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Analyzing Performance for Laser Additive Manufacturing

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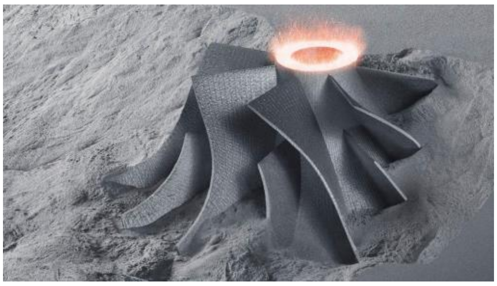

Recently, a new emerging technology of metal 3D printing or LAM (Laser Additive Manufacturing) is recognized as the new advantageous process for metal parts manufacturing. For this application, lasers play a significant role because they can focus large amounts of energy on a wide range of material powders, fusing the particles into 3D parts. Important laser and machine optical parameters need to be analyzed in order to insure repeatable and excellent results. The process is based on a layer-by-layer construction, wherein each layer is selectively fused on top of each other until the part is a finished product. Although many technologies are involved in making an LAM machine, this article will concentrate on laser critical parameters and their measurements for better performance. Today, most lasers for 3-D printing machines are based on fiber optics high power technologies in conjunction with an optical scanning head for effectively placing the laser beam at the necessary locations.

Parameters to be measured

The most important parameters affecting the machine performance will then be: focus spot width and location, focal shift, centroid location, absolute power and the real time measurement of laser dynamics. Duma offers a measurement instrument that will perform these measurements in real time using knife-edge or camera systems technologies. Moreover, for ensuring precise measurements, the instrument has a special optical beam path design which is calibrated to the beam location at its fusing surface. To allow fitting the system into tight spaces, the system dimensions are minimal and in such a way that it can be integrated as a part of the LAM machine.

Measurements made easy

The LAM Beam Analyzer is designed to enable exact positioning over the point to be measured by providing a reference hole on its bottom. Beams striking the input aperture will focus exactly on the surface layout where the instrument is stationed on. Laser beam position in 3 axes-- XY and Z, will be displayed in real time relative to the reference hole. To complete required measurement parameters, the beam profile will be measured at this exact same location to yield a real-time full-test diagnostics.

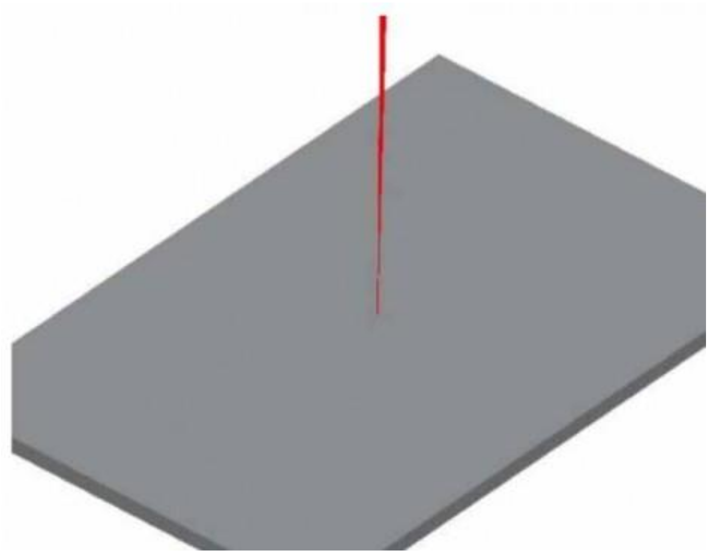

Figure 2 shows in a schematic way a focused beam designed to focus on the top plane. For quality assurance of laser beam performance, we'd like to measure the laser beam characteristics as follows: power, position & profile. In order to do so, the instrument will be accurately positioned at the point of interest -- this is facilitated by a reference hole on the instrument's bottom, which exactly represents the measuring point of the instrument.

