Laser Cutting - When to choose a single or multi-mode laser.

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This paper is a guide to help determine whether a single-mode or multi-mode laser is appropriate for a given cutting application. Very often single-mode (SM) lasers can cut faster than multi-mode (MM), particularly for thin materials using the same power output, but there is usually a compromise elsewhere. In this paper we identify the trade-offs involved with choosing the SM laser option.

Spot Size

For cutting applications the focal spot size is a key factor, which is mainly driven by the type of laser (single or multi-mode) and the laser output power as shown in ***figure 1***, which shows the typical range of focal spot sizes used for cutting within the laser power range 200W to 6kW. Once the focal spot size has been chosen, many other design elements can be decided such as optical magnification factor, the collimator and focusing optic focal lengths, the model of cutting head as well as the maximum machine cutting speed.

For a given metal thickness, in general as the focal spot size increases, the cut quality will increase, the cutting speed will decrease, and parts are more easily removed from the sheet (good for intricate designs which are easily damaged). However, as the spot size increases the assist gas jet has to work harder to remove more melt, otherwise there will be dross on the cut-edge. In a similar manner as the focal spot size decreases, the cut quality will decrease and cut speeds will increase, but the kerf (cut width) will become narrow so that it will be harder for enough gas to blow through the cut to remove the dross. The work of our Applications team is to experimentally find the optimum focal spot sizes for each laser system configuration and to determine the conditions when a SM or MM laser should be used.

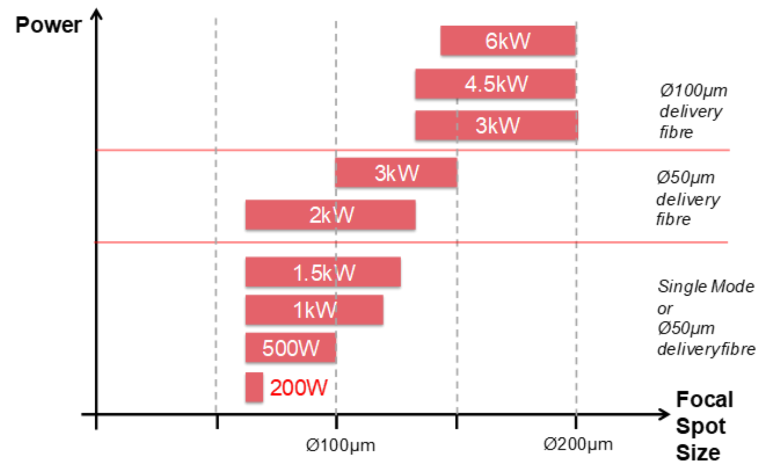

Figure 1: *Typical range of focal spot sizes used for cutting within the laser power range 200W to 6kW*

200W Laser Power

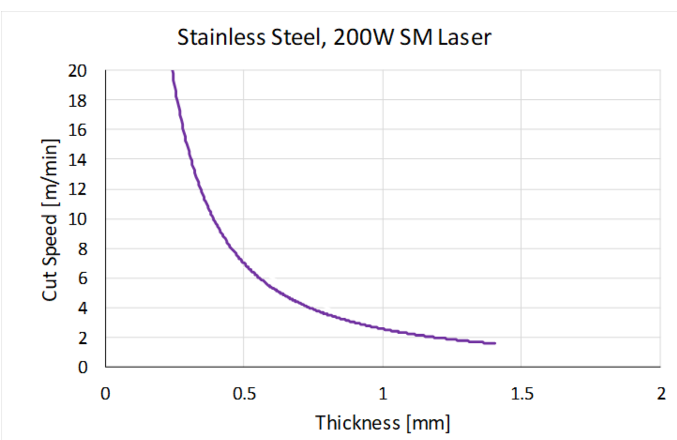

Figure 2: *Cutting performance of a 200W SM Laser using a 60µm focal spot size*

For cutting thin stainless steel at reasonable speeds the 200W laser can be used. Only the SM laser is used at this power level using a 60µm focal spot size; the cutting performance is shown in ***figure 2***.

