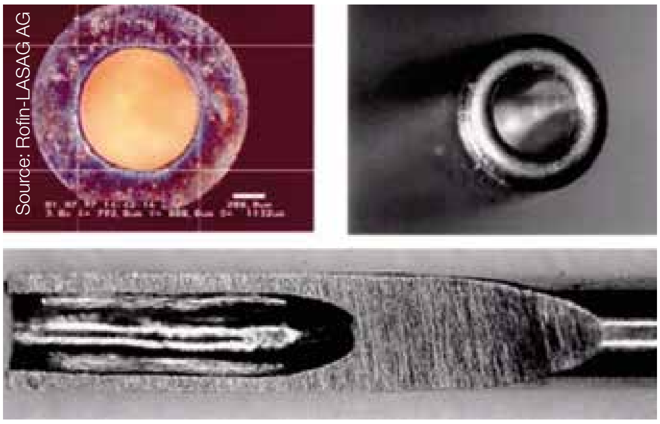


Figure 4: Surgical needles drilled with a single shot, hole diameter 50 to 600 µm, aspect ratio 1:4 to 1:12.

Laser drilling is a procedure which is mainly used for series components being produced in large quantities. As such, most machines and equipment are specialised to one usage or one work process.

More examples of usage:

- Drilling flow-through filters and sieves
- Drilling micro holes in flexible ceramic rollers
- High-speed drilling of turbine guide vanes
- Drilling silicone
- Drilling diamonds in order to remove imperfections

Laser beam material processing, labelling and inscribing
The possibility of processing a multitude of materials, along with the multifaceted advantages of laser beam treatment in comparison to conventional methods, made the laser the preferred tool in the domain of material treatment. Lasers can be used for practically all label applications and requirements for metals, ceramics, plastics and other materials.

Work pieces are processed in small and the smallest dimensions when structuring and ablating. Structuring means creating regularly arranged geometries in surfaces. These geometries purposefully change the technical properties of these surfaces, for example its reflectivity or frictional properties. The individual element of such a structure is often just a few micrometres in size. Ablating is different to structuring in the following respect: Indentations which are generated by individual pulses overlap to lines and lines to surfaces. The laser beam ablates the material layer by layer until the indentation is as deep as required and has the shape desired.

During the manufacturing process, logos, codes, symbols and information can be inscribed on a component in seconds, or even in split seconds. Laser marking makes it possible to achieve a high quality finish in a short space of time with flexible forms and contents. The properties of both the laser beam and the material determine whether the component will be engraved or whether a colour change technique will be used.

Real-life applications:

- Marking barcodes on tools
- Marking medical instruments
- Making contrast marks on metal pendants
- Edge isolation for solar panels
- Removing thin layers on metals and synthetic materials
- Making wafer marks
- Marking keyboards and earmarks
- Ceramic filter production
- Multicolour marking on titanium
- Marking diodes
- Laser engraving jewellery

Laser beam cutting
Laser beam cutting is a large field of application within laser beam technology (figures 5 and 6). It is possible to use this technology to separate the most diverse materials (metals, synthetic materials, glass, ceramics, semiconductors, textiles, wood and paper etc.). For the cutting process, the laser beam is brought into focus. It's entire capacity is then pooled into one point. The metal will immediately begin to melt where the focussed beam touches the work piece. In some instances, it even burns or vaporises. Oxygen is used as the cutting gas when flame cutting construction steels. Nitrogen or argon is used as the cutting gas when other metals or ceramics are involved in a fusion cutting process. Argon and nitrogen are inert gases. This means that they do not react with the molten metal in the cutting gap, rather, they just blow it downwards and out.

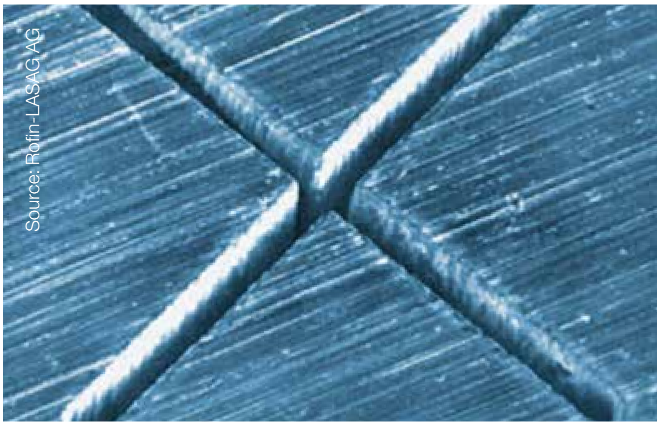


Figure 5: Precision Cutting in spinnerets (40 µm).

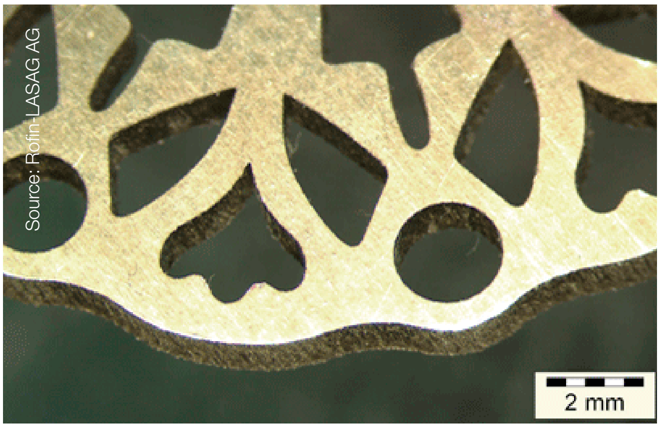


Figure 6: Fine cutting in silver.

A selection of materials that it is possible to cut with a laser:

- Non-alloy and low-alloy steels
- High alloy steels
- Precious and non-ferrous metals
- Aluminium alloys
- Titanium alloys
- Wolfram and molybdenum
- Ceramics, such as aluminium oxide and silicon
- Fibre composites
- Carbides and polycrystalline diamond
- Nickel-titanium alloy, inconel, hastelloy
- Synthetic materials, as well as carbon fibre reinforced plastics (CRP)
- Coated, galvanised steels
- Wood

Automated welding with lasers.

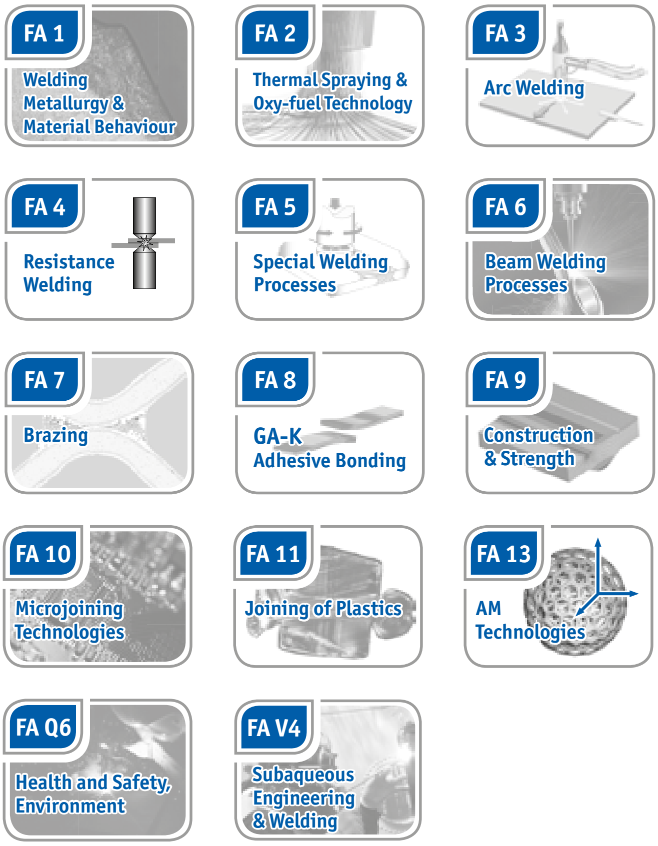
Research in the DVS

DVS FORSCHUNG

The Research Association on Welding and Allied Processes e. V. of DVS

The research into joining technology in the DVS is a successful partnership between industry, research and the state. The Research Association on Welding and Allied Processes e. V. of DVS represents as a modern, professional and service-oriented institution for joining technology. As a research-promoting institution in the form of a non-profit association, it offers materials, process and industry-specific research focussing on joining, cutting and coating through its specialist committees in the professional world and the interested public. The specialist committees cover the entire value added and process chain of joining technology.

