Strategies Unlimited
A Research Unit of PennWell

The Worldwide Market for Lasers

Trends and Five-Year Forecast (2017 – 2023)

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Chapter 1: Executive Summary & Totals

1.1 The Overall Laser Market

This report attempts to cover the entire laser market, worldwide. With each issue of this report, we encompass more and more of the expanding laser market. In this report, we add more detailed coverage of laser cinema. In some of the other segments, we haven't added coverage, but rather we have broken down some subcategories into finer granularity. We like to think we have it all covered, but the reality is the laser market is so wide and diverse that it is difficult to know if everything is included in the analysis. As if attempting to cover the entire industry isn't hard enough, knowing exactly which category to place each application in can be even more difficult. If you are looking for a segmentation that isn't covered in this report, please contact the author as we may have it; if not, we could work to include it in a future report, and all feedback is welcome.

1.2 Good News From 2017

There was lots of good laser news in 2017. The very encouraging trend was that lasers were more the "go-to" technology in 2017 than any time in the past. In materials processing, not only did lasers have a strong year overall, but in many areas, laser cutting and welding displaced non-laser cutting and welding in large numbers. Since lasers are not devices that constantly wear out and need to be replaced, growth from replacement laser purchases is rather limited, but lasers for uses that hadn't formerly used lasers is very encouraging.

In segments other than materials processing, there were very good results as well. Apple and other smartphone manufacturers are using lasers for sensing in new and novel ways. These sensors include measuring distances for camera autofocus, measuring object distance for virtual reality applications, and measuring multiple distance points as Apple does for its "Face ID" feature. In addition to laser sensors in phones, LIDAR sensors for self-driving automobiles are becoming increasingly important.

A third strong area in 2017 was lasers used to anneal amorphous silicon into polycrystalline silicon for OLED screens for smartphones. While larger OLED screens for TVs generally don't require this step, high-density OLED screens like those used for smartphones do require this step, and excimer lasers are the most cost-effective method available. Once Apple decided to produce the OLED iPhone X in 2017, sales of excimer lasers for annealing have rapidly increased. With Coherent being the only manufacturer of these (although it's rumored that Gigaphoton will be entering the business as well), volume has been brisk, and Coherent has increased production capacity as much as possible.

Materials processing, smartphone sensors, and OLED screen annealing are just three examples where lasers have become the mainstream solution to tough problems. Much in the same way that microprocessors have become the solution to many problems in the last few years, lasers are joining them as a tool with almost unlimited potential. Overall, 2017 was the best year for laser revenue ever, and total laser revenue over 2016 jumped the largest percentage of any year in memory.

The outlook for each application segment is summarized below. More highlights are presented in each chapter.

- **High-Power Materials Processing (Chapter 3)**

  An increasing amount of KW+ materials processing lasers are being purchased by Chinese companies, but in 2017, an almost equal increase in new lasers went to Europe as well. Welding applications grew faster than cutting, but cutting still makes up the largest segment of laser revenue.

- **Micro Materials Processing (Chapter 4)**

  The micro materials processing segment was generally strong in 2017, driven largely by excimer lasers purchased to anneal OLED flat screen displays for smartphones. If you exclude the lasers for OLED screens, micro material revenue was mostly flat in 2017.

- **Marking (Chapter 5)**

  This segment has expanded through the years, but price pressure from Asian manufacturers has greatly decreased the price of marking lasers. Most marking lasers are fiber, and most of these lasers come from China, but U.S. manufacturers are well represented here also, with SPI, IPG, and a few others participating. The marking segment increased 6% in 2017.

- **Photolithography (Chapter 6)**

  This segment entered the recession in 2007 and came back stronger than many other segments; however, it has been down since 2011 and only started to recover in the second half of 2013 through 2014. Up until 2015, the segment was doing well, but it slowed a bit in 2015 and 2016. In 2017, it returned to life with revenue growing almost 18%. Growth in 2018 is expected to be 15.6%.