When cutting thin foils, for example, material less than 250µm thick which is typically used for making PCB stencils or for medical applications, it is common to modulate the laser to maintain the peak power whilst reducing the average power to avoid burning the cut-edge. This brings the advantage of being able to use pulse-width-modulation (PWM) techniques to cut with high quality at varying speeds around the design, which is very useful for cutting intricate parts (e.g. medical stents) without dross or burr.

500W Laser Power

At this power level the optimal focal spot sizes are the same for single-mode (SM) and multi-mode (Ø50µm) lasers, both using Ø60µm. A comparison of the cutting performance for stainless steel is shown in ***figure 3***, which shows that the performance is similar for both single and multimode (MM) except for thin (<1.0mm) sheets where there is a 50% gain in speed with the SM. If the focal spot for the SM laser is reduced to 30µm the 0.5mm thick cutting speed can be further increased to 40m/min, but there is no improvement for thicker sheets.

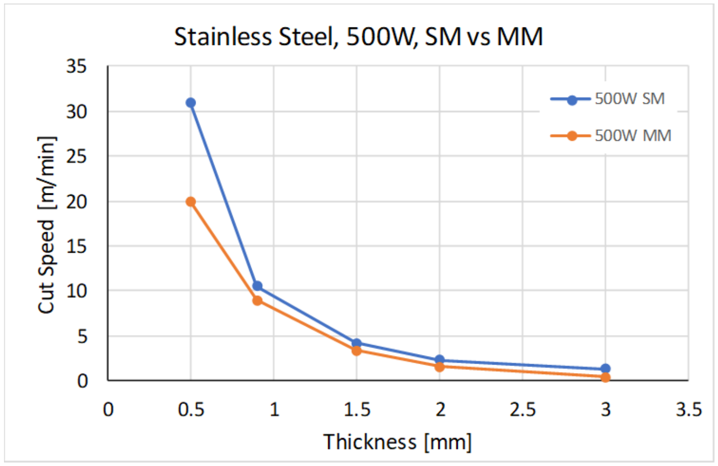

Figure 3: *Comparison of 500W stainless steel cutting performance of SM vs MM*

For mild steel cutting with oxygen the SM laser produces very poor quality cuts characterised by a rough cut edge with large, deep striations and significant dross whilst the MM laser produces good cuts in material up to 6mm thick, as shown in ***figure 4***.

In order to produce a good laser cut in mild steel, a larger incident spot size is needed which generates a wide kerf so that enough low pressure (slow moving) oxygen assist gas can flow down through the cut. When the 500W MM laser is used, the focus position is set above the top metal surface so that the beam size through the sheet metal is relatively large. However, in contrast, the SM laser has low divergence (in comparison the MM laser has a divergence which is 5.5x larger for the same focal spot size) so it is not possible to defocus enough to obtain a sufficiently large incident beam with standard cutting head optics.

In summary, the cutting performance of the 500W SM and MM lasers (**figure 5**) is quite similar for nitrogen-based cutting. Thin sheets (<1.0mm) can be cut much faster by decreasing the focal spot size with the SM laser. Only the MM laser can cut mild steel with oxygen assist.