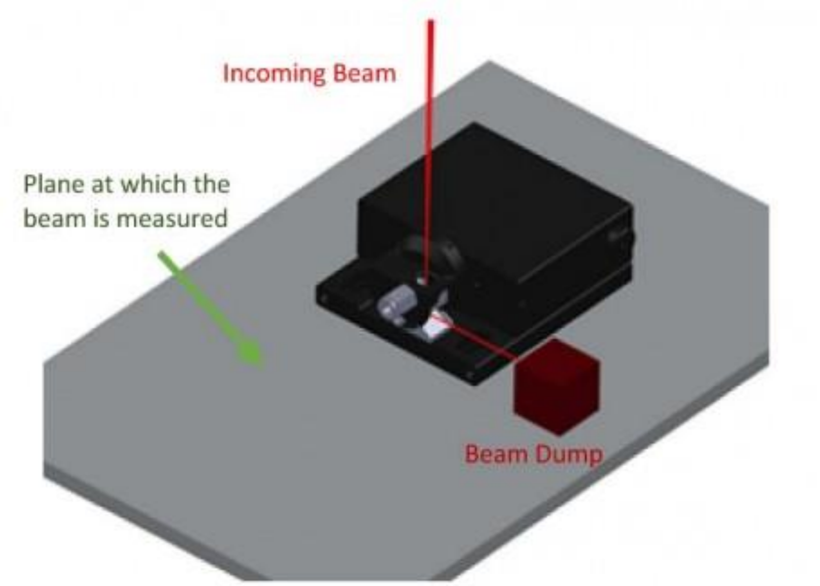

Figure 3 shows the instrument mounted on the point of interest on top of the plane, performing the necessary measurements. The ray trace design is such that the incident beam is sampled as if its position is exactly at the plane's incident point.

Key measurement technologies

Scanning knife-edge technology

Knife-edge profilers use an aperture large enough to pass the entire beam. The aperture has one sharp, straight edge (knife edge). As the aperture traverses the beam, the system measures the portion of the beam that is not blocked by the blade (see figure 4) and plots the differential (rate of change in intensity) vs position of the power through the aperture. As the knife edge passes through the beam the system approximately calculates the beam size and a sophisticated electronic circuit samples across the beam 12000 times per sweep. Further processing yields over 1000 useful points per profile regardless of beam size. Very small beams in the micron range are sampled with lower resolution. This auto zooming procedure offers highest possible accuracy independent of beam size. This is advantageous when compared to slit- or pinhole scans: The beam intensity is not limited by the size of the pinhole or slit; resolution is not limited by the size of the aperture, allowing beams of a few microns in diameter to be measured. Moreover, accurate power measurement is also provided since at some point the full unobstructed power incidents the detector surface. A special needle-like gage will display power on real-time five times per second (see figure 5).

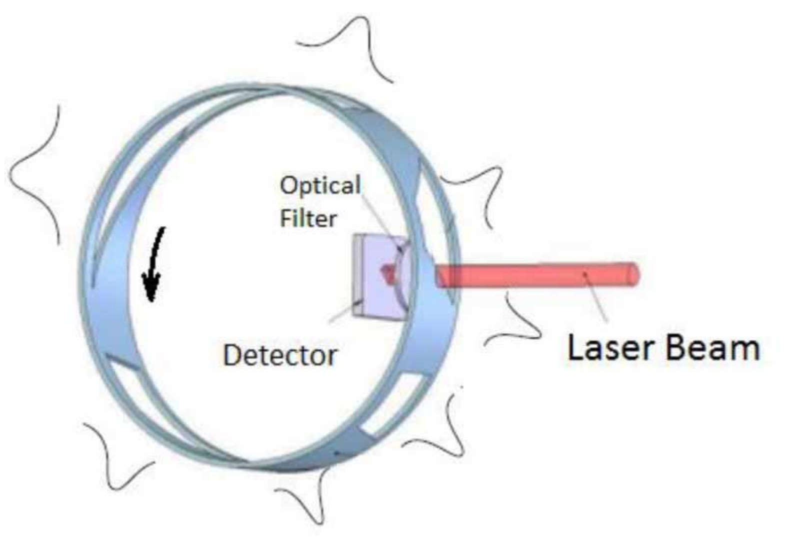

Figure 4: Multiple scanning knife, each generating a different profile

Figure 5: Accurate power measurement

The scanning technology is advantageous for its wide dynamic range of beams from less than 3 microns up to 9 mm. Using special sensitive detectors, it can measure beams up to a wavelength of 2.8 microns. Proprietary to Duma, the generated profiles from the multiple scanning knife edges, each differently oriented, are reconstructed as an image using tomographic techniques.

