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The laser industry reports a slightly less-than-average growth 2012 will be followed by a more difficult 2013, says Editor-in-Chief David Belforte

Features

Departments

Online!

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FEATURED ARTICLE

Quality inspection for remote laser applications

On-line monitoring using diode-based solutions or special CMOS cameras sensitive in NIR

BY THOMAS GRÜNBERGER AND DANIEL NUFER

DABbling

A blog by DAVID A. BELFORTE

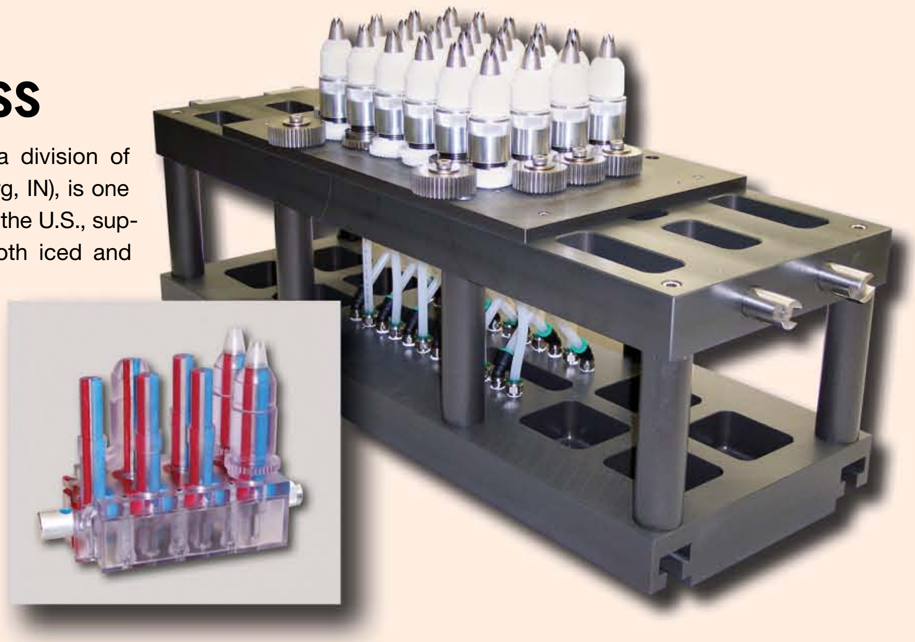
David shares his insights and opinions on current activities affecting industrial laser materials processing.

www.industrial-lasers.com/blogs/dabbling/index.html

update

Sweet success

MANCHESTER, NH — Freed's, a division of Maplehurst Bakeries (Brownsburg, IN), is one of the largest cupcake makers in the U.S., supplying in-store bakeries with both iced and un-iced cupcakes in a variety of sizes, flavors, and colors. Recently, their two-color icing tool, a complicated mechanism that applies precisely the right amount, pattern, and color of icing to the products on their main automated production line, was nearing the end of its useful lifespan. Obtaining a replacement tool was a problem as the manufacturer had discontinued this particular line and was no longer servicing it. For a solution, the company turned to 3-Dimensional Services Group www.3dimensional.com of Rochester Hills, MI, a rapid prototyping firm that specializes in the design, engineering, and analysis, in-house tool construction, and complete build of first-off parts and low- to medium-volume production runs.



3-Dimensional Services was able to increase uptime and improve quality for Freed's with this new design of a production cupcake icing tool. Inset photo shows an SLA model developed by 3-Dimensional Services to prove out the design concept.

There were no available CAD drawings for this tool, so 3-Dimensional Services reverse-engineered the tool—disassembling it, dimensioning the components, and drawing them in order to create a CAD file for use by one of its stereolithography (SLA) machines that produces a solid working model of the design, critical for hands-on review of form, fit, and function. This process was accomplished in a week. *continued on page 4*

Laser melting of inserts for mold tools

BREMEN, GERMANY — Plastic injection molding and die casting are key processes for cost-effective mass production. The especially complex shaped tools are very expensive to produce. To ensure high productivity, tool durability has to be high. The choice of materials is made on the basis of a trade-off: the need to be machineable but also to provide high wear resistance.

