High-Power Lasers and Industry 4.0: Focusing on Knowledge

A new measurement procedure allows for the fast and contact-free measurement of the focused laser beam. At the same time, modern measuring devices have Profinet interfaces and allow the processes to be documented. These are enormous advantages, especially in times of just-in-time production

Automated laser welding is a big topic in modern production and more and more new applications are being developed. Be it pairing materials that were previously considered to be non-weldable, complex contours or extremely stressed components, a good deal of specialist knowledge is always required; after all, everything has to fit perfectly, from material properties to clamping technology and laser beam. This also applies to the measurement technology used for quality assurance. The weld seam itself can only be checked by random samples where material is destroyed or by time and cost-intensive ultrasound tests. If weaknesses are actually found during such an inspection, the bad parts must be sorted out after all costs of the value chain have already been incurred. It is significantly cheaper to proactively ensure the consistent quality of weld seams. The joining gap caused by the clamping process and the position of the weld seam are often checked by cameras or laser triangulation sensors, but exact compliance with the defined specifications of the focused laser beam itself is a challenge at high power densities. MKS Instruments developed the robust and compact performance measuring device Ophir Helios to be specifically used in automated production, which, for less critical applications, provides reliable clues as to whether the basic parameters for the precise implementation of weld seams can be observed. The measuring device measures the power and energy of industrial diodes, fiber or Nd:YAG lasers during a short irradiation time between 0.1 and 10s and uses this to calculate the total power up to a maximum of 12 kW or total energy up to 10 kJ. If the measured values lie outside the process window defined by the user, intervention is required.

Higher laser quality increases process quality

Fig. 1: The robust and compact performance measuring device Helios was developed for

Especially with laser processes in industrial production, where narrow tolerance limits have to be observed, only one beam profile measurement provides real information about the quality of the laser beam.
On the one hand, the different materials that make up the laser source or beam guide are subject to thermal changes. On the other hand, many manufacturing processes generate particles or vapors that contaminate the optics despite protective gases and flows directed away from the optics. The result: The optical properties of the laser system deteriorate and its efficiency over time is reduced. If you want to keep the quality of your processes at a consistently high level, you have to continuously check laser parameters such as focus position or ageing, contamination or temperature-related shift, the quality index M^2 of the laser and the power density of the laser. But how can you measure the focused laser beam with an enormous power density without damaging the measuring device or distorting the laser beam and thus making the measurement absurd?

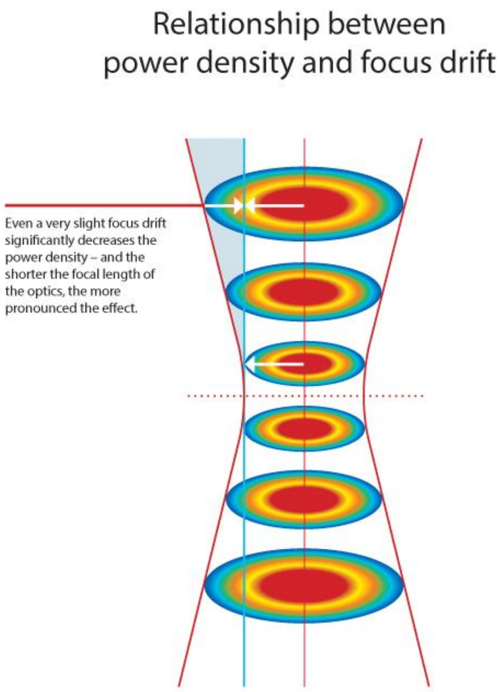

Fig. 2: A change in the focus position changes the power density and thus the entire laser process.

Rayleigh scattering enables non-contact measurement

The Ophir developers used Rayleigh scattering as the basis for the design of a new, non-contact measurement method. This describes the scattering of electromagnetic waves on particles whose diameter is small compared to the wavelength, such as oxygen or nitrogen molecules in the air. The electric field of laser radiation induces an oscillation of the dipole molecule at the laser frequency and thus leads to elastic scattering at the same frequency. The scattered laser light is imaged from the side with a telecentric lens structure on a CCD or CMOS camera. Each individual pixel in one line of the CCD camera detects the scattered light as an intensity measuring point in the beam profile.