- **Printing (Chapter 7)**

  The commercial printing industry has been contracting but has stabilized. Diode lasers dominate, both for prepress applications and in conventional laser printers. The laser printing market has been stable with new printers being deployed in developing countries, but this could quickly slow if their economies slowed, which is happening in places like China. In 2017, laser revenue from printing was down 5.9%.

- **Medical and Cosmetic (Chapter 8)**

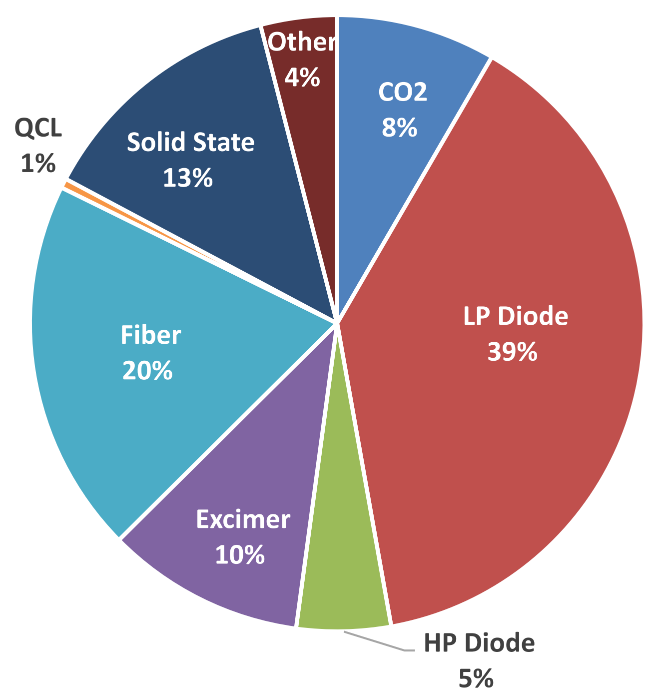
  The last five years have been good ones for medical lasers. Although 2014 started off with a new 2.3% medical device tax that had been feared would negatively impact medical device sales, this wasn't seen much at all, and this tax was suspended in late 2015. Overall, two forces were at work increasing laser medical equipment sales: first, the economy was strong in most regions, which tends to drive elective procedures such as laser tattoo and hair removal; and second, a growing middle class in developing nations drove much demand for new medical equipment, especially for aesthetic lasers. Overall, in 2017, medical laser revenue grew 10.1%, and cosmetic lasers grew the most, 14%.

between 4th Generation wireless deployments and 5th Generation deployments. Today, wireless handles more data and voice traffic than wired communications.

1.5 Laser Market by Laser Type

Figure 1.4 below contains the laser revenue segmentation by laser type for 2017. As this figure shows, low-power laser diode revenue was the largest slice in 2017. While these lasers are among the least expensive lasers available, they are in everything from communications and UHD Blu-Ray players to laser pointers and laser wrinkle removers. Second largest are solid-state lasers, which represent a mainstay of the laser industry. Solid-state lasers can be small or very large, like Nd:YAG lasers than can be used in medical products or industrial manufacturing products. But as Figure 1.4 below shows, while solid-state laser revenue is quite large now, it is not growing very quickly. In many cases, fiber lasers, which operate on the same wavelength as Nd:YAG and Nd:YVO, are replacing them in one direction, while high-power diode lasers are replacing them at the other end.