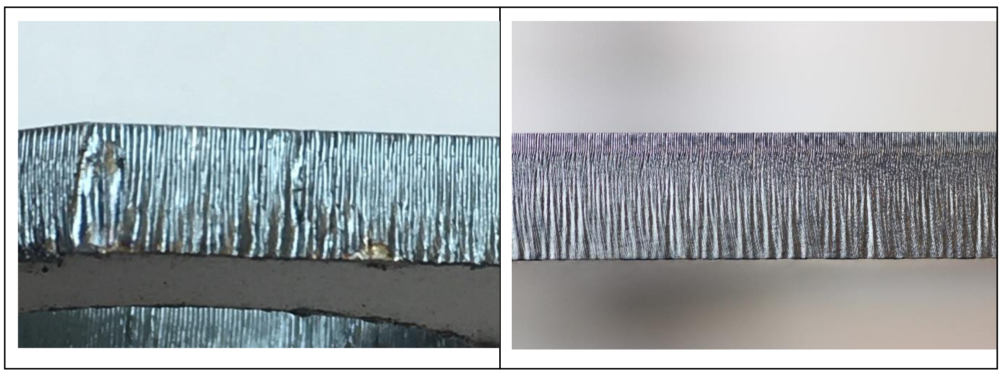

Figure 4: *6mm mild steel cutting with (left) 500W SM laser and (right) 500W MM (50µm) laser. Note the strong striations, rough cut-edge and the droplets of dross of the SM laser cut*

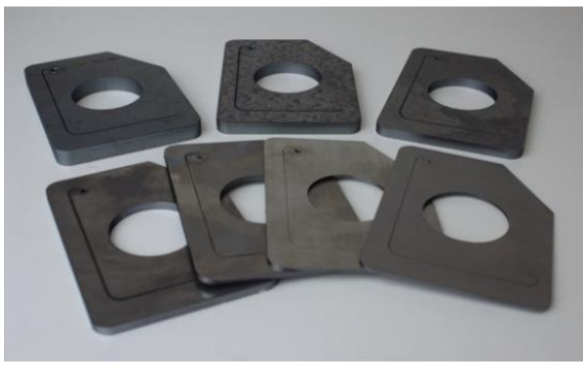

Figure 5: *Mild steel cutting with 500W MM laser*

1000W Laser Power

At this power level the optimal focal spot sizes are Ø60µm (3.0x mag) for the SM laser and Ø100µm (2.0x mag) for the MM laser (Ø50µm delivery fiber). The cutting performance for stainless steel is shown in ***figure 6***, where the SM laser shows a clear speed advantage for sheet thicknesses <2.0mm, but the same performance for thicker sheets. In addition, the maximum cutting thickness for the SM laser is 4mm and for the MM it is 5mm.

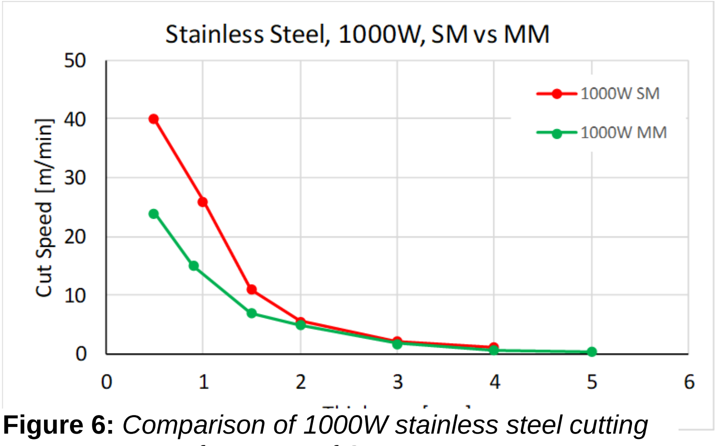

Figure 6: *Comparison of 1000W stainless steel cutting performance of SM vs MM*

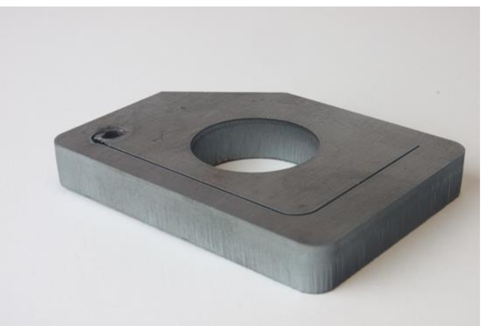

Figure 7: *10mm MS cut with 1kW MM laser at 0.6m/min*

For mild steel cutting with oxygen the SM laser produces very poor cuts (which is due to the low divergence) whilst the MM laser produces good cuts in material up to 10mm thick (**figure 7**).

