

Centre for Diagnostics of Laser Based Production Processes in the FGSW

The globalised competition enforces the continuous reduction of development time as well as lower production costs even with increasing product variety. A substantial contribution for this could be achieved by reducing the number of rejections which requires assured manufacturing methods and reliable monitoring systems. For that a profound knowledge of the factors for irregular process instabilities is necessary which does not exist even for multiple industrially applied laser processes for cutting, welding and drilling. This is, because it is very difficult to obtain experimental based knowledge concerning process instabilities which usually occur within extremely short time regimes and lateral dimensions in the micrometer range and mostly below the surface of the workpiece. The complex and difficult task requires a combination of different investigation methods, which offer maximum resolution in time and space.

In the *Forschungsgesellschaft für Strahlwerkzeuge mbH* (FGSW) at Stuttgart, Germany, a new "Centre for Diagnostics of Laser Based Production Processes" is installed. This centre will offer most modern and comprehensive diagnoses and measuring equipment for extended purposes of process monitoring. It is financed with 1,5 million Euros by the German Land Baden-Württemberg in the frame of its "future offensive".

The multi-purpose diagnostics equipment of the centre enables the FGSW to realise different investigations to the clarification of process failures in laser cutting, laser welding and laser drilling. It will be able to support the industry in solving acute production problems. Thus the FGSW will be able to offer an essential contribution to the development of assured manufacturing methods and reliable monitoring systems.

The following equipment and measuring systems will be available in the "Centre for Diagnostics of Laser Based Production Processes" when completed in its final stage:

Real Time Picture Processing

Highspeed-Colour Video

Highspeed-Infrared Camera

Highspeed Microfocus-X-Ray System

Light Cutting System

Short Time Diagnostics with ICCD-Camera

Laser Beam Diagnostics

Topography Measurement System

Picosecond Laser System

Nanosecond Laser System

Highspeed-Handling System

Highspeed Spectrometer

Below mainly the existing equipment, which allows for real time process diagnostics, will be described.

Real-Time Picture Processing

The real-time picture processing system allows for investigation of real-time performance of picture processing algorithms used for identifying the melt pool and keyhole geometry during laser beam welding. For realising an adequate refresh rate a special accelerator hardware (DSP: Digital signal Processor) together with fast calculation algorithms is used. The system represents a stand alone, real time, ultra-fast image processing system with complete process periphery. It allows for a flexible use of picture processing algorithms and offers the possibility of synchronised data logging of single detector signals and picture data and their correlated processing. In combination with one or multiple highspeed detectors, process images can be recorded, processed and the results can be displayed for monitoring.

Highspeed-Colour Video

For process comprehension of highly dynamical procedures a digital highspeed-video camera is indispensable. With laserbeam welding e.g. flow rates occur that are by magnitudes higher as the feed speed of the laser which can lead to process instabilities. Visualisation of the melt pool dynamics helps to document processes like melt pool ejections and spillings which result in reduced seam quality. Shutter times in the microsecond regime as well as recording speeds in the kHz regime with maximum resolution and more than 100 kHz with reduced resolution allow for detailed documentation of the machining process. Furthermore in combination with a pulsed illumination laser the penetration of the hole during laser beam drilling of ceramic materials can be traced in detail yielding more insight about the development of the drilling process.

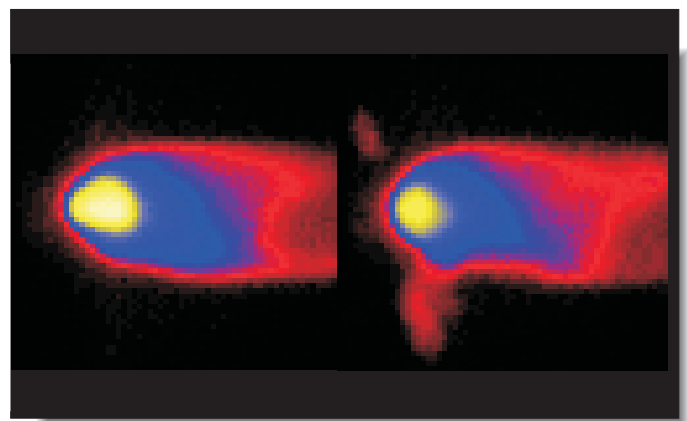


Fig. 1: Melt pool images in pseudo colour at laser beam welding. The keyhole region (yellow), the melt pool (blue) and the melt front (red) are clearly visible.

Highspeed-Infrared Camera

Thermal visualisation of the melt pool during laser beam welding provides information about the temperature distribution and thus allows for conclusions about the flow mechanisms inside the melt pool, directly improving process comprehension. The spectral range of CCD- and CMOS- Cameras is not sufficient for the visualisation of the melt pool. Here IR-cameras come into play. Frame rates of common IR-cameras however are limited to 50 Hz and are therefore too low to document melt pool dynamics. The IR-camera of the "Diagnostics Centre" represents one of the newest developments in the field of image processing detectors in the infrared spectral range. The full frame (256 x 256 pixel²) repetition rate of the camera is 880 Hz with an excellent thermal resolution in the mK range. The shutter times can be adjusted from some microseconds up to several milliseconds. In combination with maximum sensibility in the spectral range from 3,4 μm to 5,1 μm and a high dynamic range for good resolution of bright to dark contrasts this highspeed-infrared-camera is suited at best to document the temperature distribution in the melt pool with sufficient temporal resolution.