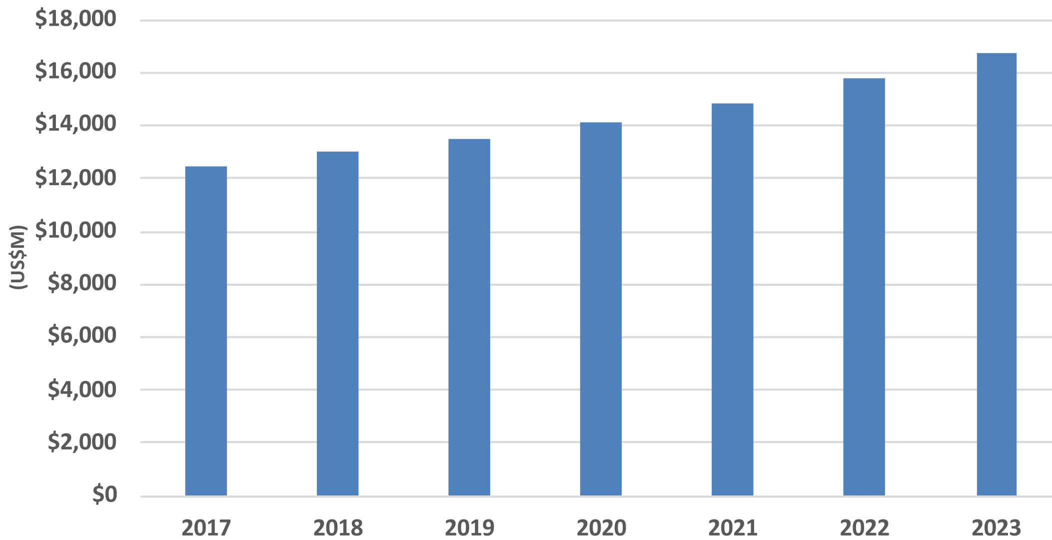
Figure 1.4 Laser Revenue Segmentation by Laser Type for 2017



1.6 Laser Market Summary

As a whole, the laser market has been growing steadily, in a few cases growing at a much faster rate than the worldwide GDP growth, but not always. In 2017, several areas saw unprecedented growth spurts, including KW+ materials processing, micro materials processing, displays, and sensors.

Figure 1.12 Total Laser Market (US$M)



Overall, the laser marketplace is large, expanding, dynamic, and strong. Although lasers have been available for more than 50 years, the number of uses for these very versatile devices continues to grow, and their price continues to decrease. In many applications, price is definitely a factor, and as prices drop, the number of possible applications increases. Overall, the future continues to look good for lasers and their applications.

absorption at visible wavelengths for semiconductors and in nonferrous metals, such as aluminum, titanium, copper, and gold. This is possible because solid-state lasers can be frequency-shifted from 1.0 micron to 532 nm (green), 355 nm, or 266 nm (UV), using a nonlinear crystal. Frequency-shifted lasers are used for many other applications, from medical lasers and biomedical instrumentation to photoprocessing.

The most common gain material is Nd-doped YAG (with output at 1.064 micron), but a number of other dopants and crystals are used. Yb-doped YAG is most commonly used for disk lasers. Other well-known crystal materials include vanadate (Nd:YVO_4), ruby, and alexandrite.

Solid-state lasers include several types: lamp-pumped (LPSSLs) which generally aren't used outside of some lower-cost medical applications, diode-pumped (DPSSLs), and a type of DPSSL called the thin-disk laser. In addition, the fiber laser is yet another type of DPSSL, but because of its popularity, it is broken out as a type by itself. Sometimes disk lasers are also separated from other solid-sate lasers as well.

In some areas, solid-state lasers are losing market share to fiber lasers and to diode lasers. Fiber lasers are gaining share in the materials processing area and in several others. Diode lasers, especially diode lasers in visible wavelengths, are replacing solid-state lasers in display areas, especially as new diode lasers get more powerful and their range of wavelengths expand.

2.2.2 Lamp-Pumped Solid-State Lasers (LPSSLs)

As noted above, LPSSLs are a mature technology and are slowly being phased out, but they are still used in low-cost applications like medical equipment and some research applications in which high pulse power is required. The lamps used can be inefficient and have short lifetimes. Short lamp lifetimes increase the maintenance, and lamp failure is catastrophic to the operation. LPSSLs have poor beam quality, particularly at high output power. This makes them a poor choice for high-volume cutting and welding applications compared to a CO_2 laser of equal power.

LPSSLs remain an inexpensive, robust, and mature laser design that is still well-suited for some applications. LPSSLs are superior for producing the highest energy pulses because the lamps can be driven with a large stored electrical charge that is more cost effective than having a large bank of pump diodes reserved for the same purpose. Even in this area, DPSSLs are overtaking LPSSLs; in a few years, they might go the way of a CRT TV set. Still, LPSSLs are considered easier and less costly to repair, which is important in remote locations, although the costs of diode pumps are dropping to the point where the cost benefit is quite small. The market share of LPSSLs is declining, but they will remain in the market in some applications indefinitely, particularly for those requiring high peak power (such as cutting nonferrous metals and drilling) and many legacy medical system designs.