From these measurements, beam and beam quality parameters according to ISO 13694 and ISO 11146 standards including focus diameter, focus position, divergence, ellipticity, M^2 (1/k) and beam parameter product (BPP) can be calculated with high accuracy using integrated software. However, due to very weak scattered radiation, it is necessary to control and minimize any secondary light source that could distort the Rayleigh light and add artefacts. This is achieved through

optimal placement of the individual components and light-absorbing material in the measuring chamber. A laminar flow of scavenging air ensures that there are no particles such as dust within the measuring range that could influence the measurement. Each individual line of the CCD camera provides an intensity profile. With typical CCD or CMOS cameras with a number of pixels of 1090 x 2048, 2048 individual profiles are thus measured simultaneously.

BeamWatch and BeamWatch Integrated

This innovative measuring principle is used in the Ophir BeamWatch system. Thanks to non-contact measurement, there is no upper performance limit; even 100 kW lasers have been measured with BeamWatch without any problems. For the area of automated production, the company also offers BeamWatch Integrated, which, in addition to non-contact measurement, also enables integration into production networks and automated production processes. In addition to an optimized design and an integrated performance measuring device, BeamWatch Integrated has various interfaces that enable the measurement data to be transferred directly to production networks. Both BeamWatch variants are characterized by the fact that they determine an exact image of the beam caustic within a fraction of a second and can use it to easily and efficiently calculate focus shifts without touching the laser beam and thus influencing the focus to be measured or the measuring device itself. If desired, measurements of the focused laser beam can be carried out before the machining of each new workpiece during the loading and unloading process, and the data - according to Industry 4.0 standards - is forwarded to the central production data management together with the part number. If necessary, deviations in the laser parameters can be corrected immediately thus preventing the production of defective parts. Suppliers and producers can therefore protect themselves from expensive product recalls, especially in industries where just-in-time production is typical. If there are doubts about the production quality, the company always has the data to verify the correct laser beam setting - if necessary, it can be resolved exactly per piece.

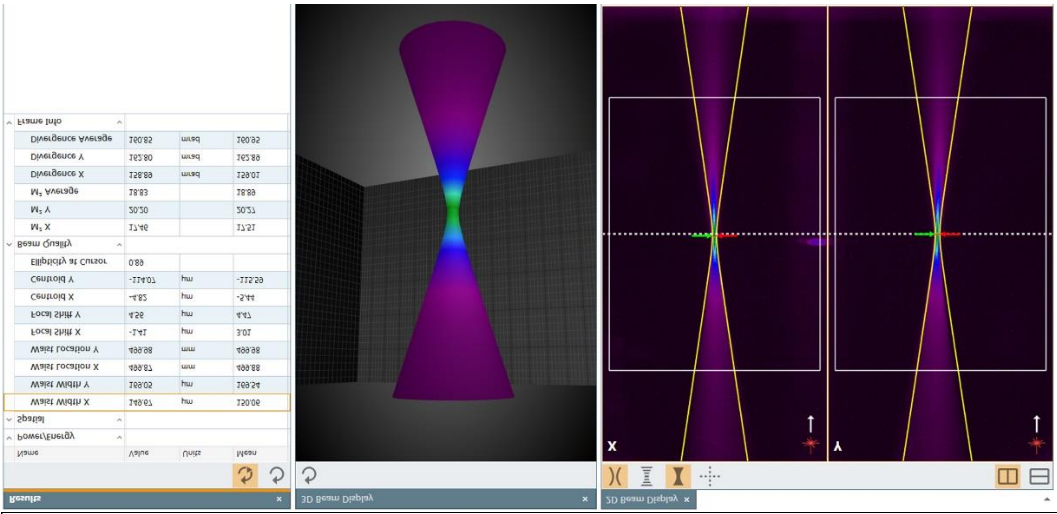

Fig. 3: BeamWatch draws an exact picture of the beam caustic and shows focus shifts almost in real

Efficient production

Experience shows one thing: measuring the laser beam pays off quickly. This applies to performance measurement with Helios in automated production as well as to the non-contact measurement of laser beams with BeamWatch within a few seconds. The financial commitment for acquiring measurement technology is comparatively low, because problems regarding quality are excluded from processing, leading the way to production without errors. The weld seam or cutting path can be created more precisely with the same or reduced laser power, with a higher traversing speed and therefore with a less pronounced heat-affected zone. Costs per unit are reduced because less process gases and energy are required and the scrap rate diminishes. With narrow margins and high penalty costs in the event of recalls, the interpretation of empirical measurement methods is definitely not worth the while. Rather, foresight is demonstrated by production managers and quality officers who continuously monitor their laser system.