More than 500 experts from industry and science are successfully involved in the research association's network. More than 100 ongoing research projects are guided and supported annually. The research group is interdisciplinary oriented and open to different cross-industry research collaborations.



The Expert Committees of the Research Association of DVS.

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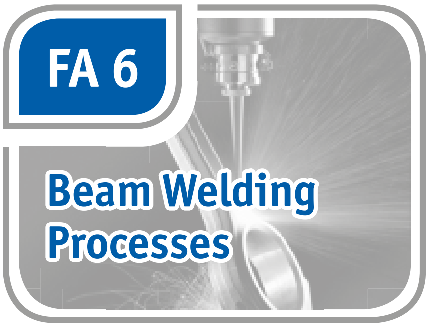
Further and up-to-date information on the work of the Research Association of DVS is available at:
www.dvs-forschung.de

The Expert Committee 6 “Beam Welding Processes”



Principles/tasks of the Expert Committee

The task of the Expert Committee is to assess new and enhanced beam welding processes whilst taking account of application based aspects, as well as to accelerate the transfer of process innovations to small and medium-sized companies (SMEs) through supporting research. They try and make sure there is a balance between laser and electron beam technology. In this respect, the focus is not just on developing processes and procedures, but also their simulation.

Experience gained over the past years shows that making improvements in operation, implementing aids for simplifying and optimising procedures, as well as optimising system components for each specific application, such as improved beam guidance and beam decoupling systems or processing optics, very rapidly leads to successful results on a regular basis, and these results can be implemented in SMEs.

Within the scope of various projects, signalling useful process and application limits represents another important form of support for SMEs. Besides process technology, it should be considered how materials will react when they are processed in cool conditions with laser beam technology and high cooling speeds. It should also be taken into account how mechanical-technological material properties are affected by particularities of so-called short-time metallurgy.

Even in early development stages, any new developments in laser and electron beam technology, as well as in materials, should be fostered by performing fundamental and technological investigations.

Research projects are undertaken by Expert Committee 6 in close coordination with Working Groups V 9.1 “Electron Beam Welding” and V 9.2 “Laser Beam Welding and Allied Processes” within the Technical Committee (AfT) at the DVS.

Fields of research and focus topics

- In the future, the options for joining challenging types of materials will be increasingly investigated, as there is a high potential for demand in practically every sector of industry and this means innovative ideas for production will be expected.
- In connection with the dynamic advancement of laser sources, beam guidance systems and tools for process recognition, requirements will be set in order to improve the options for managing process involving well-known materials and in order to develop new materials and material compounds. Focus areas are the parameters of quality, cost and competitiveness.
- More research should be undertaken into combinations or couplings of beam processes with each other, or with conventional technologies and, in doing so it will expand the areas in which laser technology is employed. The processes involved in beam technology are regarded as main processes, which are then overlapped with supporting tools, such as electric arcs.
- Simulating processes and material behaviour is yet another important field.
- It is also extremely important to improve the way processes are monitored and managed, in turn improving the ability to guarantee that production process can be reproduced and that laser and electron beam processes are safe, as process monitoring and management are often some of the most important criteria for using beam technology within the industry.
- Against this backdrop, it is becoming increasingly important to rework and link existing knowledge. Findings from national and international research projects will be analysed and investigated for complex interrelations.
- A more broad objective is to merge material and process data using databases, simulation tools and neuronal networks in order to form the basis for intelligent systems for process control.

How application-oriented research works

Research balance – transfer of results and implementation in the project:

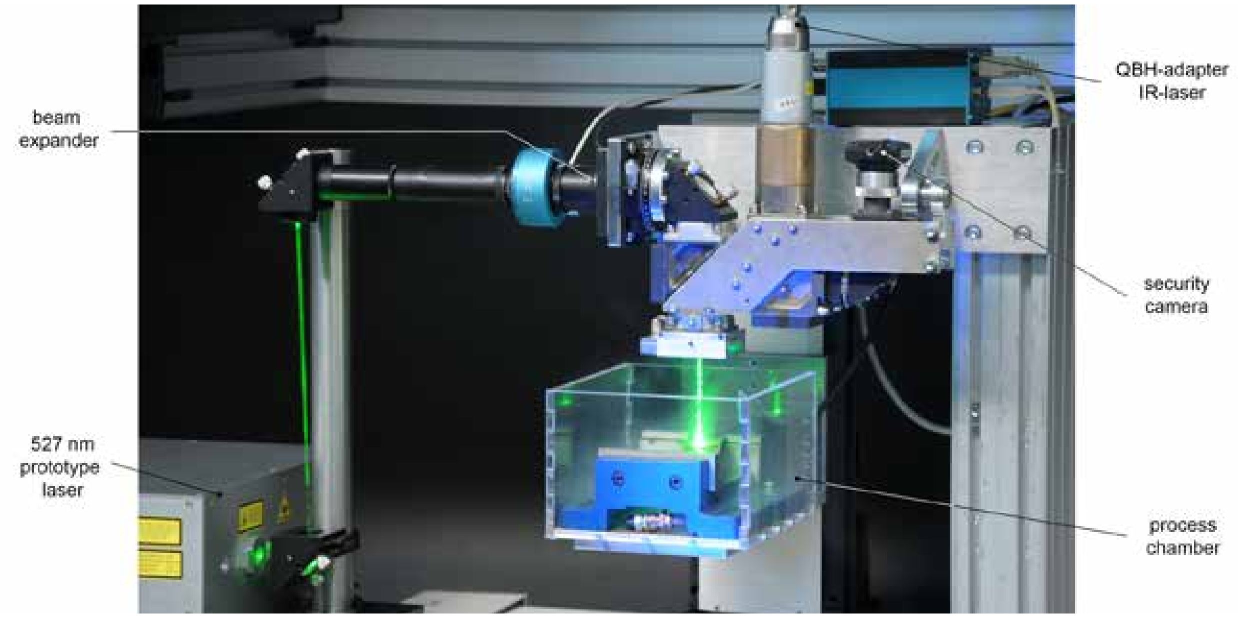
Surface conditioning of copper materials for stabilising continuous laser micro welding processes
(IGF-no. 18.335 N / DVS-no. 06.094)
Duration: 1st September 2014 – 31st August 2016
Dr. rer. nat. D. Kracht, Laser Zentrum Hannover (LZH) e. V. (Hannover laser centre)

The research project addressed methods for enhancing reliable processes to join copper and copper materials for competitive industrial use. In this respect, investigations were performed into how, and to what extent, the advantages of surface conditioning using a frequency-converted, cost-effective, pulsed nanosecond laser module (conditioning laser) can be used in welding processes (figure 1) involving continuous infra-red laser beams.

