



**FLEXIBILITY MEETS
PRECISION:**
In-Focus Spot Magnification
in Additive Manufacturing

Dynamic adjustment of spot size for
maximum productivity and quality

QUICK  FINDER



**AT A GLANCE /
THE MAIN POINTS**

AM IN SEARCH OF HIGHER PRODUCTIVITY

SPOT MAGNIFICATION FOR FAST AREA EXPOSURE

Defocus – Simple method for spot magnification exhibiting an ill-defined focus profile

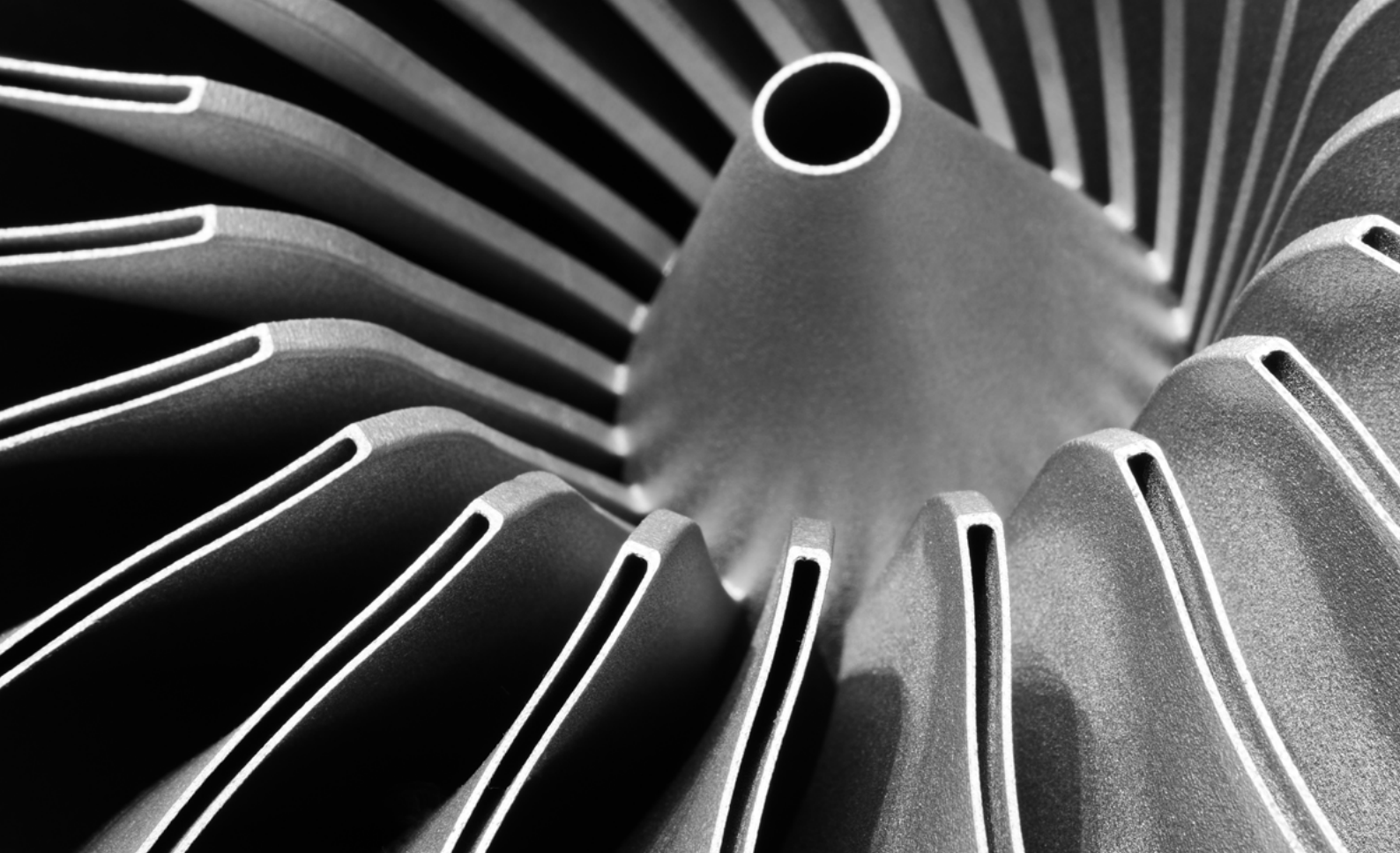
Multicore and Ring Mode Lasers –

Alternative Beam Shapes with Fixed Focus Diameters

Optical Zoom – Continuous spot magnification with optimum beam quality

**COMBINATION OF MULTICORE LASER AND ZOOM
FOR MAXIMUM FLEXIBILITY**

**OPTIMAL BEAM GEOMETRY ENABLES
EFFICIENT AM APPLICATIONS**



⦿ AT A GLANCE - ZOOM FUNCTION OFFERS FLEXIBLE FOCUS MAGNIFICATION

- **Cost-effectiveness is a core objective in additive manufacturing (AM):** When producing large components in additive manufacturing, efficient exposure processes are needed to reduce time and costs. Dynamic magnification of the focus diameter can help to achieve this goal.
- **Problems with conventional spot magnification using defocus:** Traditional approaches such as defocus can negatively impact the focus profile. Multicore lasers offer only fixed focus sizes. This limits productivity and adaptability, especially when different levels of detail are required in the part.
- **Optical zoom enables reliable focus magnification:** By using zoom optics, focus diameters can be continuously adjusted without sacrificing imaging quality. Even complex spot profiles such as ring mode or top hat can be magnified without loss of quality.
- **Combination of precision and efficiency through zoom and multicore laser:** By using the zoom function, the advantages of multicore lasers can be optimally utilized and the exposure can be specifically controlled. This enabled shorter production times, increased throughput and improved end product quality.

