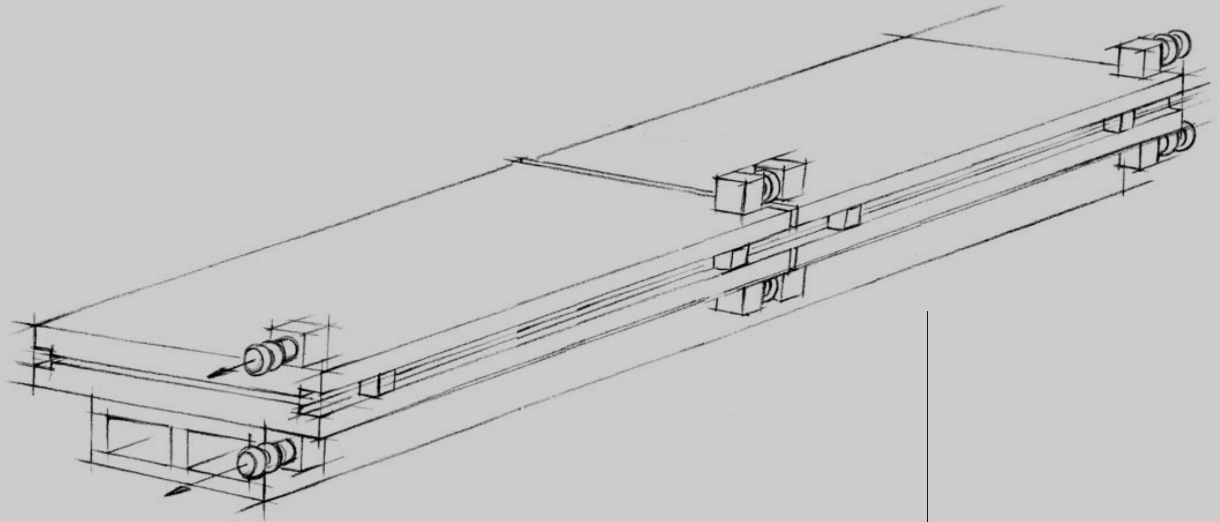
THE SLAB PRINCIPLE

A Fact Book for the Most Advanced
CO_2 Laser in the World



THE POWER OF LIGHT

ALMOST A CLASSIC

For more than 10 years CO_2 Slab lasers from ROFIN have been in use all over the world. Cutting structural steel and acrylic-glass, welding drive gears and airplane components: over the years this laser has gained an excellent reputation in industry due to its operating principle and extraordinary characteristics.

Rofin began development in the early 1990s, of the first CO_2 Slab laser. This was the beginning of the success story of this robust, low-maintenance laser series. In 1993, Rofin presented a diffusion-cooled CO_2 Slab laser of the DC series with 1 kW output power at the "LASER" exhibition in Munich. The potential of this laser principle was soon recognized, and in 1995, a 2 kW laser was in production.

Due to its outstanding features, the DC series has remained a success. Through continued development, an 8 kW version is now available and the product line will see further advances. The high availability, low service and maintenance expenses, as well as the excellent beam quality have been convincing customers from a wide range of industries all over the world.

More than 4,000 DC series lasers have been delivered up to date and they have provided reliable service, night and day for a wide variety of applications.

With this manual, we would like to bring home to you the most important features and advantages of this laser series. This book has been developed as a guide to the Slab laser and provides short and clear answers to the most important questions.

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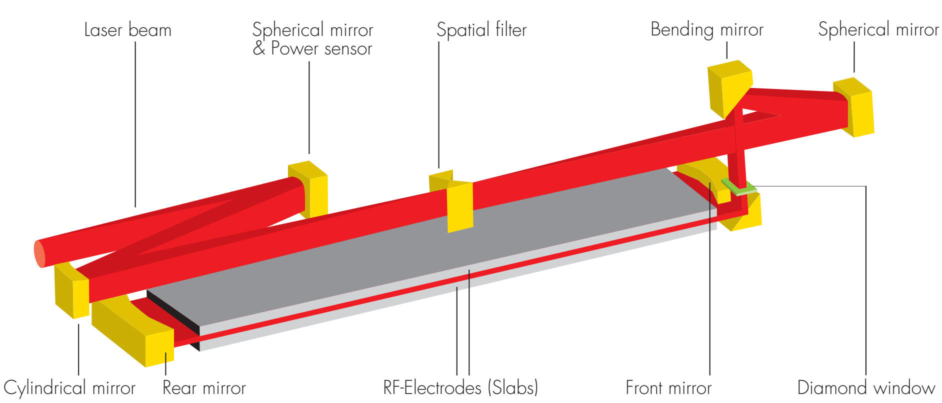
THE SLAB LASER TECHNOLOGY

How Does a CO_2 Slab Laser Work?