The fundamental investigations into the effects of conditioning involved the experimental characterisation of the used materials copper Cu-OFE and copper alloy CuSn6 with sheet thicknesses of 0.15 mm to 1 mm with respect to the variability of their surfaces. For the conditioning process, it was demonstrated that both the oxygen content, as well as the roughness and extent to which surfaces expanded, increase as the power of the pulse and the degree of overlap also increases. In addition, it was determined that increased amounts of infra-red (IR) laser beam radiation were absorbed. It was also demonstrated that conditioning copper surfaces means the start of the welded joint can be repeatedly defined and energy can be saved by low amounts of reflection being lost (figure 2). The extent to which this effect has an influence depends on the fluence of the laser beam, as well as the thickness of the material and the material properties, to a large degree.

Important findings from the research project are:

- The beginning of the welded joint for copper materials can be repeatedly defined
- Improved robustness with respect to variable alloys and batches
- Higher process speeds than during pulsed seam welding processes
- Energy is saved due to lower reflection losses
- Reliable seam welding for copper materials with sheet thicknesses of < 0.5 mm



Source: Laser Zentrum Hannover (LZH) e. V.

Figure 1: Image of a trial set-up – wave-length combined laser head.

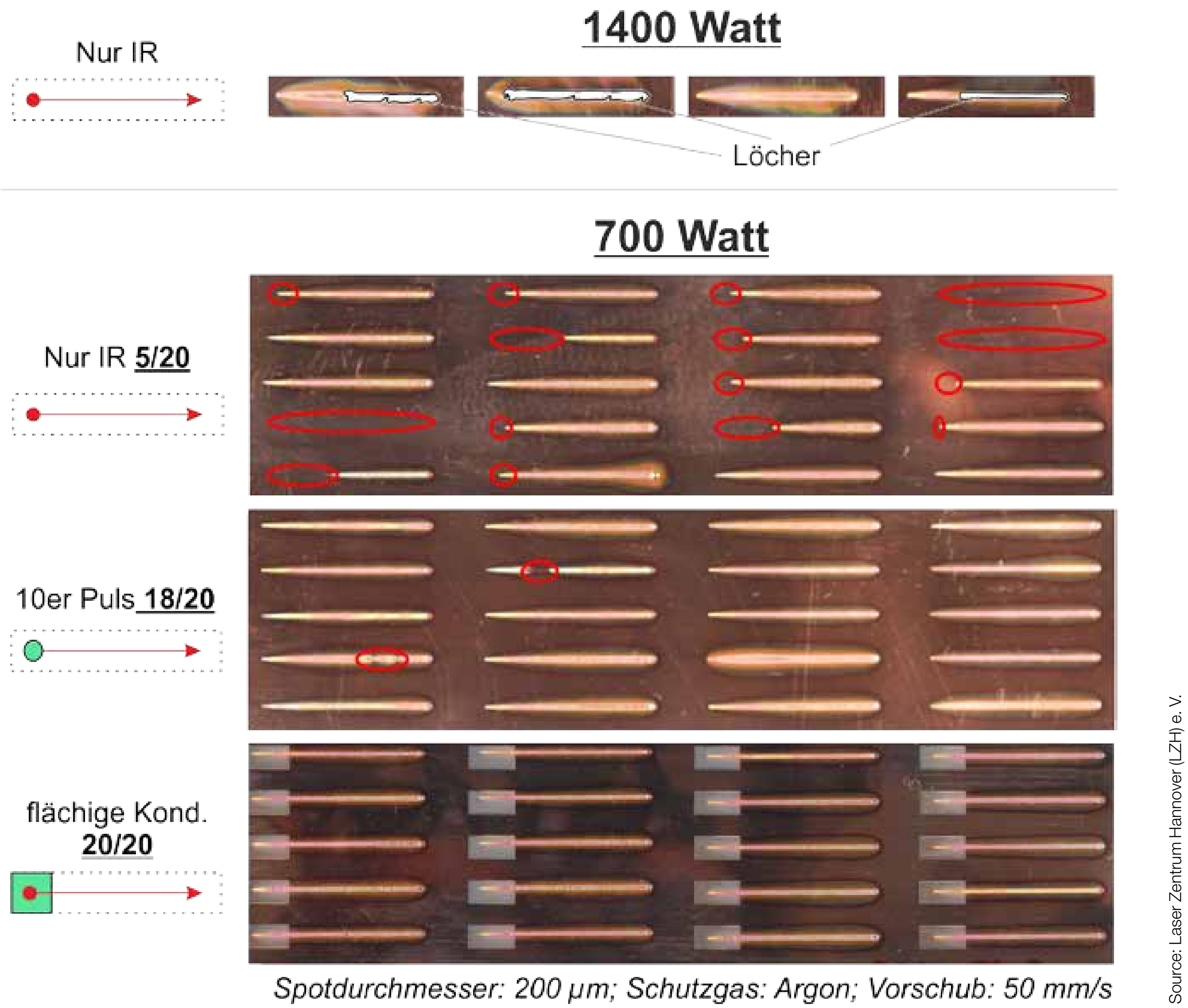


Figure 2: Results from the research into reliable seam welding of the material Cu-OFE with a sheet thickness of 0.15 mm. Conditioning copper surfaces means the beginning of the seam can be repeatedly defined and it also significantly improves process stability. If surfaces are not conditioned, only 25% of welds could be manufactured with a high level of quality, however, just by using a spot conditioning process at the beginning of the welded seam, it was possible to achieve a figure of 90%, and by conditioning the surface at the beginning of the welded seam, it was possible to achieve a figure of 100%.

Company opinions

Dipl.-Ing. Peter Schlüter (graduate engineer), LMB Automation GmbH, Iserlohn:
"As we have good contacts in the domain of electronics, there's always demand to weld thin copper material. As the threshold for coupling when welding copper is very high, it has always been necessary to use high levels of peak pulse powers. Time and time again, this meant that the thin material got destroyed. However, by preconditioning using green laser beams, it means that we can use significantly less power. Now, we only have to use around one quarter of the peak pulse power. As such, we can significantly improve quality and safety during production. What's more, this also allows us to save energy."

Dipl.-Ing. SFI/IWE Peter Stahl (graduate engineer), Wieland-Werke AG, Ulm:
"The research undertaken within the scope of the "OKuDaLas" project has not only made essential contributions to stabilising laser welding processes for copper, but it has also, all things considered, significantly increased our understanding of the processes involved in laser welding thin copper sheets. The knowledge gained within the scope of the project, and the welding strategies for generating flawless welded joints that were able to be deduced therefrom, are ideal for being implemented in industrial series production processes. The findings from the project provide the end user with a both simple and effective method for avoiding welding defects on thin copper sheets."

The Expert Committee 13 “AM Technologies”

Principles/tasks of the Expert Committee

Expert Committee 13 is addressing the research fields of additive production with metal and non-metal materials, taking the entire process chain into consideration, including pre and post treatment processes. In doing so, their focus lies on technological developments, increasing the acceptance of using this technology within SMEs and the creation of new areas of application. This is Germany's most influential Expert Committee, made up of manufacturers and users of additive production processes, as well as those in charge of research organisations, so they can all work together to shape the research environment. Expert Committee 13 is involved in the field of additive production and works in close cooperation with Expert Committee 105 of the VDI – Association of German Engineers – in order to cover all activities across the fields of research, technology and education. In doing so, the VDI Committees are developing a technical codes and what’s more, standardisation is being advanced within the standards committee for material technology (NWT) “Additive Manufacturing”. Research is being undertaken in FA 13 of the Research Association on Welding and Allied Processes e. V. of DVS, suitable training concepts are being devised in Expert Group 4.13 “Education in Additive Manufacturing” within the committee for education as part of the DVS and these are offered by DVS educational institutes.