Perhaps the only thing that is certain is that thick metal cutting is a highly dynamic process. In a practical system, it is likely to be less stable, which yields a lower quality cut.

While improved performance can increase the cutting speed, faster is not necessarily better. The actual cutting speed depends not only on the nominal straight cut speed, but also on the contour of the cut, the cutting head design (for example, how much inertia it has), and the desired cut quality, including distortion of the sheet due to the dwell time.

We believe that systems engineers will gradually solve the challenges to make fiber lasers increasingly competitive with CO_2 lasers in all metal thicknesses.

3.4 Metal Welding and Brazing

Welding joins two metals using a similar filler material, while brazing joins two metals with a dissimilar filler material. Brazing usually requires a lower temperature than welding and has more relaxed requirements on beam quality. Metal welding also overlaps with other processes, such as metal cladding and metal cutting.

3.4.1 Auto Industry

The auto industry comprises only a minority of the high-power laser segment, and that segment itself is only a minority of the overall laser industry. So why is the auto industry so important?

One reason is the sheer volume and complexity of metal that goes into a vehicle. The auto industry produces about 65 million vehicles per year, and each vehicle requires a great number of pieces to be cut, formed, and joined. Due to the large number of models, there are an estimated 56,000 blanking dies required each year, which are used to assemble about two vehicles per second, assuming 24-hour, 7-day-per-week production. The cost of making and maintaining the blanking die alone may amount to as much as $2 billion per year, not counting the time required to change the die in the manufacturing line.

In addition, automobiles must be assembled mostly as curvy three-dimensional objects, not as sheets that are folded and welded as rectilinear forms. This makes some of the cutting and nearly all of the welding a complex process, often involving robotics. The automotive industry is unusual for its need for such complex welding.

In addition to body components, in the last few years, components for electric and hybrid cars have required laser welding. Tesla has opened a mega battery manufacturing plant in Nevada, and many other automotive batteries are being manufactured in China.

The auto industry had strong years from 2013 to 2016, and it remained strong in 2017. In 2016 – 2017 oil prices started to rise, but still prices are considered relatively cheap. At the time of this writing, oil hovers around $62/barrel.

3.4.2 2D vs. 3D Welding

Most laser and non-laser welding today is done with 2D systems and not 3D. Despite the appeal of using lasers to remotely weld or robotically weld auto parts, and the widespread

Table 3.4 Industrial KW+ Laser Unit Forecast by Laser Type (Units)

Units		2017	2018	2019	2020	2021	2022	2023	CAGR '18 - '23
CO_2		1,533	1,410	1,368	1,341	1,341	1,341	1,341	-1.0%
	y-to-y		-8%	-3%	-2%	0%	0%	0%	
Fiber		13,144	14,564	15,874	17,303	18,341	19,442	20,608	7.2%
	y-to-y		11%	9%	9%	6%	6%	6%	
Solid State/Disk		3,100	3,379	3,683	4,015	4,316	4,639	4,987	8.1%
	y-to-y		9%	9%	9%	8%	8%	8%	
Direct Diode/Other		4,050	4,487	4,972	5,599	6,102	6,652	7,250	10.1%
	y-to-y		11%	11%	13%	9%	9%	9%	
Total		21,827	23,840	25,897	28,257	30,100	32,073	34,186	7.5%
	y-to-y		9.2%	8.6%	9.1%	6.5%	6.6%	6.6%	

Source: Strategies Unlimited

Table 3.5 Industrial KW+ Laser ASP Forecast by Laser Type (US$)