The comparison of cut performance for aluminium and brass for 1kW SM and MM is shown below in **figure 8**. Generally, the SM laser produces faster cuts, by a factor of 50% for 1.5mm thick Al and by 89% for 2mm brass. The range of thicknesses which can be cut is the same for SM and MM.

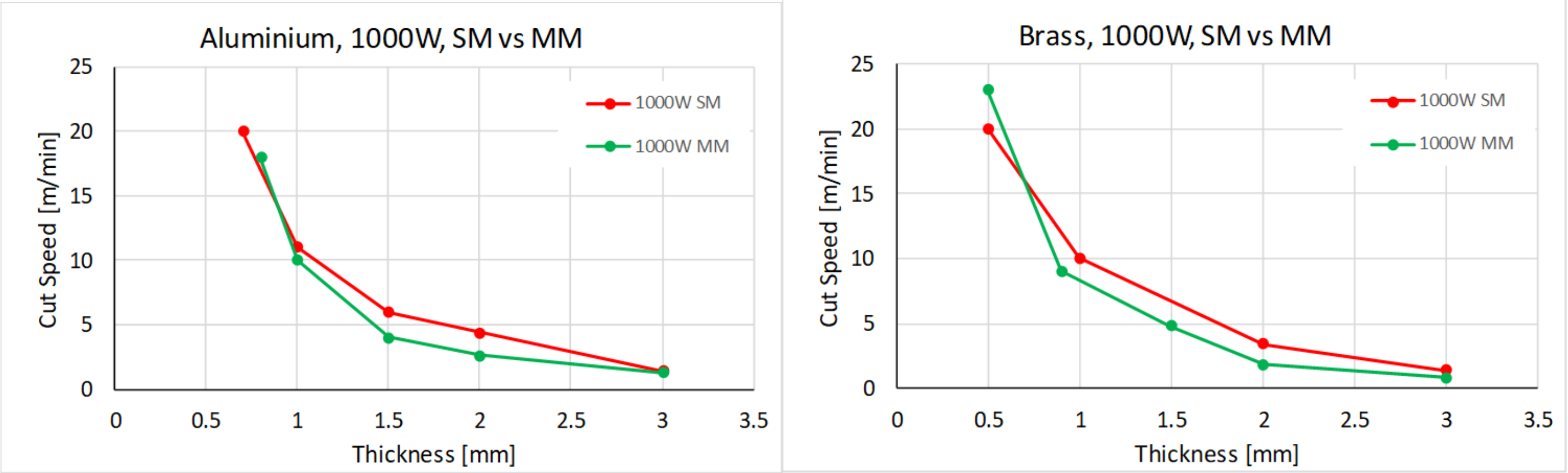

Figure 8: *Comparison of cut performance for aluminium and brass for 1kW SM and MM*

In summary, the stainless steel cutting performance of the 1kW SM and MM lasers is quite similar for sheets thicker than 2mm. Faster cuts can be obtained with thinner SS sheets (<2.0mm) and across the whole range of aluminium and brass with the SM laser, however only the MM laser can cut mild steel with oxygen assist. Therefore, for all-round general performance including mild steel cutting (e.g. a job shop) the 1kW MM laser is a better choice but for specific cutting applications, where mild steel cutting is not needed it is better to choose the 1kW SM laser.