Fields of research and focus topics

Selective laser beam melting:

- Size of the components (time advantage compared to cast components)
- Cost reduction
- Process efficiency (particularly with nickel-base alloys
- Risk of cracking (parameter window for cracks not to occur)

Polymer sintering:

- Process capabilities, process safety, reproducibility (for repeated construction jobs)
- Improve surface quality
- Make series processes economical for large unit quantities (> 10,000 units)

Powder:

- Interlink/coordinate equipment and material manufacturers
- Fire and explosion protection
- Toxicity testing
- Pollution of the environment in the long term

Series production:

- Manufacturing problems have gained a new importance with the introduction and implementation of series production. Problems have become noticeable in recent years.
- Evaluate major influencing factors. Scientific demands are considered crucial here.
- Evaluate materials globally. Ceramic materials should always be included in evaluations.
- Consider product liability, profitability and property guarantees.

How application-oriented research works

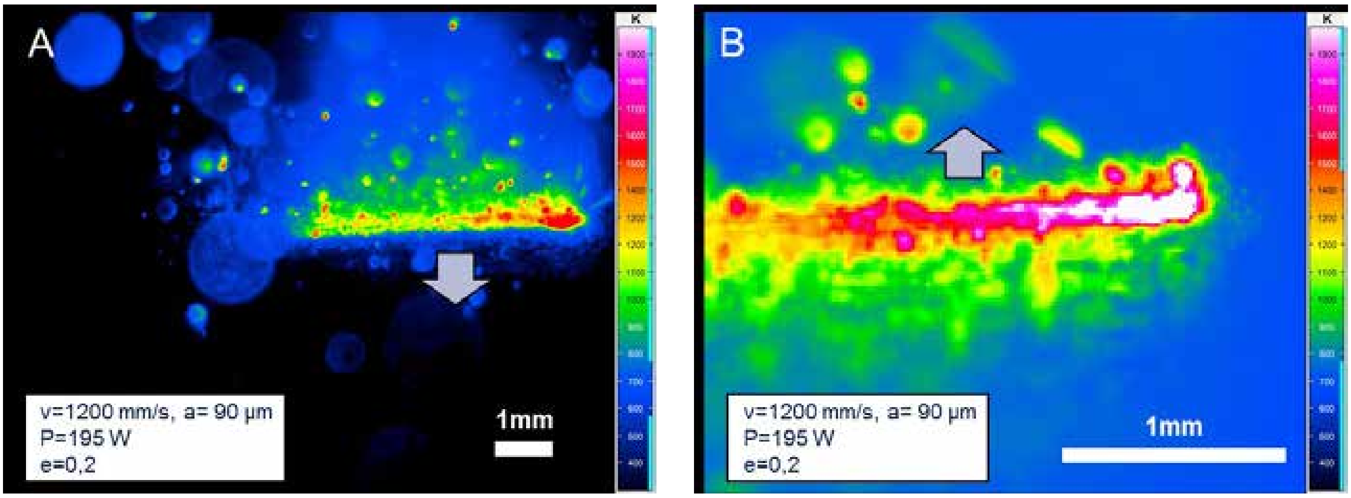
Research balance – transfer of results and implementation in the project::

Quality assurance during the laser beam melting of metal components by way of thermographic monitoring of layers
(IGF-no. 17.911 N / DVS-no. 13.007)
Duration: 1st January 2014 – 30th June 2016
Prof. Dr.-Ing. M. F. Zäh (graduate engineer), Institute for Machine Tools and Industrial Management, TU Munich

One key challenge that arises in additive manufacturing is the fact that the mechanical properties of manufactured components are, in general, subject to a multitude of influential variables. This are sometimes systematic and sometimes coincidental in nature. Subsequently, abnormalities occur in the form of bonding defects, cavities and pores. These abnormalities mean components have varying levels of quality. In current systems, these problems are predominantly met with monitoring a multitude of global process parameters (output performance of laser sources, residual oxygen content in the process chamber, the coater's engine current, construction board temperature).

Using this information, assertions can be made about the construction process, these admittedly being resolved in good time, however mostly just averaged in the local area. Generally speaking, the user is only informed that a certain threshold value has been exceeded or that figures have fallen short of this value. For example, if inadmissible variations were recorded and the levels of quality required for the component cannot be guaranteed without further measures being taken.

In addition to existing approaches, the strategy of monitoring the process layer by layer was used during the research project.



Source: Institute for Machine Tools and Industrial Management, TU Munich

Figure 1: Sample images of a high speed/thermographic system in different measuring ranges, A (left) and B (right); the colour spectrum corresponds to temperatures between 300 and 2,000 kelvin.

As a basis, it was established that individual layers would be observed as a whole during solidification. For this purpose layer information was compared with measurement data from the layer currently solidified, as well as with information from previous layers, and then correlated with the resulting component properties. Using a database as a basis, it is then possible to make assertions regarding the component quality achieved by assessing individual layers during the production process. Thermographic procedures come into play here. These procedures make it possible to characterise thermal management, for example the heat distribution of a layer (figure 1). These factors have a huge impact on the resulting microstructure and make it possible to recognise interactions between neighbouring parts and abnormalities occurring during the process (figure 2).

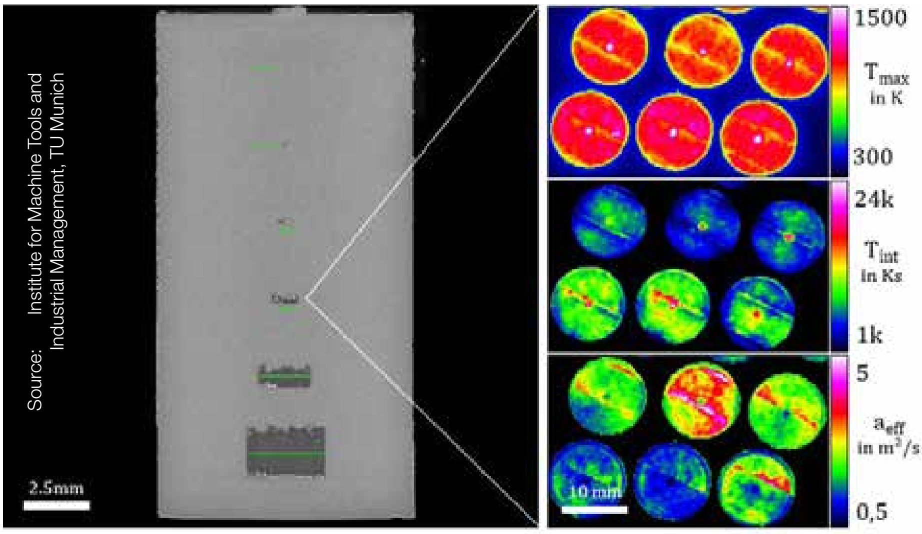


Figure 2: Attempt to detect local defects; using downstream methods of analysis by means of computer tomography (left), it is possible to compare the defects existing in reality, and those detected. The image on the right-hand side shows three indications: maximum temperature (T_{max}), cooling curve integral over 550°C (T_{int}) and effective thermal conductivity (a_{eff}).

Company opinions

Rainer Rauschenbach, Thermografiesysteme, InfraTec GmbH, Dresden:

"It has been confirmed that professional thermographic technology used in laser sintering processes can be a huge help in detecting defects in formation stage. As a result of this project, InfraTec GmbH was able to gain important technological knowledge and as such we are able to provide users in the field of this promising manufacturing technology with suitable and innovative thermographic technology."

Dr. Joachim Bamberg, Non-destructive testing methods, MTU Aero Engines AG, Munich:

"The objective of MTU is to implement a testing procedure during the manufacturing process in addition to a conventional component test. In this way, it should be possible to detect even the smallest defects. The thermographic testing technology developed within the scope of the project guarantees exactly that. During extensive testing, it was demonstrated that critical types of defects, such as non-consolidated powder or joining defects, could be detected online and with a high local resolution. By using progressive signal processing, it was possible to establish a correlation between thermographic displays and actual sizes of defects. As such, the project findings provide a solid base for efficient quality assurance during additive manufacturing processes by using laser powder-bed melting. The online thermal imaging technology developed will become an essential part of additive manufacturing facilities in the domain of aerospace in the future."