> ADDITIVE MANUFACTURING IN SEARCH OF HIGHER PRODUCTIVITY

High productivity is the key in every AM application. You probably know this from your own experience. Only if you can produce the necessary quantities and also keep the costs per part low, additive production is a real alternative to conventional production.

So, if you are in the process of redesigning or optimizing an AM system, you are probably also looking for ways to reduce the exposure time. Because especially with large part production, a more efficient exposure is an important way to increase the output.



In additive manufacturing, modern pre-focusing deflection units, such as our AM-MODULE III, can demonstrate their advantages. Because these scan systems enable high laser power combined with high scan dynamics. And both are essential for the high build rates required by AM users.

Dr. Jan Habedank

Head of Technical Competence Center at RAYLASE



> SPOT MAGNIFICATION FOR FAST AREA EXPOSURE

In addition to the obvious increase in exposure dynamics, an enlargeable focus diameter is a good option for optimizing exposure time. Much like a master painter who uses different brushes for the large areas as opposed to the details, a larger spot size is also a good option for filling bulk material in additive manufacturing. After all, this allows you to generate more volume with each pass, significantly reducing the number of hatches and reversal points.

However, since you still need a spot as small as possible for the fine structures of your component, a dynamically adjustable focus diameter becomes an excellent option.

To achieve this, you have several options at your disposal:

- ▶ Increase of the spot diameter by defocusing
- ▶ Beam shaping with adaptable ring mode lasers
- ▶ Spot increase using a zoom function