1500W Laser Power

At 1500W the SM cutting speeds for thin material reach speeds as fast as the maximum cutting speed for many flatbed cutting machines. **Figure 9** compares cutting speeds for 1mm thick material (SS, Al, brass & Cu) for SM and MM (Ø50µm) lasers. This comparison used the same cutting head magnification of 2.0x, so the focal spot sizes were Ø40µm for the SM laser and Ø100µm for the MM laser. The figure shows that the SM laser has a significant speed advantage over the MM laser, cutting stainless steel and aluminium at 47m/min (in fact this is likely to be higher but this was the maximum speed available from the test flatbed cutting system). This means that higher SM power levels are unlikely to be used for flatbed cutting applications, and at 2kW and above the discussion moves to deciding whether to use a Ø50µm or Ø100µm delivery fibre. However, the main problem with using SM lasers for full-size (1500mm x 3000mm) flatbed systems is the inability to cut mild steel with oxygen assist with good quality. For jobshop type cutting applications where all-round performance is required, the 1.5kW MM laser is the most appropriate option, however for applications areas where thinner mild steel sheets can be cut with nitrogen assist (HVAC panel cutting, for instance) the SM laser is an option if the bed size allows. Note that the absolute minimum delivery fibre length for a 2 axis gantry-style cutting system is 1.5x the total movement length of both axes, for example a 1.25m x 2.5m system has a minimum delivery fibre length of 5.7m through the flexible guide chains plus 1m at each end = 7.7m, so in this case a 10m delivery fibre should be used. At 1500W laser power the maximum delivery fibre is 15m which is fine in this case.

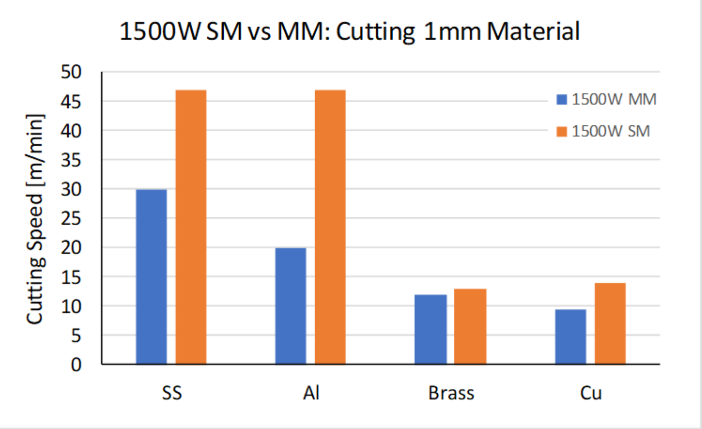

Figure 9: *Comparison of 1mm cutting for 1.5kW SM and MM lasers*

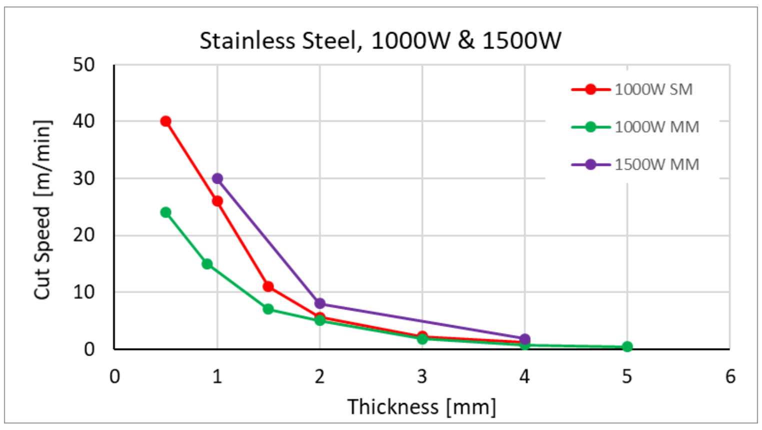

Figure 10: *1000W vs 1500W cutting stainless steel*

When considering sheet thicknesses <2.0mm, it is possible that a 1kW SM laser could be used instead of a 1500W MM laser. The cutting speeds are close, as shown in **figure 10**. For 1mm stainless steel the 1kW SM laser cuts at a speed of 26m/min and the 1500W MM laser cuts at 30m/min – the price vs performance comparison would be very close.

2kW Laser Power

At 2kW laser power the Ø50µm MM laser has good performance with a Ø100µm focal spot (2.0x magnification). This produces fast cutting speeds and good all-round cutting performance, as it is able to cut stainless steel (**figure 11**), brass and aluminium up to 6mm thick, mild steel up to 15mm thick and copper up to 3mm thick. For an entry-level flatbed cutting machine this is a good choice.