The operating principle has a laser active CO_2 gas mixture between two parallel copper electrode slabs. In this small space of only a few millimeters, a high frequency discharge occurs. This excites the CO_2 molecules to a higher energy state and creates a 10.6 μm wavelength laser beam, typical for CO_2 lasers. The laser light is reflected in the resonator cavity by parabolic mirrors, before a portion of this radiation is allowed to exit the resonator area. This eliminates the need for a conventional output coupler. As the resonator cavity is in vacuum, this is achieved by a diamond window that has no optical characteristics of its own. The diamond window, unlike the output coupler, is not subject to thermal effects and is not a consumable optic.



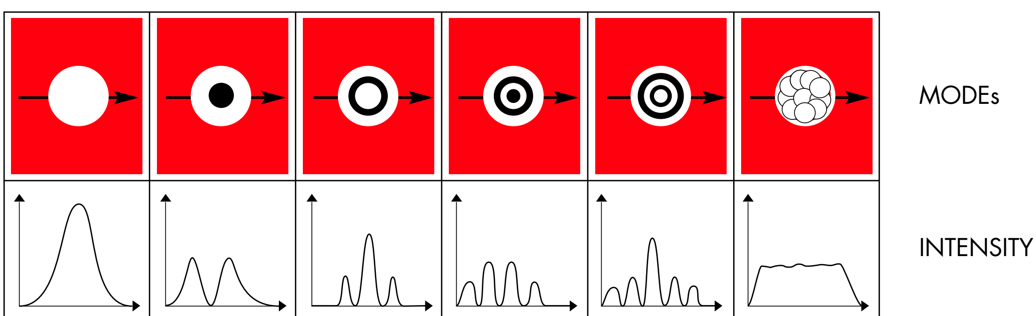
Having left the resonator the laser beam is led through a variety of optics. In order to provide accurate cuts, regardless of direction, water-cooled and reflective beam, components form the originally rectangular beam into a round symmetrical one.

The laser beam is directed by a plane mirror before it passes through the spatial filter by way of a spherical mirror. Behind the last, partially transmissive mirror is the power sensor which detects the laser output and forwards the value to the electronics that regulate the resonator output.

What Does Beam Quality Mean?
What is the K-number and the Beam Parameter Product?

The beam quality is a measure of the performance of the laser. In general, the beam quality indicate how focusable the laser beam is. It is specified by the K-number or is otherwise referred to as the beam parameter product (BPP). This BPP (unit mm*mrad) describes the beam distribution (mainly the parameters of focus diameter and depth of field). The high beam quality of the Rofin Slab provides smaller focus diameters and an improved depth of field.

One (1) ist the optimum K number. This provides a Gaussian energy distribution across the beam profile. Slab lasers typically have a beam quality of K ≥ 0.9, which is close to the theoretically maximum value of 1.0. Slab lasers are distinguished by excellent focusability. In the following diagram, several modes with different beam qualities are compared. The lower the K-value, the lower the beam quality.



TYPE	TEM_{00}	TEM_{10*}	TEM_{10}	TEM_{20*}	TEM_{20}	MULTIMODE
K-FACTOR	K=1	K=0.5	K=0.33	K=0.25	K=0.2	K=0.14

Some beam qualities in comparison:

CO_2 Slab Laser	**CO_2 Laser** (conventional)	**YAG-Laser** (rod)	**YAG-Laser** (disc)
K ≥ 0.9	K ≤ 0.6		
≤ 3.75 mm*mrad	≥ 5.5 mm*mrad	12 bzw. 25 mm*mrad	8 mm*mrad

Lasers with high beam qualities provide more efficient process control because higher feed rates with smaller focal diameters can be reached. This is particularly useful when welding. The smaller focal diameter produces a higher energy density on the work piece allowing large welding depths to be achieved with a minimal heat effected zone.

DC Series, CO_2 Slab Lasers or Slab Lasers – Why All These Different Names?

This laser series is accurately named "ROFIN DC series", since DC stands for "diffusion-cooled". The addition of "010" to "080" indicates the laser power, and the W stands for welding. So a DC 010 has an output power of 1 kW and a DC 080W an output power of 8 kW. The word "slab" describes the design of the electrodes. CO_2 Slab laser therefore stands for a CO_2 gas laser with a discharge module (resonator) that is in the form of a slab. Over the years, the word "Slab laser" or simply "Slab" has become standard in the market and defines this unique design of high-power lasers by ROFIN.

Diffusion-Cooled? What's That?

In conventional CO_2 lasers, the gas flows with the help of a turbine or a blower through the resonator. The heat created is dissipated outside of the resonator and cooled by an external heat exchanger. The gas can then be returned to the laser. In contrast to this principle, the Slab laser operates without any gas circulation. The narrow inter-electrode spacing allows effective removal of the heat from the discharge chamber via the directly water-cooled electrodes. Heat transportation is achieved solely by diffusion of the heated molecules to the cooled electrode plates. This principle is simply referred to as diffusioncooling.

What Makes This Principle So Special and Good?