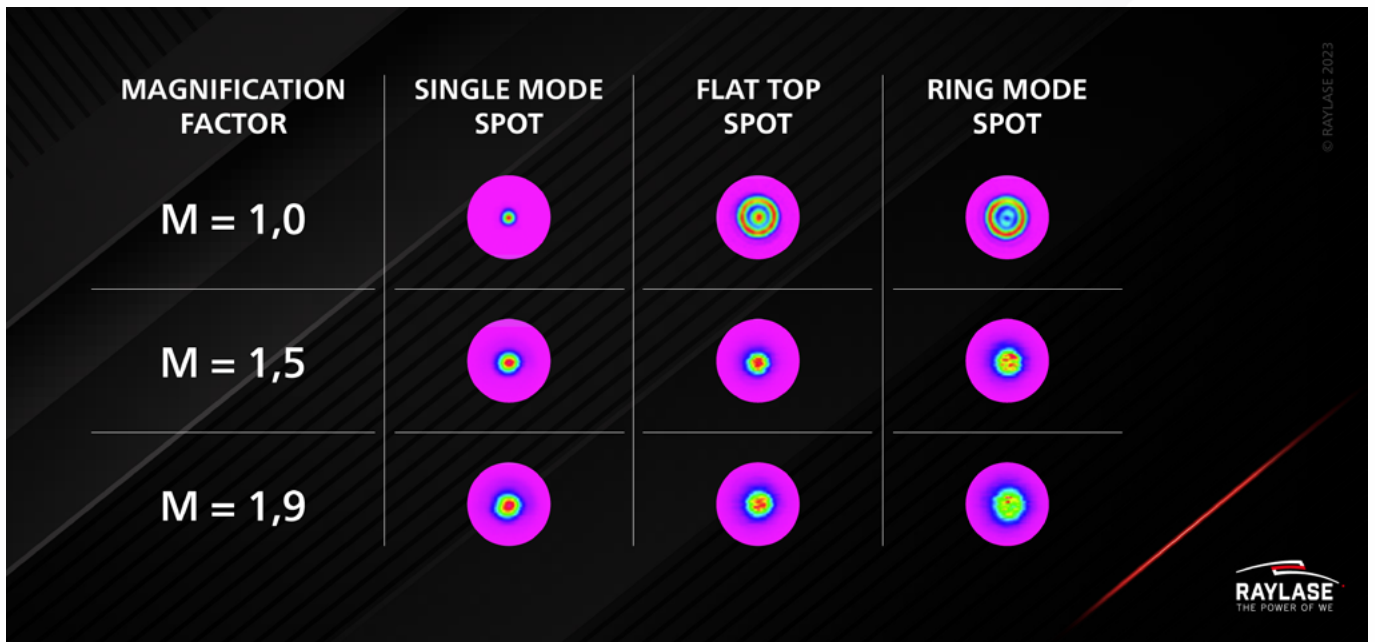
Let's take a closer look at the advantages and disadvantages of these options below.



Defocus - Simple method for spot magnification exhibiting an ill-defined focus profile

The simplest way to dynamically increase the spot diameter is to defocus the laser. You move the focus position below the working plane via a z-axis. This results in an enlarged spot diameter in the powder.

Especially with pre-focusing deflection units, this possibility of spot enlargement is ideal, since the required optical z-axis is already part of the scan system. However, this leads to a poorly defined beam shape outside the focus. As a result, the defocused spot does not retain its original energy distribution, but becomes blurred (Fig.1). While with single mode lasers the beam profile remains "Gaussian-like", the blurring is clearly visible with more specialized beam shapes such as flat-top or ring mode profiles.



△ **Figure 1: Influence of defocusing on different beam shapes of an AFX laser.** By working outside the focus position, the spot is no longer sharply imaged. The beam profile becomes blurred. While this effect is less pronounced with single mode lasers, for alternative beam shapes such as flat-top or ring mode the beam profile is lost.

Since the power distribution in the spot depends strongly on the amount of defocus, you have to determine the distribution experimentally for each magnification factor and develop the associated process parameters specifically for this setup. This additional effort and the fact that the magnified spot is only accessible in a blurred state limit the possible applications of the defocus.