A typical material used in mold construction is the steel 1.2343 (AISI grade H11), which needs to withstand different types of wear. Tool wear can be increased dramatically on spots of injection where respective inserts are used. To generate wear-resistant inserts, the selective laser melting process was chosen as it offers to produce near net shape parts out of a variety of materials. The highly wear-resistant tungsten-carbide cobalt alloys WC-Co 83/17 and WC-Co 88/12 were chosen to be generated on steel substrates. A major challenge was the determination of process parameters and exposition sequence strategies to meet desired densities and avoid cracking. The influence of process parameters and weld trajectories on the density was investigated. It was found that the key to achieve densities of >95% through the complete specimens was the combination of comparatively low scanning speed, large beam diameter, and checkerboard-shaped weld trajectories. In the studies, it could be shown that the single boards were to be made with overlap. A tool insert is shown in FIGURE 1. These inserts fulfilled the requirements for being brazed to the tool steel 1.2343. The brazing process was successfully developed and applied by the project partner ISAF of TU Clausthal. *continued on page 4*

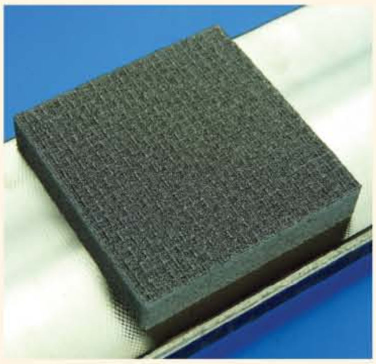


FIGURE 1. A tool insert that fulfilled the requirements for being brazed to the tool steel 1.2343.

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SCANLAB innovators for industry

update

Sweet success CONT.

The model of the design was inspected and approved by Freed's, and 3-Dimensional Services rapidly built and delivered the replacement tool.

This was not the end of the story because during this project, Freed's revealed that they weren't completely satisfied with the tool's existing design. For one thing, this two-color icing tool was too heavy to be used on any but Freed's most heavy-duty machine. The company would have liked the flexibility to employ it on other machines as well. It was also a very complex mechanism so periodic maintenance was time-consuming, and it sometimes had problems with icing leakage.

The 3-Dimensional Services team also wasn't completely satisfied because the reverse-engineering process had revealed several areas where the design could be improved. After explaining this to Freed's, the team got the green light to try and create an improved design.

For starters, there were the hoses that conducted the icing from the mixing vats to ports in the nozzles, with two hoses feeding each port. Long exposure to the strong, food-industry-strength cleaners used on the machine left the hoses brittle and susceptible to breakage; replacing them, though, was difficult and time-consuming. Each time a hose broke, Freed's had to remove all of the hoses that stood in the way of the failed hose, including removing each hose's clamps. Since hose failure was not a rare occurrence, this was a major source of downtime.

3-Dimensional Services responded by cutting a runner system into the aluminum plate of the tool's interior to facilitate the flow of icing, eliminating 24 of the tool's 48 hoses, slashing in half the potential number of hose breakage incidents. They also replaced the conventional hose clamps with quick-connect fittings that were faster and easier to attach and reattach. A new hose arrangement enabled maintenance personnel to change a broken hose without having to remove good hoses in order to get to it. This combination boosted uptime and productive capacity by over 50% and also led to weight savings.

"Additionally, pockets cut in the tool's aluminum plates got rid of excess aluminum that wasn't needed for its structural integrity," says Jerry Eversole, Senior Designer/CAD Operations Manager for 3-Dimensional Services. In addition, with the aid of some design changes, two rods could adequately perform certain valve functions, eliminating two stainless steel rods and further reducing weight. As a result, the new two-color icing tool can now be used on Freed's other, lighter machines if the need arises, giving the company the flexibility it had long desired but never had.

