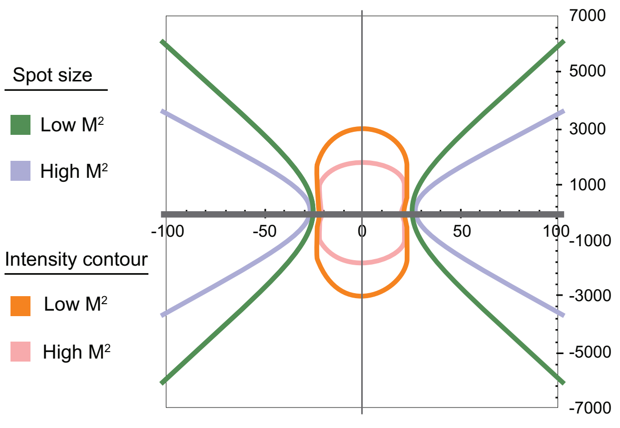
Advantages of Low-M^2 Laser Processing

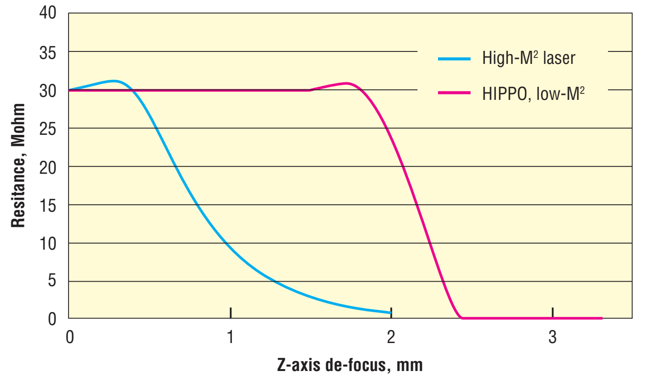
With the variety of performance parameters used to characterize today's lasers systems, a sometimes overlooked characteristic is the M^2, or "beam quality", factor. However, for a majority of laser processes, a higher quality, lower-M^2 beam offers finer-feature machining, improved process robustness, and overall superior process results.

In the context of laser materials processing, a low M^2 is commonly associated with the ability to focus the beam to a tighter spot and hence generate finer features. While this is true, this is not the only significant advantage to be had. In addition to allowing for small spot sizes, a low M^2 results in an increased depth of focus when the beam is focused to a particular spot size. This is important because, regardless of the M^2 of the laser beam, the optics of a system will be chosen to create the focus spot size best-suited to generate the targeted feature size (the width of a thin film removal scribe, for example in solar cell processing). And if high- and low-M^2 beams are focused to the same optical spot size, then the low-M^2 beam will have a longer *Rayleigh Range* and hence a better tolerance for system defocusing.

Defocusing of the optical system is caused by various factors, including material height variation, mechanical slop and slip, and thermal expansion/contraction. For the case of low-quality, high-M^2 laser systems, building a system to accommodate all of these potential variations is not without a price. In the extreme scenario, an auto-focusing subassembly may be required; and for processes with beam scan speeds in the meters-per-second regime, the cost of such a system can be prohibitive. Alternatives may include using expensive, higher-quality materials with strict flatness tolerances, or to suffer decreased production yield—both of which are undesirable for any high-volume production operation.



Graphic depicting low-M^2 advantage of elongated intensity contour for the same focus spot size



Data plot comparing electrical isolation of TFPV P1-level scribe with defocusing for high- and low-M^2 laser beams

In thin film photovoltaic (TFPV) manufacturing, laser scribing is used to remove various thin film materials from a substrate or other film(s). Very commonly, an electrically-isolating "P1" scribe in a conductive film is required. For manufacturing considerations, it is important to determine how sensitive this process is to system de-focusing. In carefully executed studies using tin oxide-coated TFPV glass, electrical isolation was quantified for scribes executed with various amounts of de-focusing. With the high-quality beam and low M^2 ~1.2, of Spectra-Physics' HIPPO™ laser, good scribe electrical isolation was maintained for defocusing by as much as 2 mm; whereas scribes made with the low-quality beam (M^2 = ~1.8) become ineffective after only 0.5 mm of defocus.

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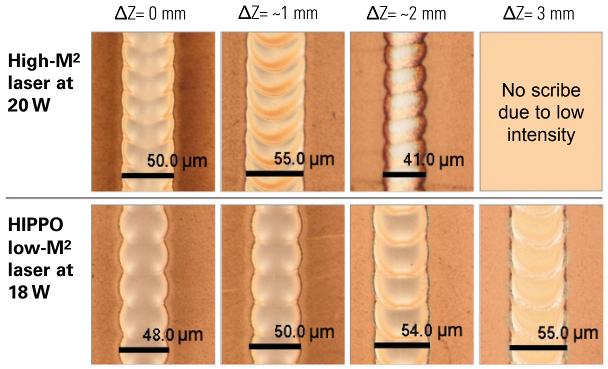
In addition, when scribing with low-quality, higher-M^2 beams, we see a pronounced degradation in scribe quality as the system is defocused. This is illustrated through a series of optical microscope photos taken at various de-focusing amounts. For 2-mm de-focus, where the high-quality laser beam still generates electrically-isolating scribes, the lower quality laser has barely modified the TCO surface; and at 3 mm, there is no visible modification whatsoever. The benefit of TFPV scribing with a low-M^2 beam is clearly illustrated.

As TFPV panels scale to larger and larger substrates, glass quality and flatness will decrease as manufacturers strive to lower costs. Beam quality will become increasingly important for ensuring robust, high-yield scribe processes that are more forgiving of variations in glass substrate flatness, thickness, and other surface irregularities. With Spectra-Physics' offering of high beam quality, low-M^2 laser systems to the marketplace, the potential savings of robust, high-yield laser-processing systems can be fully realized.



Photos showing laser damage with system de-focus for high- (top series) and low- (bottom series) M^2 laser systems

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4 W				
5 W	Navigator		HIPPO	
6 W		Navigator		
7 W				
8 W				
9 W				
10 W			Pulseo	
11 W		Mosaic, HIPPO		
12 W				
15 W		HIPPO		
17 W	HIPPO			
20 W			Pulseo	
27 W	HIPPO			
34 W		Pulseo		

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