Multicore and Ring Mode Lasers - Alternative Beam Shapes with Fixed Focus Diameters

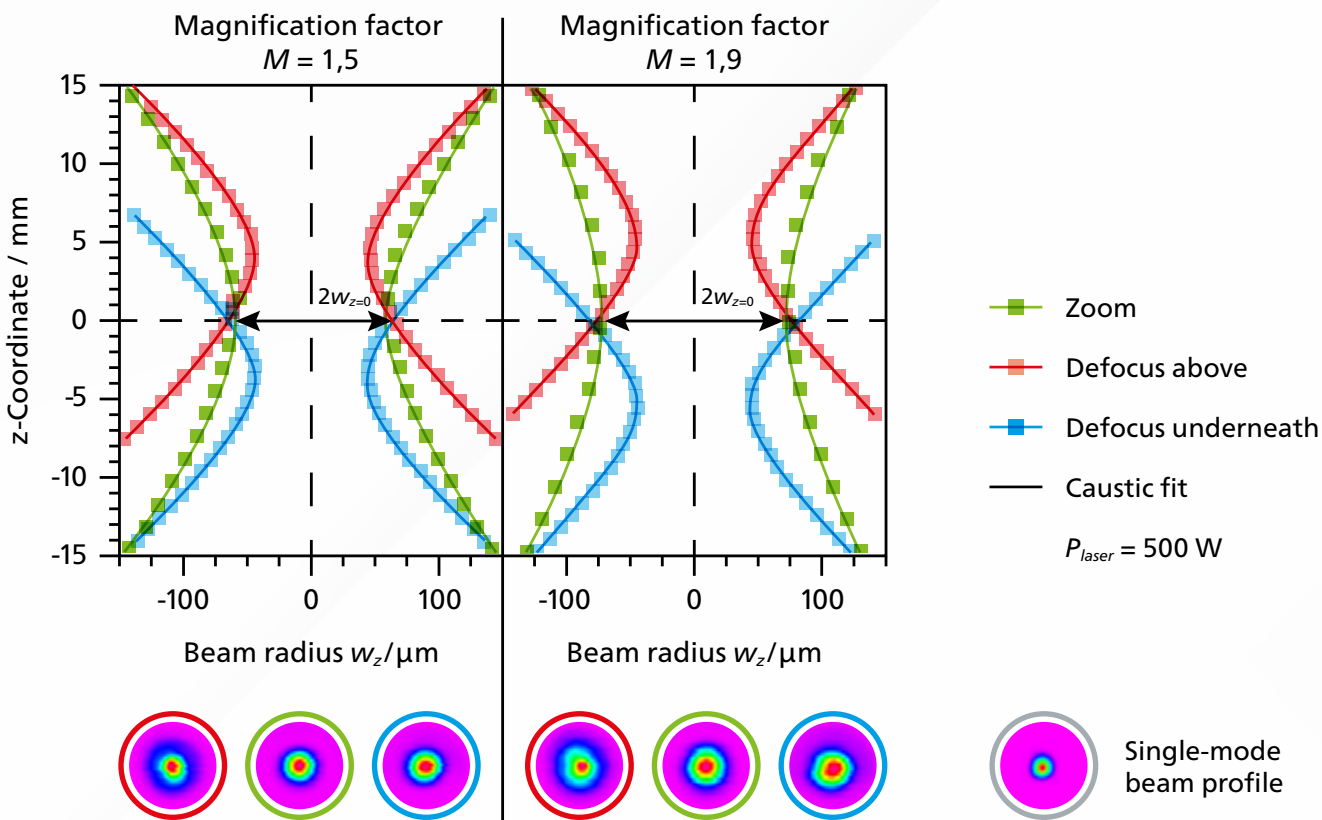
Another option to obtain larger spot diameters are multicore fibers or adaptable ring mode lasers. Here, the fiber core usually delivers a single mode spot, while the fiber ring creates a donut-shaped ring with a larger diameter. Typically, you can distribute the power of the laser between the core and the ring to create a variety of beam shapes. You can flexibly switch between single mode, ring mode, or flat top profile. Both the core and the ring are in focus, ensuring a clean beam profile.

Due to their larger diameter with the ring or flat top profile, the adjustable ring mode lasers are well suited to realize a speed advantage when filling large areas. However, the magnification ratio between core and ring is fixed. In addition, the large spot is only available as a ring or top hat.

So if you want to keep the identical power distribution in focus even with a magnified spot or want more than one magnification factor, a customizable ring mode reaches its limits.