Bernd Klötzer, bkl-Lasertechnik, Rödental:

"In the future, bkl-Lasertechnik will look into this topic even further for the purpose of their own developments. It is very important to monitor manufacturing processes in real time and it is absolutely essential to do so when the process lasts for several days. In the future, such aids will become indispensable, as some manufacturing processes cannot be monitored visually. These monitoring processes are also important to ensure quality."

Technology in the DVS

The Technical Committee (AfT)

Considering the currently more than 250 established joining processes, the technical-scientific collaboration work in the DVS can and must be systematic. This is guaranteed by the Technical Committee, which has more than 200 work councils. The AfT brings together more than 2,300 experts from business, academia, organisations and corporations who work together to capture and continually advance the state of the art. The fact that the DVS with this bundled expertise is also acknowledged on the international stage as a confident and competent partner in all assembly engineering issues is clear.

DVS is a major contributor to the international joining technology network through its involvement in the International Institute of Welding (IIW) and the EWF – European Federation for Welding, Joining and Cutting. The work results originating from the AfT are published as DVS technical bulletins and guidelines.

At the national level, the AfT works very closely with the Normenausschuss Schweißen und verwandte Verfahren (NAS) des DIN e. V., in particular in the numerous community committees. The constructive cooperation with NAS enables optimum coordination of the DVS technical code with the normative requirements. The DVS technical code provides valuable application notes for practical application.

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DVS members benefit from free access to the DVS technical code under www.dvs-regelwerk.de.
All the DVS technical bulletins and guidelines are available electronically.

Laser beam cutting under water.

Source: Laser Zentrum Hannover (LZH) e. V.

Structure of the Technical Committee (AfT)

AfT-Board → consultation → **AfT-Conference**

V: Prof. Dr.-Ing. U. Reisgen
GF: Dipl.-Ing. J. Jerzembeck

Main Division W
Basic materials, filler materials and auxiliary materials

- **AG W 1** Technical Gases
- **AG W 2 **** Welding of Cast Materials
- **AG W 3 **** Joining of Metal, Ceramic and Glass
- **AG W 4 *** Joining of Plastics
- **AG W 5 *** Welding Consumables
- **AG W 6 *** Welding of Aluminium and other Light Metals

Main Division V
Processes and equipment

- **AG V 1 *** Gas Welding
- **AG V 2 *** Arc Welding
- **AG V 3 *** Resistance Welding
- **AG V 4** Underwater Engineering
- **AG V 5 *** (Thermal) Cutting
- **AG V 6.1 *** Brazing
- **AG V 6.2 *** Soldering
- **AG V 7 *** Thermal Spraying and Thermal Sprayed Layers
- **AG V 8** Adhesive Bonding
- **AG V 9.1 *** Electron Beam Welding
- **AG V 9.2 *** Laser Beam Welding and Allied Processes
- **AG V 10 **** Mechanical Joining
- **AG V 11** Friction Welding

Main Division Q
Quality management, design, calculation, health and safety

- **AG Q 1** Design and Calculation
- **AG Q 2*** Quality Assurance of Welding
- **AG Q 4*** Testing of Welds
- **AG Q 5*** Qualification Requirements for Welding and Allied Processes Personnel
- **AG Q 6** Health and Safety and Enviromental Protection

Main Division I
Information

- **AG I 1** Information and Communication Technology
- **AG I 2*** Application Oriented Welding Simulation
- **AG I 3** History of Welding Technology
- **AG I 4 *** Illustration, Terms and Definitions

Main Division A
Applications

- **AG A 1** Welding in Turbo Machine Building
- **AG A 2** Joining in Electronics and Precision Engineering
- **AG A 3** Welding in Plant-Tank and Pipeline Construction
- **AG A 5** Welding in Construction Settings
- **AG A 6** Welding in Shipbuild and Marine Engineering
- **AG A 7** Welding in Railway Vehicle Manufacturing
- **AG A 8** Joining in Vehicle Manufacturing
- **AG A 9 *** Welding in Aviation and Aerospace Engineering

Specialist Societies

- Specialist Society for “Brazing/Soldering”
- Specialist Society SEMFIRA/EMF ***

AG: Working Group, * Joint Working Group with NAS (Standardisation Committee Welding and Allied Processes of DIN e. V.),
** Joint Working Group with other Societies, ***SEMFIRA = Safety in ElectroMagnetic Fields, EMF = ElectroMagnetic Fields.

Working Group V 9.2 "Laser Beam Welding and Allied Processes"

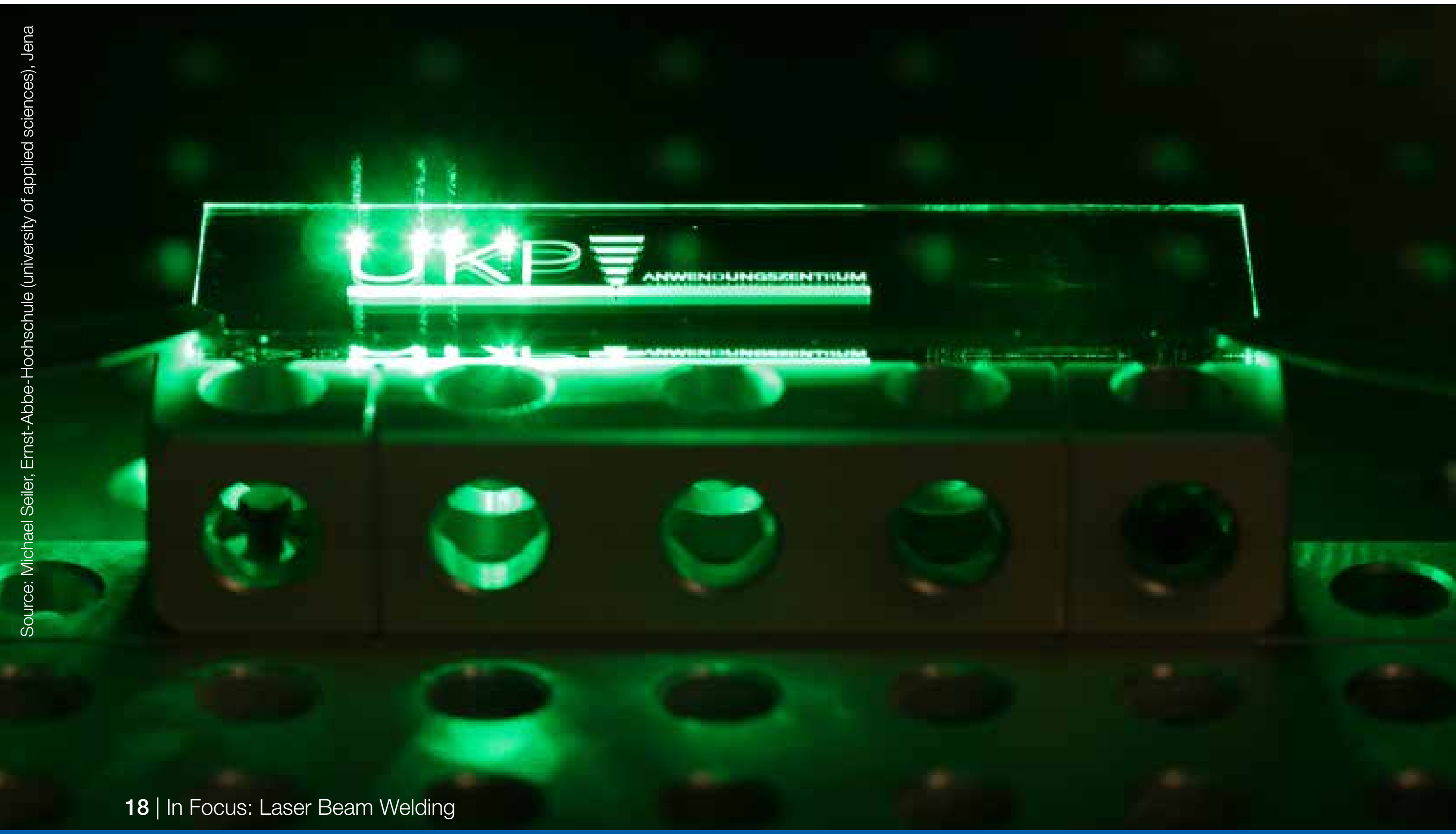
Joint committee AG V 9.2/NA 092-00-21 AA "Laser Beam Welding and Allied Processes" have dedicated themselves to helping users of laser beam technology, to giving them recommendations and operating advice as well as guideline values for using the laser and for manufacturing processes, as well as to providing them with information on the latest technology. Specialists in laser beam welding technology (manufacturers, users, research institutes) are working together to produce technical codes, to determine terminology for processes and devices, and to provide recommendations for the laser beam welding of metal materials and other areas, such as laser cladding, laser beam remote welding or new laser beam technologies. In the future, content which describes the usage options for new beam sources (gas, disk, rod and fibre lasers) and (pico-, femto-) ultrashort pulse lasers will be produced.