No moving parts or consumable optics – There are several major advantages of the Slab laser principle related to service and operating costs! There is no need for turbines and blowers, which are susceptible to wear and tear and high maintenance requirements. Optics contaminated by flowing laser gas (especially the outcoupling windows) are a thing of the past. The Slab principle also has advantages in the "standby" mode: by omitting loads like turbines or blowers electrical costs are cut. The relatively small amount of cooling water in circulation further reduces energy consumption. The minimal service requirements and energy efficient features reduce overall cost of ownership.

Why Is No External Gas Supply Required?

Unlike to cross-flow CO_2 lasers, gas only needs to be replaced every 72 hours. The small 10 L gas bottle (with a filling volume of 1500 NL) integrated into the laser head, containing a (PREMIX) gas mixture, lasts up to 15 months, depending on the lasers rated power. Essentially an external gas supply is eliminated. The operating company does not require space for a permanent gas bottle rack, and does not have to deal with the logistics of regular bottle changes. Furthermore, the probability of resonator contamination by improper gas bottle exchange is minimized.

How Large Is The Footprint For This Laser?

In all power classes the Slab laser is one of the most compact CO_2 lasers on the market. The RF generator is completely integrated into the laser head and does not take up precious floor space. ✔ Due to this, the lasers are easy to integrate into quotes machine systems. The Compact version combines the control cabinet under the laser head, forming a single package. The Standard version offers the possibility to position laser head and control cabinet separately.

AT A GLANCE: THE ADVANTAGES OF THE SLAB LASERS AT A GLANCE

- ✔ A proven principal built to the highest industrial standards
- ✔ High beam quality of K ≥ 0.9 for best application results: fastest cuts and deepest welds
- ✔ Low service costs thanks to the robust, low maintenance design
- ✔ Low maintenance with no consumable components
- ✔ No gas recirculation due to diffusioncooling (no gas flow)
- ✔ Minimal energy consumption while in standby
- ✔ Space saving construction thanks to compact design

THE SLAB LASER APPLICATIONS

The Slab laser is suited for welding and cutting a wide variety of materials such as mild steel, stainless steel, aluminum etc. As a result of its high beam quality, large welding depths and high cutting speeds (especially for metal sheets of up to about 3 mm) can be reached. Materials up to about 25 mm thick (mild steel) and 15 mm (stainless steel) can be cut with output powers up to 5 kW. At the moment, CO_2 Slab lasers are available with output powers from 1,000 (DC 010) to 8,000 Watt (DC 080 W). DC 060 W and DC 080 W lasers with output powers of 6 and 8 kW are reserved for welding applications. The abbreviation W stands for Welding.

CUTTING WITH A SLAB LASER

Laser cutting is one of the most significant laser applications. Typically, mild steel, stainless steel and aluminum are processed. Other materials such as wood and plastics are exclusively cut by CO_2 lasers as their wavelength of 10.6 μm is highly suitable. Even for cutting of low strength material, high beam quality offers the advantage of small cutting kerf widths and high cutting speeds. Cutting applications using a scanning head also benefit from the high beam quality, e.g. for cutting of abrasive papers. The exceptional beam quality yields longer focal lengths (operating distance) while maintaining high energy density. Cutting of low-alloyed steels, such as mild steel, typically uses oxygen as the laser cutting gas. In the case of stainless steels and aluminum, a high-pressure gas (argon, nitrogen) is used. This process is referred to as fusion cutting and requires a higher laser power.

Does More Power Lead to Faster Laser Cutting with Oxygen?

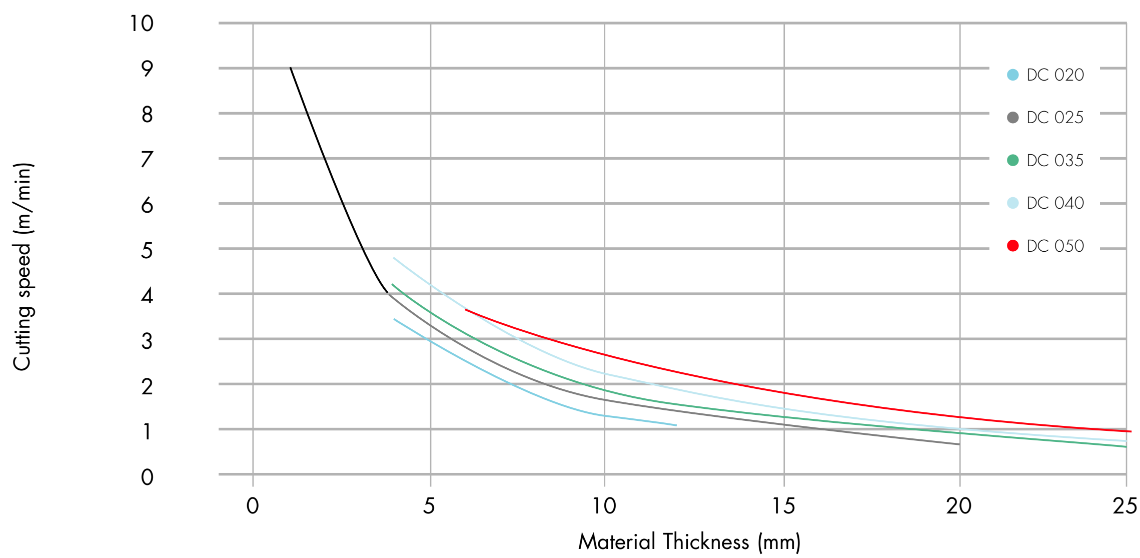
In general, the maximum cutting speed of the laser cut is not solely dependent on laser power, but also on the combustion process. If you increase the power for a certain material thickness, the speed increase will not be proportional to the power increase. This is due to the exothermic reaction being created during the cutting process. Therefore, a higher powered laser provides the opportunity to cut thicker materials more reliably, but higher powers will not provide a higher cutting speed in thinner materials, when using oxygen as the assist gas.