Average Price (US$)		2017	2018	2019	2020	2021	2022	2023	CAGR '18 - '23
CO_2		$110,241	$107,845	$106,066	$103,901	$103,901	$103,901	$103,901	-0.7%
	y-to-y		-2%	-1%	-1%	-1%	-1%	-1%	
Fiber		$96,564	$92,381	$88,991	$85,725	$84,107	$82,521	$80,964	-2.6%
	y-to-y		-4%	-4%	-4%	-2%	-2%	-2%	
Solid State/Disk		$135,484	$131,755	$128,129	$124,602	$121,704	$118,874	$116,110	-2.5%
	y-to-y		-3%	-3%	-3%	-2%	-2%	-2%	
Direct Diode/Other		$110,003	$105,237	$100,678	$95,671	$92,160	$88,778	$85,520	-4.1%
	y-to-y		-4%	-4%	-5%	-4%	-4%	-4%	
Average		$105,546	$101,296	$97,703	$94,081	$92,012	$89,971	$87,957	-2.8%
	y-to-y		-4.0%	-3.5%	-3.7%	-2.2%	-2.2%	-2.2%	

Source: Strategies Unlimited

Table 3.6 Industrial KW+ Laser Revenue Forecast by Laser Type (US$M)

Revenue (US$M)		2017	2018	2019	2020	2021	2022	2023	CAGR '18 - '23
CO_2		$169.0	$152.1	$145.1	$139.3	$139.3	$139.3	$139.3	-1.7%
	y-to-y		-10%	-5%	-4%	0%	0%	0%	
Fiber		$1,269.2	$1,345.4	$1,412.7	$1,483.3	$1,542.6	$1,604.3	$1,668.5	4.4%
	y-to-y		6%	5%	5%	4%	4%	4%	
Solid State/Disk		$420.0	$445.2	$471.9	$500.2	$525.2	$551.5	$579.1	5.4%
	y-to-y		6%	6%	6%	5%	5%	5%	
Direct Diode/Other		$445.5	$472.2	$500.6	$535.6	$562.4	$590.5	$620.0	5.6%
	y-to-y		6%	6%	7%	5%	5%	5%	
Total		$2,303.7	$2,414.9	$2,530.3	$2,658.4	$2,769.6	$2,885.6	$3,006.9	4.5%
	y-to-y		4.8%	4.8%	5.1%	4.2%	4.2%	4.2%	

Source: Strategies Unlimited

When this is the case, these lasers are counted in the KW materials processing segment, not here.

Also included here are excimer lasers for annealing on flat-panel displays. While two or four 600 W lasers are synced together to produce a higher-power output, they are included here because the base lasers are 600 W.

Table 4.1 Summary of Major Materials Processing Segments

	Marking	Micro	KW+
Optical Power	Usually 20 W or less	Under 1 kW, usually under 400w	1 kW or more
Typical Applications	Marks for human or machine vision, decorative engraving	All sub-kilowatt materials processing, except marking and decorative engraving	Kilowatt cutting, welding, and surface treatment
Typical Lasers	Sealed CO_2 lasers, fiber lasers	All types: sealed CO_2 lasers, fiber lasers, SSLs, excimer lasers	Flowing gas CO_2, fiber lasers, disk lasers, direct diode systems

Source: Strategies Unlimited

4.2.1 Semiconductors, PC Boards, and Displays

The semiconductor/PC board/Displays subsection includes the lasers used in the manufacture of electronics, semiconductors, and flat panel displays. This includes lasers for annealing, via hole drilling, glass cutting, and all other machining processes, as long as the laser is not over 1 KW. This section does include excimer lasers used to anneal silicon flat panel displays because the Coherent VYPER lasers are composed of smaller 600 W excimer lasers. Two 600 W excimer lasers are linked together to create a 1200 W VYPER laser, and two 1200 W VYPER lasers are combined to create a TwinVYPER. Although not listed on Coherent's web site, we know they are also selling a Triple-VYPER totaling 3600 W. As panel sizes grow, more laser power is required to adequately anneal the panel in a speedy fashion.

In late 2015, Coherent first announced that it had received a quite substantial order for excimer lasers for flat panels displays. The company wasn't specific as to the customer, but said the panels were OLED and smaller, as used for either automotive or smartphones and tablets. Samsung predominately uses OLED displays for its smartphones, but at the time Apple did not.

It is now known that the driving force to produce more OLED smartphone screens was Apple, who at the time was planning to produce the iPhone X. While over 400M OLED