Working Groups AG V 9.1 "Electron Beam Welding" and AG V 9.2 "Laser Beam Welding and Allied Processes" are working together to produce common technical codes for the areas in which it is useful to compare electron beams and laser beams, or for areas which concern both kinds of beam technology.

Working Group V 9.2.1 "Ultrashort Pulse Laser"

The Working Group AG V 9.2.1 "Ultra Short Pulse Laser" is the right point of contact for all matters concerning material treatment using beam-based ablation procedures. Draft guidelines entitled "UKP (Ultrashort Pulse Laser) basics and system technology" and "UKP laser beam procedures in manufacturing" are currently being drawn up during meetings. This will be published shortly and made available to users. The need for more DVS guidelines and standards concerning safe equipment design is also being discussed. The Expert Group 4.7 "Training for Beam Welding" is currently working on an educational guideline for a supplementary sheet to DVS 1187 "Laser beam specialist" concerning ultrashort pulse lasers.

Beam-based ablation.

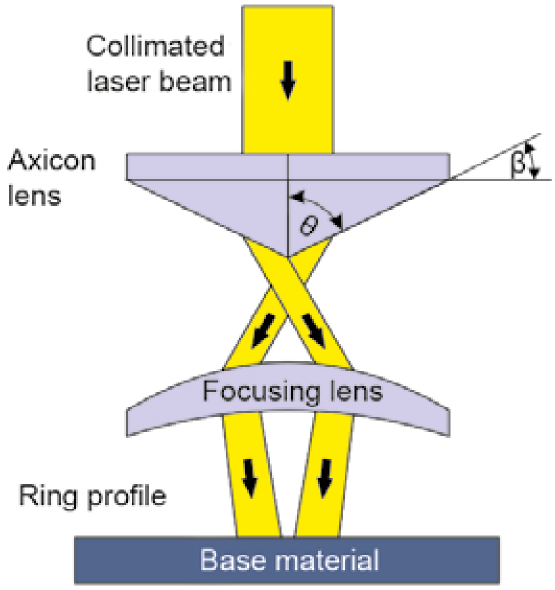


Source: Michael Seiler, Ernst-Abbe-Hochschule (university of applied sciences), Jena

DVS technical codes for practice

Technical bulletin DVS 3218 "Beam formation for welding metal materials using a laser"

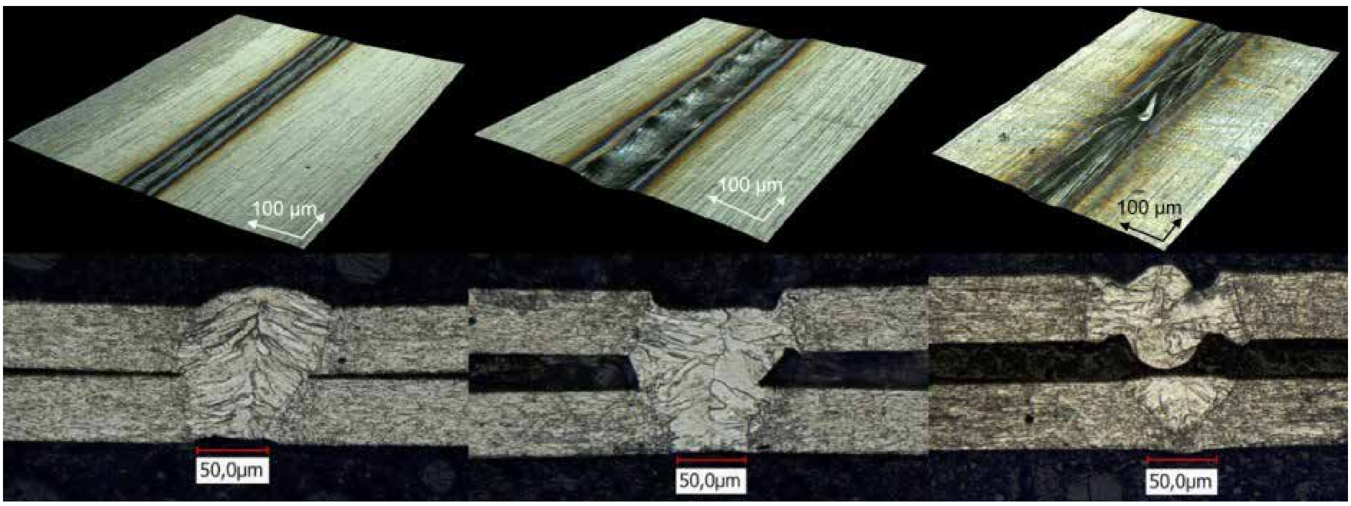
The following applies in laser technology: no material treatment without beam formation. Beam formation is much more than simply focusing the light of the laser onto one spot with a predefined diameter. Intensity distributions can be set as required via various optical elements in the beam path or in the processing optic. These can be used to improve the ability to bridge gaps or to increase welding speeds, for example. The technical bulletin DVS 3218 provides users with an overview of the available options for beam formation, what type of beam sources these can be combined with and how is it then possible to influence the process. Furthermore, real-life usage examples are listed. In particular, information is provided on how to form a beam using optical elements, mirrors, scanners and light guide cables.



Beam formation

Technical bulletin DVS 3224 "Laser beam micro-welding" (in progress)

During laser beam welding, as material thickness decreases, so does flexural rigidity and the resistance to thermally induced distortions. In addition, capillary forces which affect the weld pool increase. Laser beam micro-welding is a procedure which can be differentiated from conventional laser beam welding by the special characteristics involved in the process. This technical bulletin serves to characterise procedural features relevant to practice and provide users with process recommendations.



Source: Dr.-Ing. Andreas Patschger, Ernst-Abbe-Hochschule (university of applied sciences), Jena

3D images of welded seams.