What Advantages Does the Slab Laser Offer for Laser Cutting?

Due to their high beam quality, for sheet metal thicknesses of about 6 mm, CO_2 Slab lasers reach higher cutting speeds or need less power than lasers with poorer focusability (the beam quality compensates power). Therefore, with a Slab laser either station times in production, or capital expenditure and energy costs can be reduced. ✔ These advantages do not limit the possibility to cut thick mild steels at high laser powers. Thanks to the high beam quality and resulting low divergence of the beam, a greater depth of field can be reached in which the focus parameters are very constant.

LASER GAS CUTTING (ASSIST GAS OXYGEN)

ROFIN DC series, Cutting, Mild Steel (RAEX), 7.5" Focal Length



- The picture shows the comparison of the cutting parameters in the range of 2.0 to 5.0 kW with mild steel (RAEX 380). You can see that at 12 mm a 2 kW Slab can achieve cutting speeds of about 1 m/min.
- With a power of 5 kW higher cutting speeds can be reached (about 2 m/min), but the power does not automatically double the cutting speed, since the is controlled by the combustion process.
- From material thickness greater than 20 mm, lasers with 3.5 kW and more can achieve good results.

CONCLUSION: High beam quality results in greater speed or depth at a given power.

Does More Power Result in Faster Laser Fusion Cutting?

Exothermic reaction does not play a role for fusion cutting. Fusion cutting requires the use of high-pressure gas to remove material from the cutting zone. The cutting speed increases as the laser power is increased. The process is limited by the material flow and expulsion.

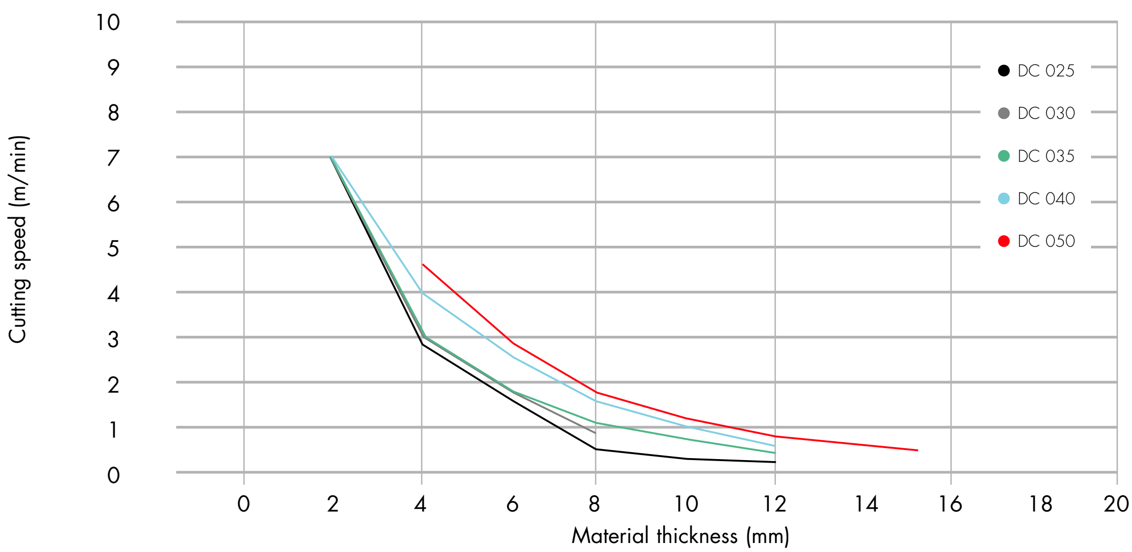
What Advantages Does the Slab Laser Offer for Laser Fusion Cutting?

The small cutting kerf can be attributed to the Slab lasers excellent beam quality. The smaller kerf achieves higher cutting speeds, far superior to those of other CO_2 lasers of equal power.