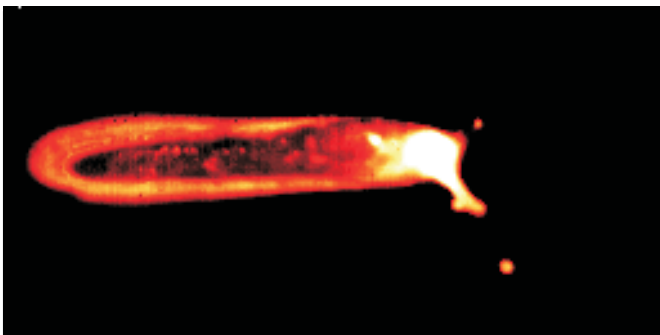


Fig. 2: Melt pool- and keyhole region at welding of steel with a Nd:YAG-Laser. Resolution 256 x 128 pixel², image repetition rate 1700 Hz.

Highspeed-Spectrometer

Through measurement of the spectral distribution of the process emissions the components of the metal vapour and the excitation levels of the involved species can be identified. This is allowing for conclusions on the process itself, for example on melt pool mixing or drilling breakdown. Common methods of process control are based on the analysis of emissions from the process in specific spectral ranges. Thus spectroscopic investigations provide basic principles for identifying suitable detection wave lengths for the development of process monitoring systems.

Beam-Diagnostics

The use of the laser beam as a tool requires a detailed knowledge of the properties of the applied laser beam. Securing a high level of quality of machining depends by all machining processes on the quality of the laser beam. A camera based beam diagnosis system with high dynamics allows for precise measurement of the propagation parameters of the beam as for example waist position, waist diameter, divergence angle and focusability. With the help of such a system changes with the laser as well as with the optical system, that could be caused for example by thermal effects or destruction of components, can be detected.

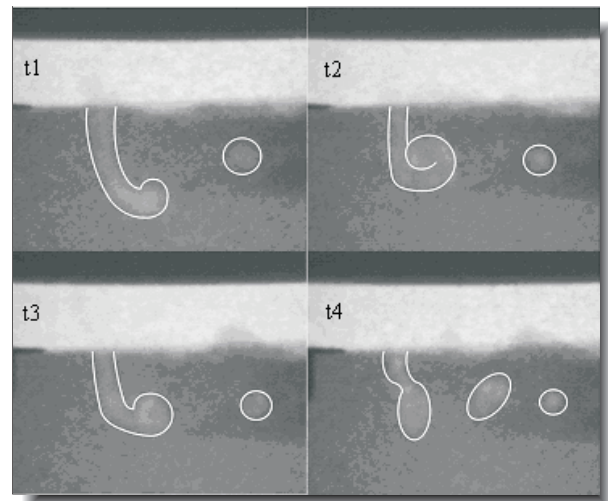


Fig. 3: Visualisation of the temporal behaviour of the vapor capillary and pore formation at laser beam deep penetration welding by means of a microfocus-x-ray-system.

The beam diagnosis system operates at the wave length range of 190 nm up to 1100 nm for pulsed and as well for continuous wave lasers. The measurement is made according to DIN ISO 11146.

Highspeed-Microfocus-X-Ray-System

With the help of an online-x-ray system, that is not provided yet, the form of the capillary with deep penetration welding and laser drilling as well as the temporal behaviour can be observed and displayed in real time. The geometry of the x-ray-beam of the system leads to extremely high geometric magnification factors of > 3600. Due to the small extension of the emitting area, very sharp images with a resolution in the micrometer range can be produced even with this high magnification. Thereby it is possible to visualise appearance processes of failures like pore formation for example. The yielded results are key to understanding of the deep penetration welding process as well as the drilling process and provide a substantial contribution to improvements in model generation, simulation and process monitoring.

With the investments into the "Diagnostics Centre" the FGSW will be able to apply for further research projects in the field of process control and process monitoring. A national project PROMPTUS (Productive Micro Process Technology with Ultrashort Pulsed Laser Sources) in the field of femtosecond technology will start in a few time. The FGSW is open for further research cooperation and also offers industrial research on a limited scale.

Address:
Institut für Strahlwerkzeuge
Stuttgart University
Pfaffenwaldring 43
D-70569 Stuttgart
Phone.: +49 (0)711-685 6840
Fax: +49 (0)711-685 6842
<http://www.ifs.uni-stuttgart.de>

Author:
Prof. Dr. Friedrich Dausinger
FGSW - Forschungsgesellschaft
für Strahlwerkzeuge mbH
Pfaffenwaldring 43
D-70569 Stuttgart
Phone: +49 (0)711351 451-12
Fax: +49 (0)711351 451-13
E-Mail: dausinger@fgsw.de

Contact:
Dipl.-Ing. Friedemann Lichtner
Phone.: +49 (0)711351 451-28
Fax: +49 (0)711351 451-29
E-Mail: friedemann.lichtner@fgsw.de
<http://www.fgsw.de>