Education in the DVS

The Education Committee (AfB)

The Education Committee initiates measures to adapt the training and certification offered by DVS to current developments and to prepare them for future requirements. The committee is supported by the Working Group “Training and Examination” (AG SP), which is responsible for training and certification, to create uniform training and testing materials within the framework of the qualification of technical specialists and managers. In doing so national and also current European and international requirements are implemented in the training and examination standards. The scope of responsibility of the AG SP is the development of the teaching and learning content of the technical training and further education as well as all other areas related to the training and examination The DVS-PersZert, the personal certification body of DVS, ensures that these training and examination standards are ultimately adhered to and implemented nationwide.

The Expert Group 4.7 “Training for Beam Welding” is continuously working on new educational guidelines and orienting these towards the needs of the industry. This ensures that the latest knowledge in the field of laser and electron beam welding technology are transferred into methodical-didactical educational concepts. As such, in addition to the advanced training for specialists in laser beam technology, advancing training courses have now been created for specialists in manual laser beam material treatment. The Expert Group is also working to offer courses for competent individuals to deal with the implementation of the safety regulations for optical radiation (OStrV). The Expert Group 4.13 “Training for Additive Manufacturing” is developing educational concepts in the domain of additive manufacturing to deal with synthetic materials and metal.

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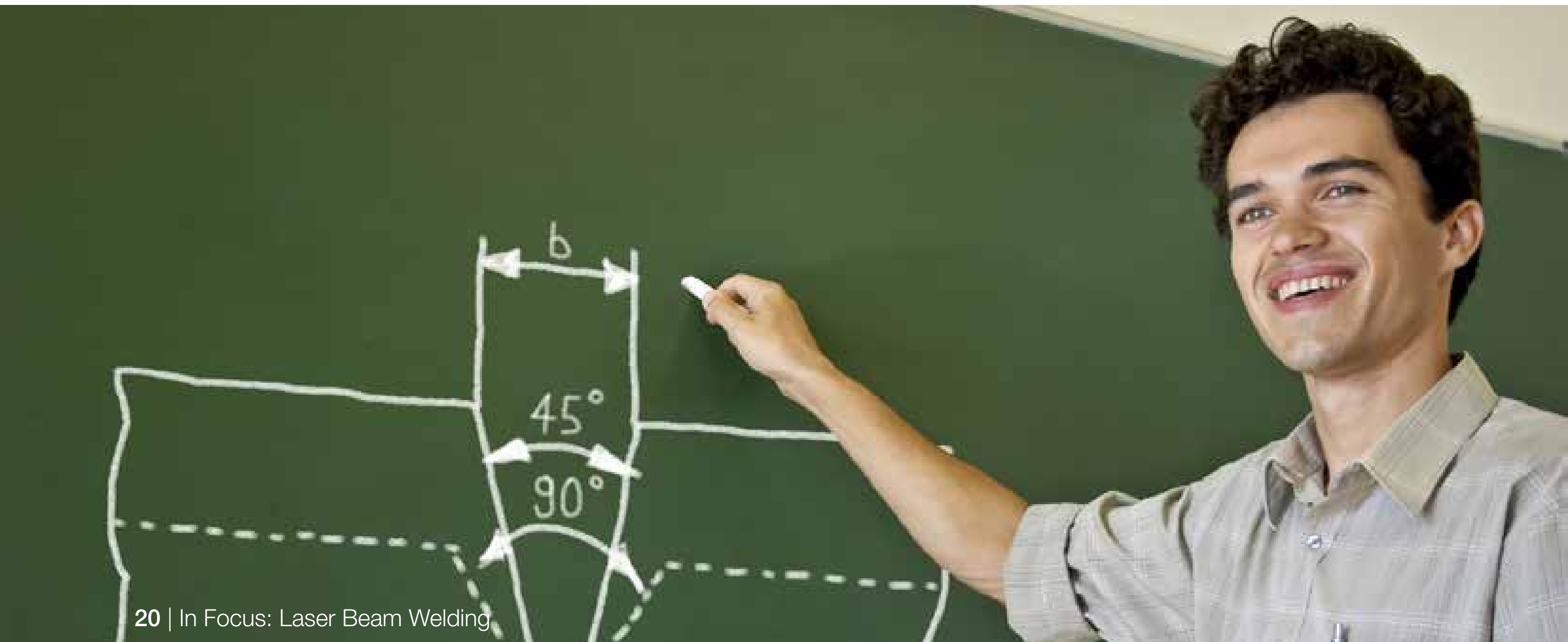
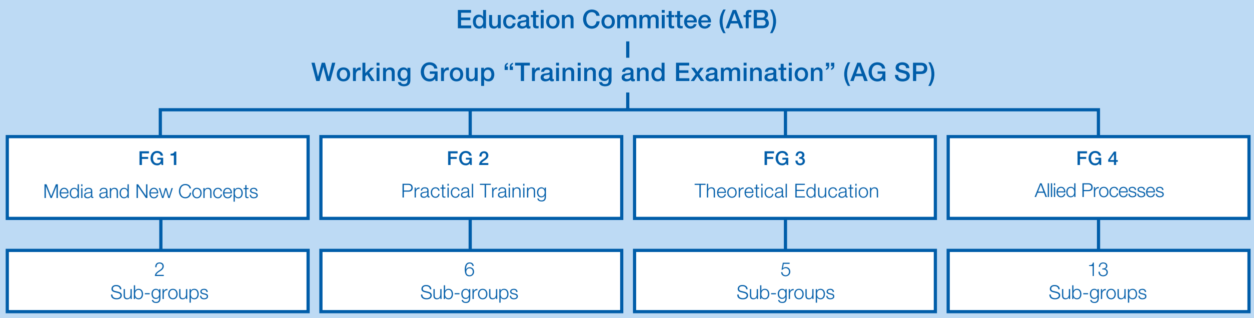
The current training and further education on offer from the DVS can be found under: www.dvs-bildungskatalog.de



Structure of the Education Committee (AfB)



FG: Expert Group

Training and career paths in the domain of “Laser Beam Welding”

The guideline DVS 1187 “Laser beam specialists – specialists in treating metal with laser radiation” was amended with supplementary sheets 1-3 on the topics of welding technology, cutting technology and surface technology.

“DVS laser beam specialists” can set up and operate laser beam equipment used for treating metal, independently complete tasks involving laser beam welding and cutting, as well as tasks within the scope of surface treatment, and also instruct and supervise operating personal. Furthermore, they act as a go-between for manufacturing and construction departments with regard to construction processes involving laser beams. They are also competent in operating, looking after and maintaining laser beam equipment within the framework specified by the manufacturer. The DVS training course is offered in three specialisations (surface technology, welding technology and cutting technology) which can be completed separately. Those who complete the training course will gain the expertise to become a laser protection officer in accordance with OStrV.

The guideline DVS 3601-1 for experts in additive manufacturing procedures with specialisation in synthetic materials and the guideline DVS 3602-1 for experts in additive manufacturing procedures with specialisation in metals

A trained specialist in additive manufacturing procedures has expertise in the following areas:

- The basics of additive manufacturing
- Laser beam generation for components
- Quality assurance procedures for components
- Designing equipment for laser beam generation
- Processing data for the construction process
- Preparing, following up on and finishing manufacturing equipment

A specialist has systematic general knowledge. They have knowledge of the specialist terminology, the process chain, and the possibilities and limitations of processes in terms of quality, costs and areas of application, and they can evaluate quality characteristics. They can operate the systems technology available and manufacture a component, for example. By training their employees to become specialists and having them taking part in the aforementioned DVS training courses, businesses can benefit from the knowledge essential to modern manufacturing processes.

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For more detailed information on DVS training courses, visit: www.dvs-bildungseinrichtungen.de

Specialised media and teaching materials for Laser Beam Welding

The DVS Media GmbH

The DVS Media GmbH is the right starting point for comprehensive publications and media regarding joining, cutting and coating. The publishing program includes German and foreign-language trade journals, technical books, teaching media, DVS technical bulletins and guidelines, videos and software. The products from the DVS Media GmbH represent all the fields of activity of the DVS Association and all the results that they develop.