Therefore, either the station times for laser fusion cutting can be reduced or capital costs can be saved. As material thickness increases, a wider kerf is needed to remove the additional material from the cut zone. The kerf width can be changed by adjusting the focus.

LASER FUSION CUTTING (ASSIST GAS NITROGEN)

ROFIN DC Series, Cutting, Stainless Steel (1.4301), 5 and 7.5" Focal Length

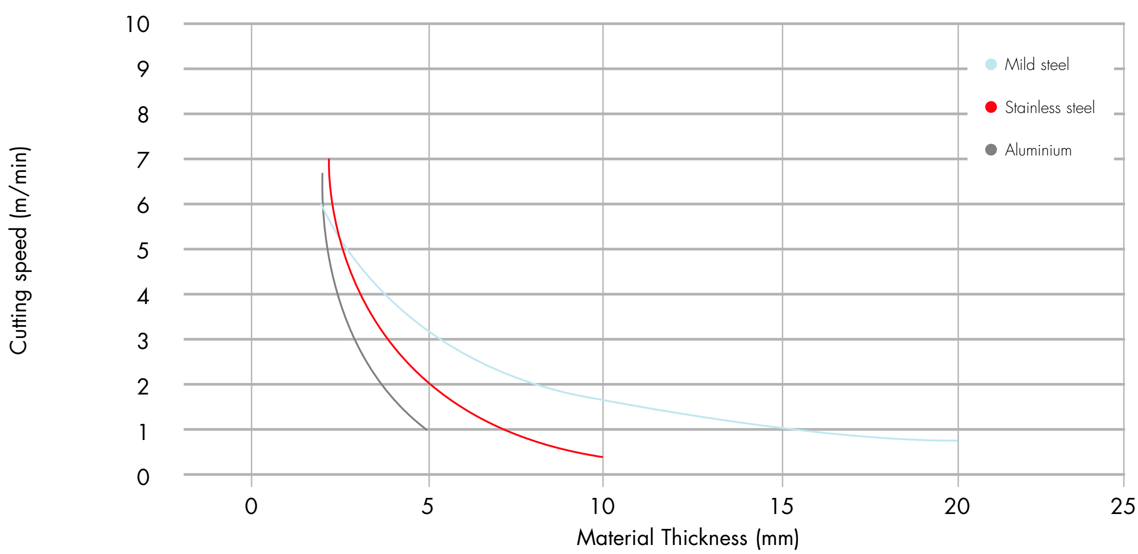


CONCLUSION: High beam quality results in greater speed or depth at a given power.

LASER FUSION CUTTING (ASSIST GAS NITROGEN)

ROFIN DC 025,

Cutting, Mild Steel, Stainless Steel and Aluminum (Comparison), Flying Optics; 7.5" Focal Length



- This graphic shows the comparison of typical materials (mild steel, stainless steel, aluminium) during the cutting process with a 2.5 kW Slab laser.

CONCLUSION: With a Slab laser of this laser power class the majority of common applications (e. g. job-shop production) can be processed.

AT A GLANCE: THE ADVANTAGES OF SLAB LASERS FOR CUTTING APPLICATIONS

- ✔ Shorter station times or reduced capital costs
- ✔ Smallest kerfs for highest cutting speeds
- ✔ High beam quality results in greater speed or depth at a given power
- ✔ Highest efficiency thanks to the excellent beam quality
- ✔ Large process steps for secure production with flying optics
- ✔ Powers for all demands: 1,000 up to 5,000 Watts

WELDING WITH A SLAB LASER

Due to its efficient application of energy, the Slab laser is capable of deep, narrow welded joints, with low distortion and minimal thermal stress (key-hole welding). High welding speeds, the ease of automation, and the possibility of monitoring the quality online have made laser welding a popular and cost effective joining method in modern industry. For welding, Slab lasers with up to 8 kW power are available. The high beam quality provides superior welding depth and therefore greater process capability.

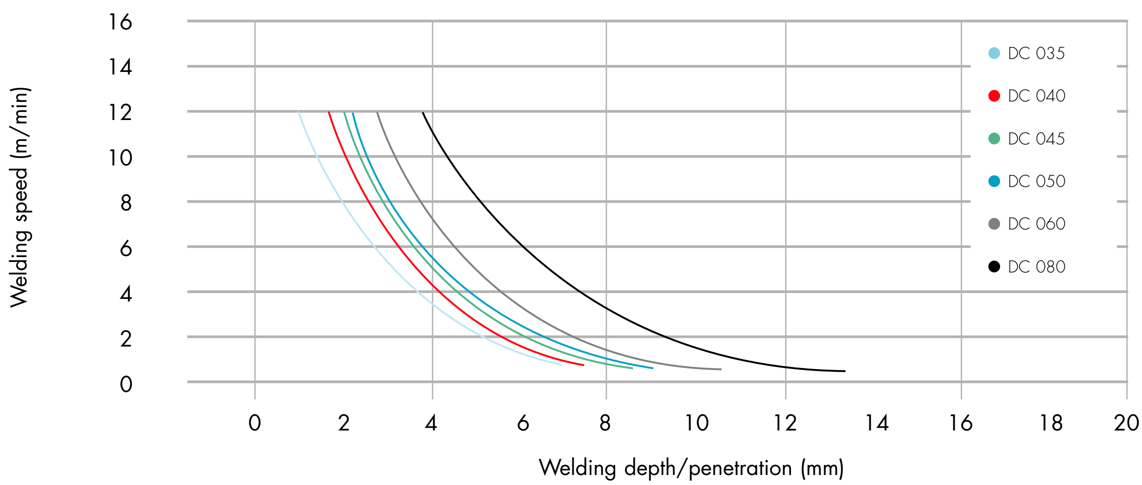
How Can Welding Benefit From High Beam Quality?