The problem of icing leakage or "color bleed" was corrected by tapering the top of the plastic cylinders in the icing heads that channel the icing, providing a tight seal when the screws are tightened. The end result was a lighter, more flexible, and more productive icing tool that was more energy efficient, with higher quality and reduced material usage.

— SUBMITTED BY 3-DIMENSIONAL SERVICES, WWW.3DIMENSIONAL.COM

Mold tools CONT.

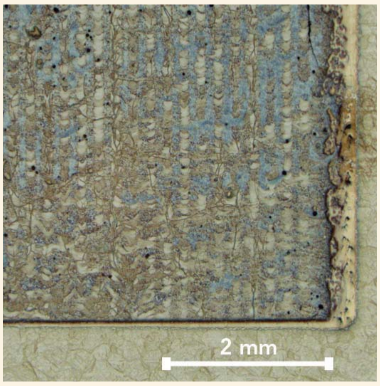


FIGURE 2. An example of a WC-Co specimen brazed to steel with a copper paste brazing solder.

An example of a WC-Co specimen brazed to steel with a copper paste brazing solder is shown in FIGURE 2. The wire-eroded lower side as well as the unprocessed right side of the SLM part are joined, without defects, to the steel. Infiltrated areas appear in light color within the WC-Co. Now, the parameters and scanning strategies determined can be used for generating more complexly shaped inserts. Together with our partners from research and industry, the complete process chain of generating and joining wear-protective inserts could be realized. The German Federal Ministry of Economy and Technology represented by the AiF funded this project 16.492 N "Generieren und Fügen von SLM-Bauteilen aus Hartmetall".

— M.SC. HENRY KÖHLER, BIAS, WWW.BIAS.DE

special report

2012 Annual Economic Review

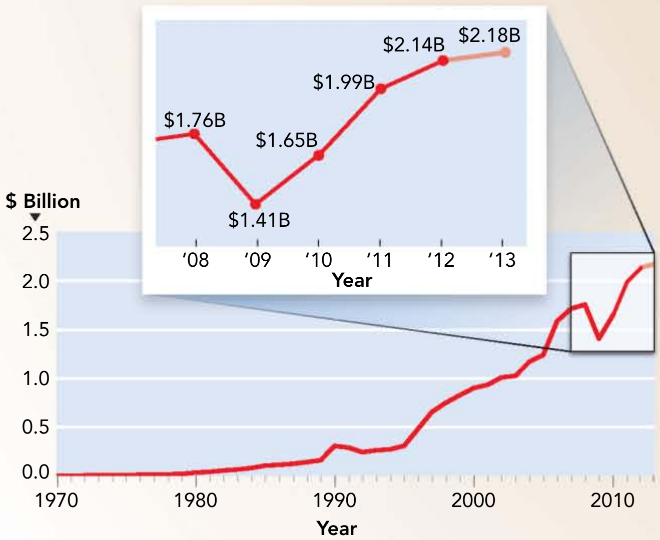
STATUS-QUO FOR 2013

DAVID A. BELFORTE

The dynamic world of industrial laser materials processing lived up to its reputation in 2012 as the world's economies fluctuated wildly with random news of: a return to recession in Europe, seeming vacillation on economic policy in China and the market trade consequences of a diplomatic quarrel between that government and Japan, and a hotly contested presidential election in the U.S. that produced a host of promises concerning government influence on manufacturing. And these were just the tip of the iceberg as month-after-month the global economic news gyrated from good to bad, over and over, producing headaches among market analysts charged with predicting the economic impact.