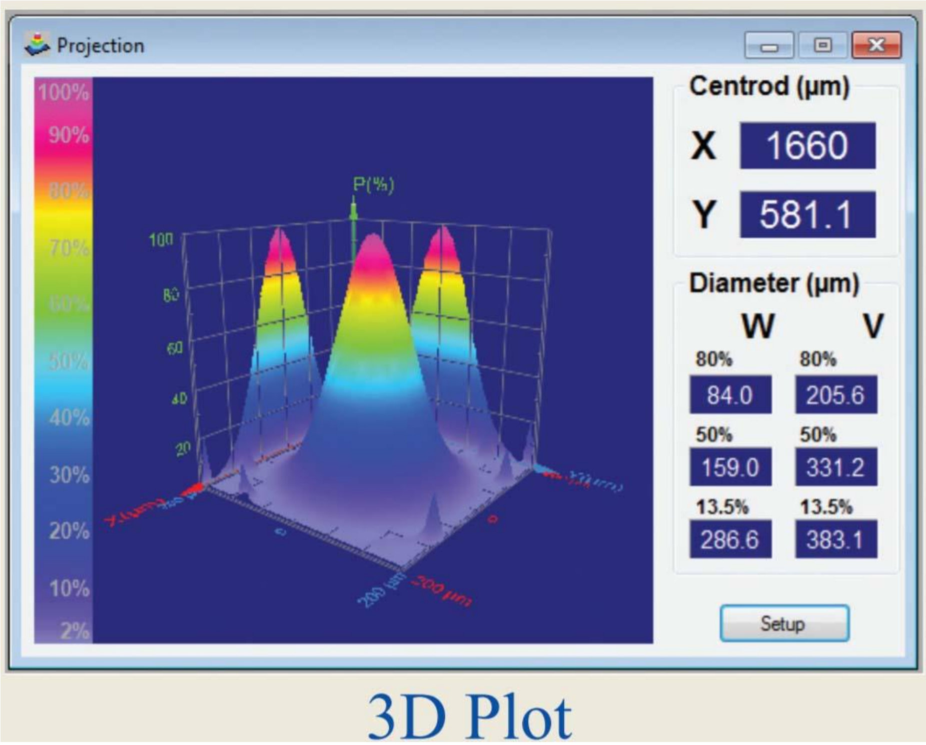

Figure 6: 3D reconstruction of profiles by tomographic techniques

Beam sampling technology

Duma Optronics' optical beam sampler for high-power lasers is an integral part of LAM Beam Analyzer, which samples the beam from the high-power system on-line. The sampled beam is examined using the knife-edge technology, yielding a highly accurate measuring instrument. Currently, two power levels are available up to 4 kW and up to 8 kW maximum power. For cooling, a pressurized air or nitrogen tube is attached to a nozzle actively cooling the first surface that the laser beam strikes.

Duma's beam sampler is non-distorting and preserves the polarization of the beam. Compressed air is used to cool the system, for preventing thermal lensing and keeping the optics free from dust and particles.

The system is able to measure power and beam size at a rate of five readings per second, faster than water-cooled power meters that work by measuring the difference in temperature of the water caused by the laser beam.

The measurement system could be used with minor changes for deep UV or up to 2.7 microns high power systems.