The excellent Slab laser beam quality of of $K \geq 0.9$ over the complete range of systems makes high welding efficiency possible. In general, lasers with high beam quality can be focussed very well which allows small spot diameters. The high energy density in the focused spot offers very deep or fast welding. Lasers with very good beam quality provide excellent depth of field, with long focal lengths. These long focal lengths can for example, be useful for remote welding. Here, the laser beam is focused by an optic with a focal length of up to 2 m onto the component achieving a very large working envelope. A small deflection of the mirrors results in a big beam deflection on the work piece beneath. Thus, the non-productive transit times can be nearly eliminated and the station times for a component can be reduced considerably. This applies especially to multiple short seams. In addition, the sealed optics are protected against contamination and dirt. ✔

And What About Welding With Higher Production Tolerances or High-Strength Steels?

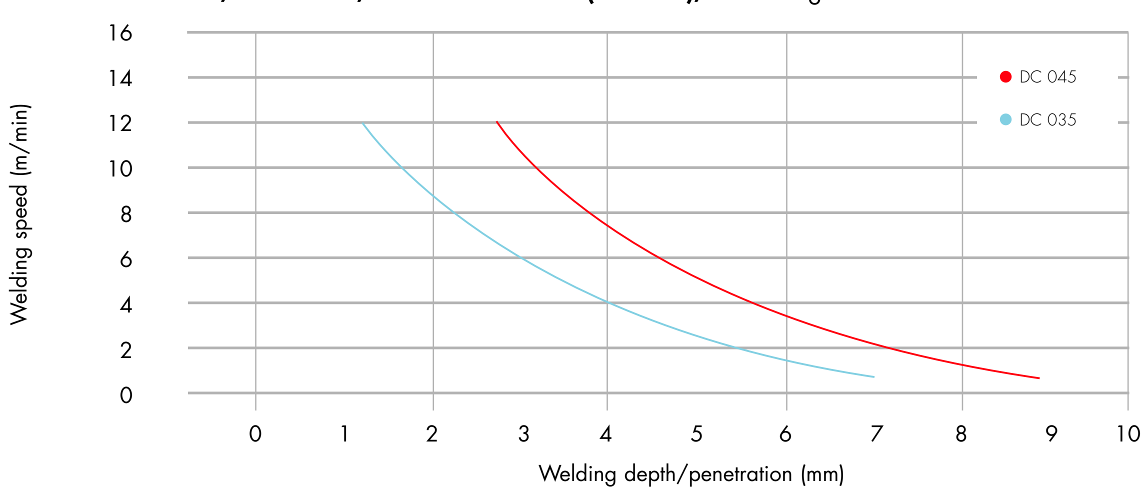
In cases where energy density needs to be adapted to a specific application the donut-mode is available as an option. By the exchange of the last optic with a specially machined mirror a ring-mode or donut-mode can be created as an alternative to the usual gaussian-mode. The reduced beam quality and expansion of the spot (annular distribution of energy) assists in applications that require an increased weld pool volume to avoid fissuring (e.g. for high-strength steels) or to bridge over gaps resulting from production tolerances. This can be advantageous for the welding of non-linear tailored blanks (butt weld).

ROFIN DC SERIES, WELDING, MILD STEEL (ST 52), Focal Length 300 mm



- You can see clearly there is a uniform increase in the welding depth and speed depending on the laser power. The comparable curve progression makes clear that all lasers are equipped with the same beam quality. Welding depths of up to 12 mm cover the majority of industrial applications.