Optical Zoom function - continuous spot magnification with optimum beam quality

However, continuous magnification cannot be implemented with a standard deflection unit. For this, you need an additional movable telescope in the beam path, which can vary the beam diameter as an extension for your pre-focusing deflection unit. This is because the minimum spot diameter in the focus also changes with the beam diameter. Therefore, such a zoom optic allows you to continuously adjust the focus diameter without leaving the focal plane. In this way, the original beam profile is still sharply imaged, which is particularly important for special beam shapes such as flat top and donut.



△ **Figure 2: Caustics of a single mode profile at magnification with defocus and zoom arrangement.** The caustic measurement illustrates the different principles of beam magnification. From the spot profiles, you can see that magnification by means of a zoom arrangement does not significantly disturb the beam. In the case of a defocus magnification, only a shift of the focus into the material leads to reasonably defined beam shapes.



Limiting factors for the magnification factor include the free aperture in the beam path, the available space in the deflection unit and the power compatibility of the mirrors and optics. In the accessible magnification range, however, you can implement continuous magnification and flexibly adapt the spot diameter to your application.



In the AM-MODULE III, our patented zoom arrangement enables a spot magnification of 2 x without distorting the beam profile in focus. This works for single mode lasers as well as for special beam profiles like donut or flat top and up to medium laser powers of 3 kW.