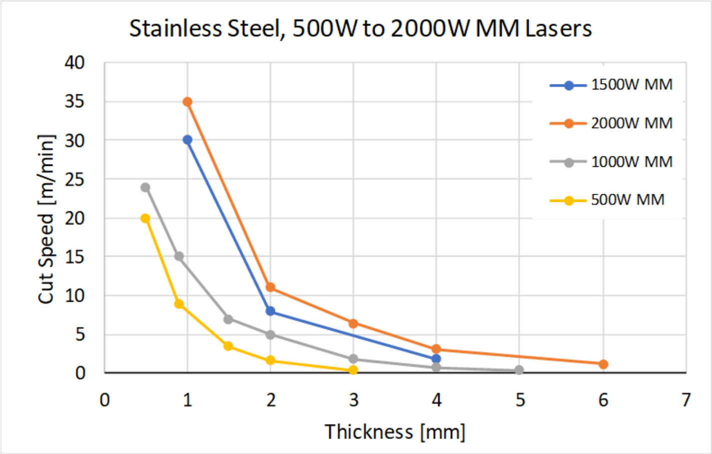

Figure 11: *500W vs 2000W cutting stainless steel*

Summary

- MM lasers are all-round general purpose metal cutting lasers which can acceptably cut mild and stainless steel, aluminium, brass and copper.
- SM lasers are not good for cutting mild steel with oxygen due to low divergence (but can cut thinner mild steel with nitrogen).
- SM lasers produce faster cuts on thinner sheet metals compared to MM lasers, particularly if a small focal spot is used.
- The 1kW SM laser can cut aluminium and brass faster than the 1kW MM laser.
- Careful choice of fibre laser supplier is needed for SM cutting applications to ensure that the maximum available delivery fibre length is compatible with the system requirement.

Note

Typical range of spot sizes for SM, 50µm and 100µm delivery fibres with standard optics:

- SM laser: maximum focal spot size = 60µm (with Fc60 (collimator) and Ff200 (focussing) lens)
- 50um has a focal spot range from 62µm (Fc100 with Ff125) up to 132µm (Fc75 with Ff200) but is typically used with 2.0x mag (Fc75 with Ff150) which provides a 100µm focal spot diameter.
- 100um has a focal spot range from 125µm (Fc100 with Ff 125) up to 266µm (Fc75 with Ff200)

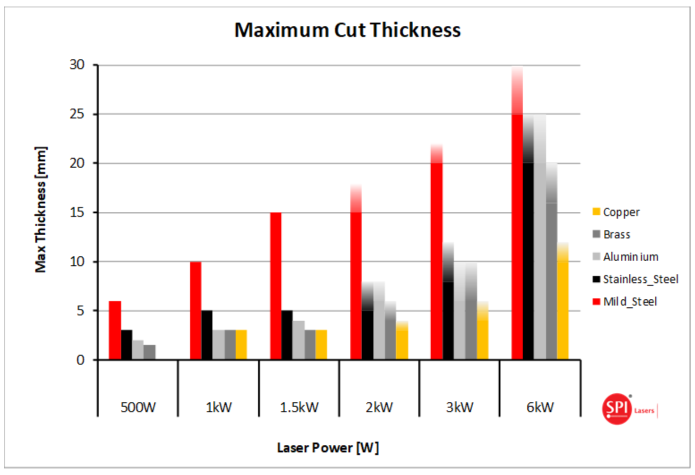

Figure 12: *Maximum cutting thickness for laser powers up to 6kW*

About the author

Dr Paul Harrison *is Chief Engineer for Product Applications at SPI Lasers. Paul graduated from Brunel University in 1992 with a degree in Electrical and Electronics Engineering. From 2001 to 2009 he was the Applications Engineering Manager at Powerlase Ltd until joining SPI Lasers where he now develops customer applications using fiber laser technology. He holds an Engineering Doctorate degree with a focus on researching laser material processing applications of DPSS lasers.*

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Inspired by Light

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