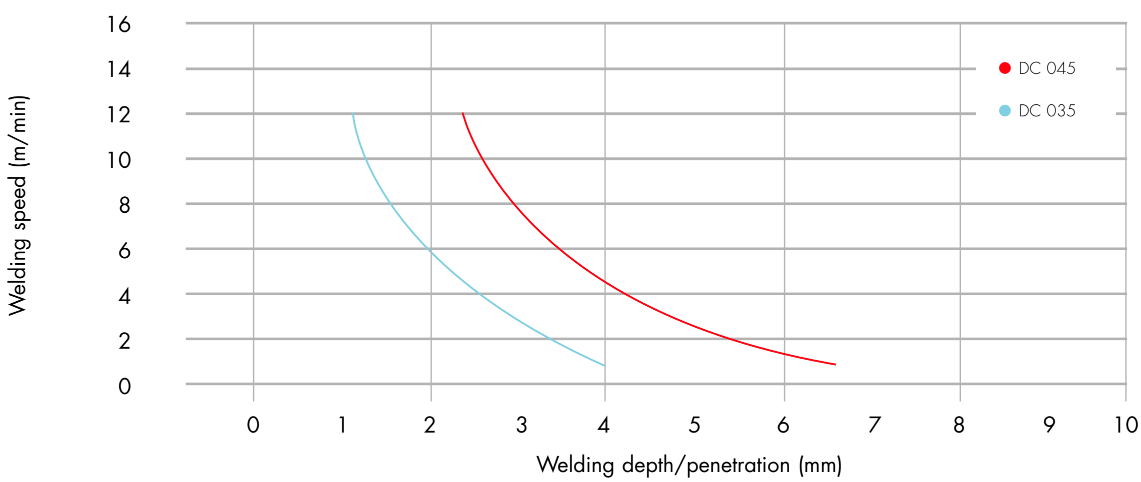
ROFIN DC SERIES, WELDING, STAINLESS STEEL (1.4301), Focal Length 300 mm



- Extract from a stainless steel welding curve for 3.5 and 4.5 kW

CONCLUSION: Compared to mild steel the welding depths in stainless steel are larger for speeds faster than 2 m/min approximately.

ROFIN-DC SERIES, WELDING, ALUMINUM (AlMg3), Focal Length 150 mm (Double Spot 0.6 mm)



- The CO_2 Slab laser is very effective welding aluminum due to its high focusability. For process stability, double focus techniques are often used. Welding speeds of about 4 m/min with a 4 mm welding depth are possible. Even when using an additional filler wire, the CO_2 Slab laser has proven itself in applications such as the Airbus-assembly (stringer welding).

AT A GLANCE: THE ADVANTAGES OF SLAB LASERS FOR WELDING APPLICATIONS:

- ✔ Distortion free welding thanks to a low heat input into the component
- ✔ High welding speeds for shortest station times
- ✔ Easily automated
- ✔ Highest process efficiency
- ✔ Excellent focusability for fast or deep welding
- ✔ Long focal lengths for large working distances
- ✔ High powers up to 8 kW available
- ✔ Donut-mode for welding components with large tolerances

THE SLAB LASER: INTEGRATION AND SERVICE

How Can the Laser Be Integrated into Already Existing Line?

Standardized interfaces and a compact design make it easy to integrate the laser into existing machines and facilities. The innovative concept enables system solutions where the laser itself is moved with consideration of the allowed acceleration values. This ensures that in large moving bridge applications the same beam or focus parameters exist for the entire area of operation. The relatively small beam divergence of the Slab lasers between 2 to 9 m is especially important in cutting machines with flying optics. It becomes possible to operate without an external telescope while providing almost constant beam parameters for the whole operational field. ✔

What About The Service? Can One Maintain A Slab-Laser Oneself?

Compared to its main competitor (the fast axial flow CO_2 laser (FAF), the Slab laser requires a relatively low maintenance effort. A preventive maintenance inspection is done every 2,000 hours and can be done by a ROFIN trained and certified customer. The annual or 6,000 running hours service will be carried out by ROFIN service technicians.

AT A GLANCE: THE ADVANTAGES OF SLAB LASERS REGARDING INTEGRATION & SERVICE

- ✔ Standardized interfaces & compact construction for simple integration
- ✔ Low maintenance effort
- ✔ Best cutting results with flying optics due to the low beam divergence even without external telescope

SLAB VS. FAF

Diffusion-cooled Slab lasers and conventional fast-axial-flow lasers (FAF) are significantly different in construction. As a result of these differences, the Slab provides improved beam quality, and availability, while maintenance requirements are reduced. There are also advantages in the investment and operating costs.

Slab vs. FAF – an Easy Choice?