To summarize, a system using the knife-edge technology and an innovative dual-prismatic air-cooled device, is presented for real-time measurement of laser beams typical to LAM machines. Main advantages are:

- Accurate beam size analysis
- Wide range of power input
- Power measurements (user calibration possible)
- Wide spectral range
- Compact, designed especially to meet the LAM industry's needs

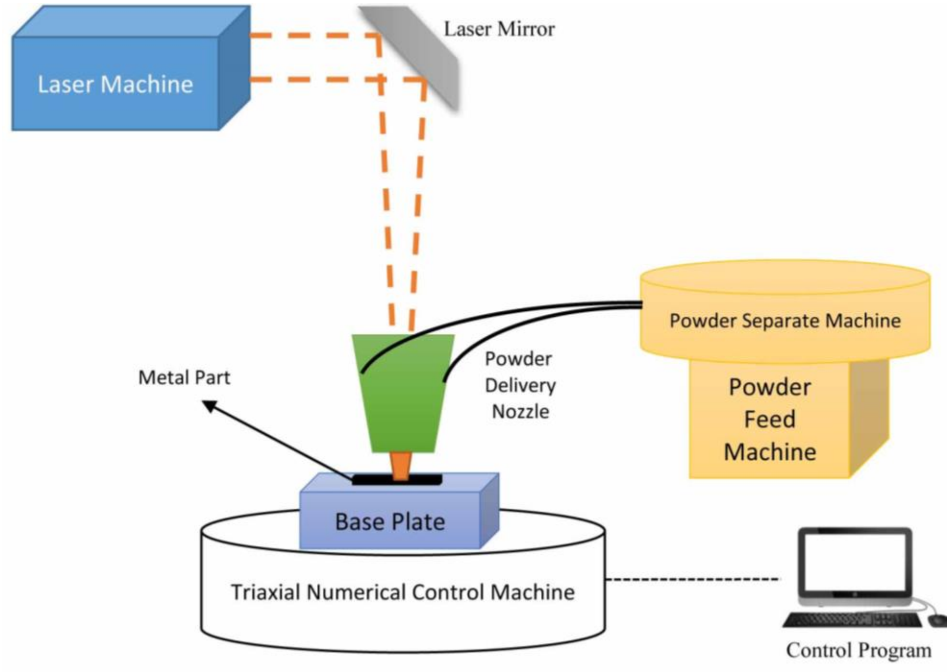

Figure 7: Schematic representation of a laser additive machine

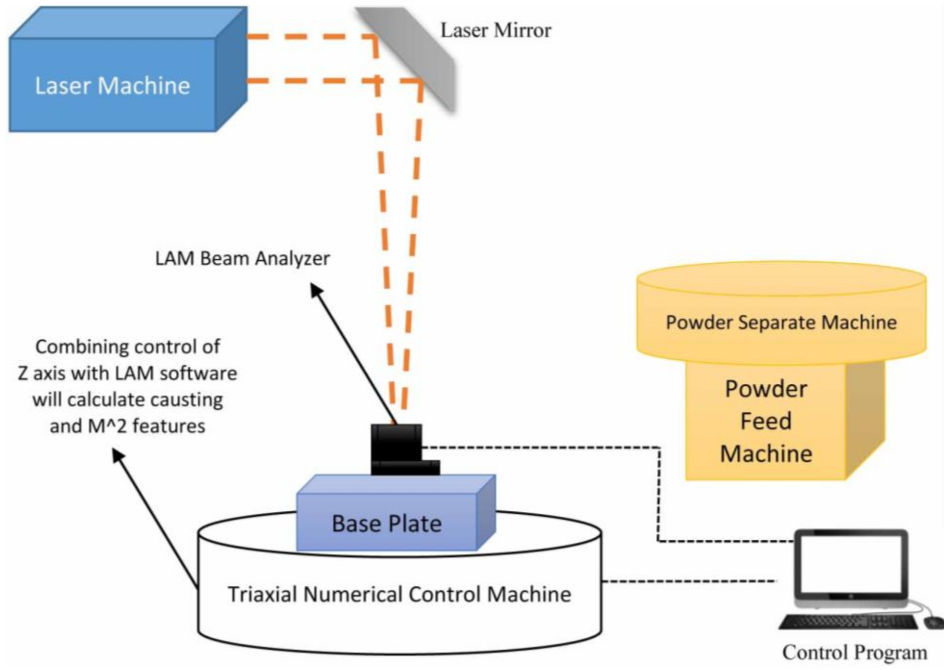

Figure 8: Schematic representation of a laser additive machine,
replacing the Power Delivery Nozzle with LAM Beam Analyzer Instrument