Wolfgang Lehmann

Head of Product Management at RAYLASE



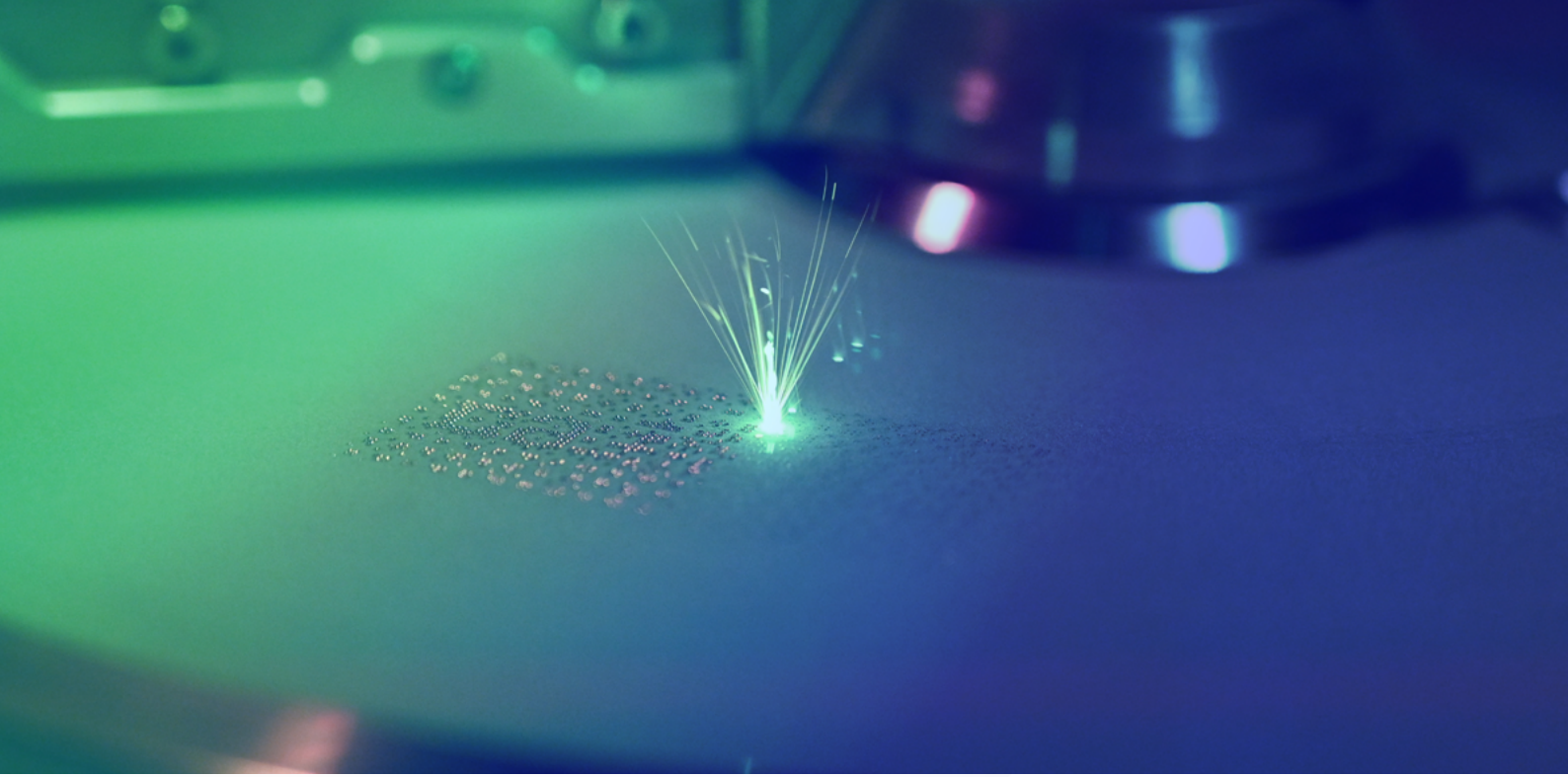
› COMBINATION OF MULTICORE LASER AND ZOOM FOR MAXIMUM FLEXIBILITY

If you are looking for maximum flexibility in focus parameterization for your AM machine, the combination of a multicore or ring mode laser and optical zoom arrangement is the solution of choice. The advantageous beam geometries of a ring mode laser enable fast exposure speeds and low balling effects. At the same time, the zoom function ensures that these beam profiles are maintained even with enlarged spot diameters. This means that even hatching with a large spot diameter can be further optimized for speed and the full performance of a modern deflection unit can be utilized.

Beam profile	Zoom	Defocus underneath	Defocus above
Single mode			
Flat top			
Ring mode			

◀ **Figure 3: Different beam profiles of an AFX laser at a magnification of 1.5x using zoom and defocus.** From the beam profiles, you can clearly see that only the zoom arrangement (and for the single mode to some extent the defocus underneath) preserves the original beam profile. With defocusing, the beam shape becomes clearly blurred. The advantageous beam properties of a ring or flat top profile are no longer available in this case.





> OPTIMAL BEAM GEOMETRY ENABLES EFFICIENT AM APPLICATIONS

Additive manufacturing technologies have developed rapidly in recent years. One aspect of success is beam geometry, as it directly affects the precision, efficiency and quality of the manufactured part.

By using technologies such as defocusing, adjustable ring mode lasers and zoom, manufacturers can precisely tailor the exposure process to meet the needs of their specific application. And a precisely defined and flexibly adjustable laser focus not only ensures faster production, but also minimizes errors that can result from inaccurate beam shapes. This results in better surface quality and less rework.

In an industry that is constantly looking for ways to reduce costs and increase efficiency, flexible beam shaping solutions offer a distinct advantage. An adaptive beam enables both fine details and large areas to be processed effectively, reducing production times and increasing throughput.



The AM-MODULE III is currently the only deflection unit in the world with which you can continuously enlarge a multicore or ring mode laser while retaining the advantageous ring shape. This allows us to offer all AM machine manufacturers the greatest flexibility in adapting the spot profile to your application.

Wolfgang Lehmann

Head of Product Management at RAYLASE



📍 **HEADQUARTERS:**

RAYLASE GmbH
Wessling, Germany

☎ +49 8153 9999 699

✉ info@raylase.de

📍 **SUBSIDIARY CHINA:**

**RAYLASE Laser Technology
(Shenzhen) Co.**
Shenzhen, China

☎ +86 755 28 24 8533

✉ info@raylase.cn

📍 **SUBSIDIARY USA:**

**RAYLASE Laser
Technology Inc.**
Newburyport, MA, USA

☎ +1 978 255 1672

✉ info@raylase.com

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