Numerous items of the DVS Media GmbH specialist media are devoted to the working results in the areas of research, technology and education around Laser Beam Welding: These include specialist books and periodicals, as well as training materials and individual or collections of DVS technical bulletins and guidelines.

Sources for the DVS technical codes

DVS members have free access to all DVS technical bulletins and guidelines under www.dvs-regelwerk.de.
Interested persons who are not members of the DVS can refer to the DVS technical codes under www.dvs-media.info.

Your contacts for specialised media and teaching materials

DVS Media GmbH
Aachener Str. 172, 40223 Düsseldorf
www.dvs-media.info

Bernd Hübner
P +49 211 1591-162, F +49 211 1591-150
bernd.huebner@dvs-hg.de

Publications on “Laser Beam Welding”

DIN/DVS-Taschenbuch 283

Schweißtechnik 6: „Elektronenstrahlschweißen, Laserstrahl-schweißen. Normen, Richtlinien und Merkblätter“

The original versions of standards, draft standards and DVS technical bulletins document the latest development in technology in the areas of electron beam welding and laser beam welding. Examples of new additions in the area of beam welding are DIN 32532:2009-08, which denotes terminology for processes and devices used in material treatment, and technical bulletin DVS 3214 on the causes of abnormalities on seams welded by laser and the corrective action to be taken.

5th edition, October 2017
554 pages, 278 pictures and figures/82 tables
ISBN: 978-3-96144-017-7, article number: 505720

DVS-Bericht (in progress)

Laser- und Elektronenstrahlschweißen von Aluminiumwerkstoffen

The volume entitled “Laser and electron beam welding of aluminium materials” is currently in progress in a series of DVS reports. It will summarise findings from current, important research projects which are relevant for practice. These projects have been undertaken by Research Association on Welding and Allied Processes e. V. of DVS.

The research projects deal with ways to improve the quality of seams welded on aluminium alloys using laser beam technology with oscillating magnetic fields, as well as with laser beam multi-layer narrow-gap welding in order to join thick sheets of aluminium alloy without any distortions or cracks due to heat.

A publication is planned for December 2017.

External publications

Booklet entitled "Areas of activity in additive manufacturing processes"

The VDI – Association of German Engineers – and the DVS successfully work in close cooperation with regard to the topic of additive manufacturing. The VDI generated a status report entitled "Areas of activity in additive manufacturing processes". This report outlines the latest technological developments and the future prospects for additive technology. In addition, it also provides an overview of the DVS and other associations that work within the area of additive manufacturing. The VDI, DVS and Research Association on Welding and Allied Processes e. V. of DVS also have an arrangement in relation to the prospective development of technical codes on this topic. Their objective is to implement the research findings from FA 13 into the joint VDI/DVS guidelines and in doing so, make them accessible to as many users as possible.

The status report can be found by clicking on the following link:
www.dvs-forschung.de/FA13

Booklet entitled "Synthetic optical radiation" – a guidance document for risk assessments

This booklet provides support to employers when performing the risk assessments necessary when synthetic optical radiation is used. Employees are exposed to this radiation and the risk of injury gives good reason to take protective measures in a workplace where synthetic, optical radiation is used. This booklet provides numerous resources with information on how to measure and assess the risks posed by synthetic, optical radiation, which protective measures to take and how to inform staff. The legal basis for risk assessments is outlined in the regulation on how to protect employees from the risks posed by synthetic, optical radiation (see OStrV).

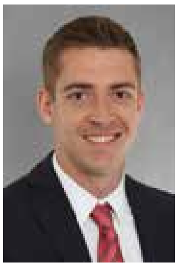
This booklet was put together by the agency for workplace protection, the Berufsgenossenschaft Energie Textil Elektro und Medienerzeugnisse (German employer's liability insurance association for energy, textile, electronics and media services, BG ETEM), the Bundesanstalt für Arbeitsschutz und Arbeitsmedizin (BAuA, German federal agency for workplace protection and occupational medicine), Unfallkasse Nord (UK Nord), Schweißtechnischen Lehr- und Versuchsanstalt Nord GmbH (GSI, SLV Nord, educational and research institute for welding) and DVS – German Welding Society. The partners worked on producing operating guidelines within the scope of a project. These guidelines should provide support for implementing the regulation on protecting the workplace from synthetic, optical radiation (OStrV).

Published by the authorities for health and consumer protection, workplace protection agency, Hamburg
www.hamburg.de/arbeitsschutz

www.dvs-ev.de (Menu: DVS media/technical operating guidelines)

Your contacts for “Laser Beam Welding”

Your contact partner for Research | Technology | Education



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DVS – German Welding Society
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www.dvs-ev.de

Technical Committee (AfT)

www.dvs-aft.de

Working Group V 9.1 “Electron Beam Welding”

www.dvs-aft.de/AfT/V/V9/V9.1

Chairman:
Dr.-Ing. Wilfried Behr
Forschungszentrum Jülich GmbH

Working Group V 9.2 “Laser Beam Welding and Allied Processes”

www.dvs-aft.de/AfT/V/V9/V9.2

Chairman:
Dipl.-Phys. Jan Hoffmann,
SLV Mecklenburg-Vorpommern GmbH

Working Group V 9.2.1 “Ultrashort Pulse Laser”

www.dvs-aft.de/AfT/V / V9/V9/V9.2

Chairman:
Dr.-Ing. Arnold Gillner,
Fraunhofer Institute for Laser Technology ILT, Aachen

DVS-PersZert
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www.dvs-perszert.de

Education Committee (AfB)

www.dvs-aft.de

Expert Group 4.7 “Training for Beam Welding”

www.dvs-aft.de/DVS/ABT/AfB/AGSP/FG4/FG4.7

Chairwoman:
Dipl.-Ing. (FH) Ilka Zajons, LZH Laser Akademie GmbH, Hannover

Expert Group 4.13 “Training for Additive Manufacturing”

www.dvs-aft.de/AfT/AfB/AGSP/FG4/FG4.13

Chairman:
Prof. Dr.-Ing. Claus Emmelmann,
Laser Zentrum Nord GmbH, Hamburg

Research Association on Welding and Allied Processes e. V. of DVS
Aachener Str. 172, 40223 Düsseldorf
www.dvs-forschung.de

Expert Committee 6 “Beam Welding Processes”

www.dvs-forschung.de/fa06

Chairman:
Prof. Dr. Ing. Ronald Holtz,
Class 4 Laser Professionals AG, Burgdorf, Switzerland

Vice-Chairman:
Dr.-Ing. Johannes Weiser
EWM AG, Mündersbach

Expert Committee 13 “AM Technologies”

www.dvs-forschung.de/fa13

Chairman:
Prof Dr.-Ing. Andreas Gebhardt
Centrum für Prototypenbau GmbH, Erkelenz

Vice-Chairman:
Dipl.-Ing. Frank Palm
Airbus Defense and Space GmbH, Munich

DVS maintains a tight network made up of **research**, **technology** and **education** as a core element of the technical-scientific cooperative work.

Laser Beam Welding is your subject?

DVS is at your service.
Your participation in our committees is worthwhile!

- Because you will learn about important changes in the rules and regulations work first.
- Because you will actively participate in shaping technology fields.
- Because you can experience first-hand technical knowledge transfer.
- Because you can identify trends early on.
- Because you can benefit from important national and international contacts.

Become a part of our network of over **3,000 companies** and **16,000 professionals** who are associated with the joining technology.

Please contact us!

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marvin.keinert@dvs-hg.de

DVS GERMAN WELDING SOCIETY

In focus: Laser beam welding in the DVS

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