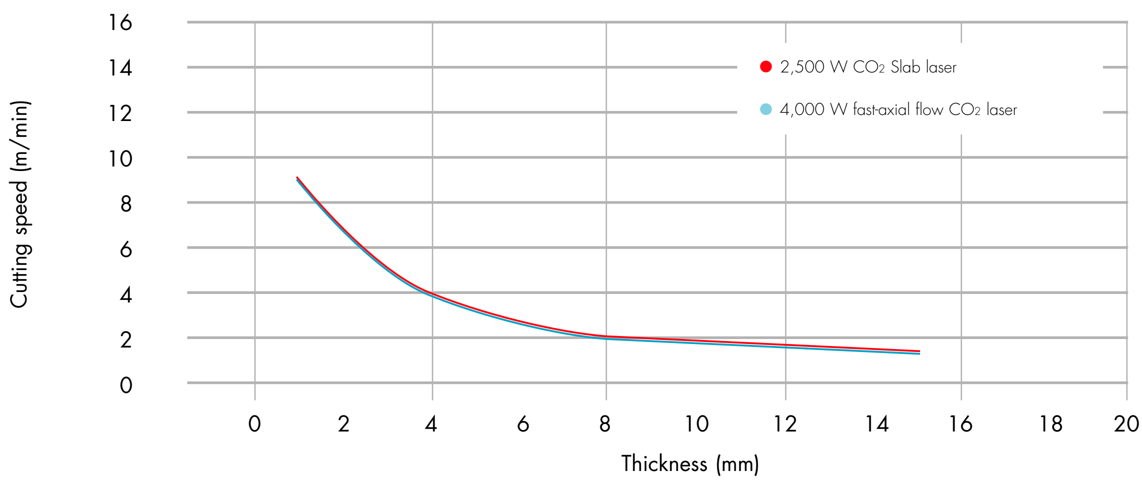
Generally, the Slab laser becomes the obvious choice when the advantages of its beam quality characteristics, as described above, are taken into consideration.The low maintenance requirements, reduced consumable costs (energy, laser gas) and capital costs, are increasingly included into the overall view. Depending on the application of the laser, in many cases direct cost advantages arise compared to its main competitor: the FAF. Furthermore, improvements in the quality of processed components can be reached. ✔

The differences of both technologies can be compared as follows:

Diffusion-cooled CO_2 Slab laser	Conventional FAF laser
High beam quality, K ≥ 0.9	Medium beam quality, K ≈ 0.5
No flowing gas, no blowers/turbines	Blowers/turbines are necessary
Minimal gas consumption	High speed flowing gas and consumption
Transmissive diamond window	Transmissive outcoupling window (ZnSe)
Minimal consumables	Cost-intensive wear parts, e. g. blowers/turbines
Low maintenance effort and costs	High maintenance effort
Highest availability	

CUTTING OF MILD STEEL WITH CO_2 LASERS

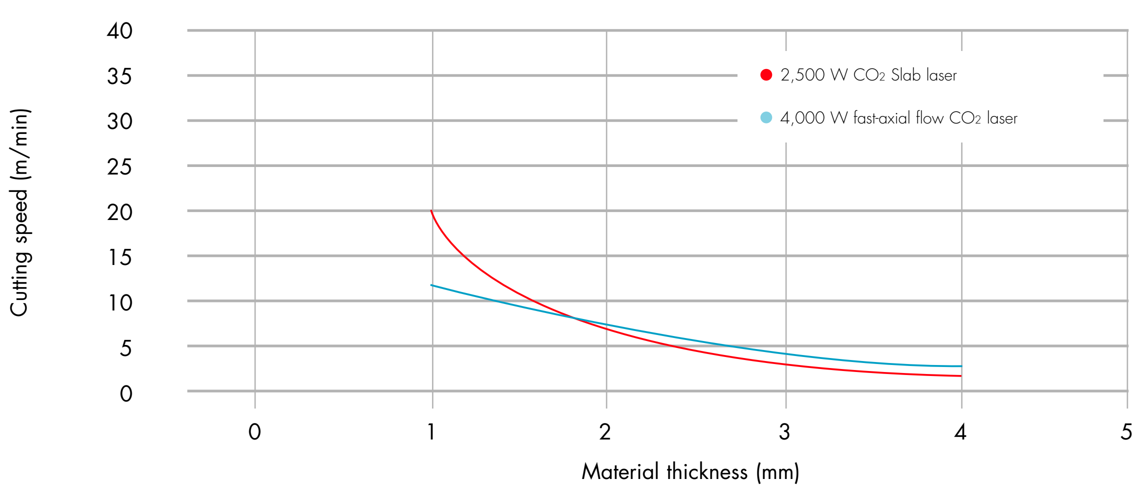
2,500 Watt Slab compared to 4,000 W FAF



- The cuttings speeds of mild steel (up to 6 mm) are nearly the same for a 2.5 kW Slab laser and a 4 kW FAF laser. For thicker sheet metals, the values differ from each other slightly.

CUTTING OF ALUMINUM WITH CO_2 LASERS

2,500 Watt Slab compared to 4,000 Watt FAF



CONCLUSION: A high beam quality can compensate for power.

AT A GLANCE: THE ADVANTAGES OF THE SLAB LASER VS. FAF

- ✔ **REDUCE COSTS:**
  Less operating costs and minimum consumables
- ✔ **SAVE TIME:**
  Lowest maintenance requirements
- ✔ **INCREASE PROCESS EFFICIENCY:**
  Highest beam quality for fastest cuts and deepest welds

FOR YOUR NOTES:

Note: The data shown in the graphics representations was recorded under laboratory conditions. In industrial applications the results may differ as they depend among other things, very much on the cutting systems and the beam guiding system.

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