As the *ILS* 2012 forecast was being put together, in December of 2011, equipment suppliers to the global industrial laser market were enjoying one of the best revenue producing years in the technology's history, with strong double-digit growth across the board in all laser types and all the applications that they serve. And yet, the beginnings of doubt about the 2012 markets began to creep into the discussions *ILS* had with the leading product suppliers, so much so that the report published in the January 2012

FIGURE 1.
Industrial laser revenue

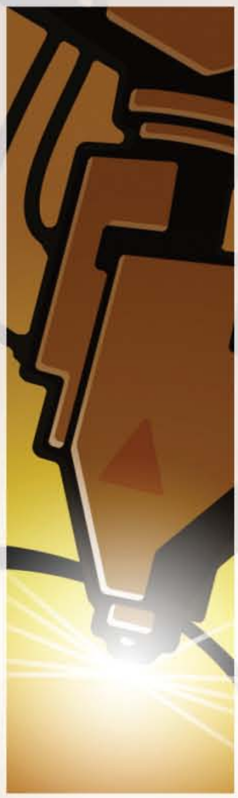


and Forecast

TABLE 1. Revenue summary ($M)

	2010	%	2011	%	2012	%	2013	%
LASER REVENUES	1657	35	1991	20	2135	7	2177	2
SYSTEM REVENUES	6090	25	7075	16	7475	6	7800	4

issue of this magazine featured a conservative and modest mid-single-digit growth. When these numbers were presented at the industry's important Laser and Photonics Marketplace Seminar in San Francisco, there was some strong disagreement among attendees, especially those concerned with the fiber laser segment, which was coming-off strong 48% revenue growth in 2011 and was comfortably situated for a repeat in the first half of 2012 based on strong fourth quarter bookings. *ILS* adopted a defensive posture that was best exemplified in the overworked cliché related to opera, "it isn't over until the fat lady sings." In this case the 'fat lady' was the fourth quarter of 2012.



It should be pointed out that ILS *forecasts are based on documented reports from four dozen public corporations, including the market leaders, all of whom are obligated to publish their quarterly financial reports, along with company officer guidance statements that project future business. So what you read in these pages is a compendium of these reports tempered with a multitude of other published comments and direct interviews and market assessments. At* ILS*, we like to think we are only the messengers, even though what we report is our opinion.*

In the Mid-Year Market report, presented as a Webcast in June 2012, *ILS* tweaked the numbers up by a percent or two, factoring in a stronger than anticipated first half with a projected slower second half. Indeed the third quarter numbers from several of the industry leaders were tempered with reports of slowing markets in Europe and the impact of a sudden and deep cutback in exports to China, the single largest market for industrial lasers and systems. The China situation seemed to have a greater impact on laser equipment suppliers located in Europe, where they were already experiencing the fallout of collapsing economies throughout the Euromarkets, and in Japan, where a drop in orders from China caused a 20% drop in laser system sales. Turkey, as described on pp. 26-28, was one of a few bright lights in an otherwise gloomy marketplace. Product suppliers in the U.S. did not begin to feel the impact until late in the fourth quarter, as this country's manufacturing economy was in the midst of one of the best growth periods in its history.

As a consequence, as shown in **TABLE 1**, the published results for 2012 came in about where *ILS* predicted and reported in the June Webcast Mid-Year Report, only off by 2% in a more positive direction. Is that the 'fat lady' we hear singing?

TABLE 2. Global laser revenues ($M)

TYPE/YEAR	2011	2012	%	2013	%
CO_2	988	1016	3	1008	-0.8
SOLID STATE	424	453	7	450	-0.7
FIBER	495	576	16	616	7
OTHER	84	90	7	103	14
TOTAL	1991	2135	7	2177	2

The economic year 2012 left many analysts scratching their collective heads, this writer among them. An almost three-inch-thick folder of positive and negative published comments on the global manufacturing situation, sorted into two almost equal piles, serves as an apt analogy for what was experienced this past year. Much of the negative pile, sorted chronologically, has to do with the up-and-down problems of certain economies in the Euromarkets. Waiting for a year-long resolve of the crisis in Greece reminds one of classic 1970's comedy sketches about the lingering death of the Spanish Dictator General Franco, which was a lead on the television network news each night for several weeks. It seems the Greek rescue experience, a model for other economically teetering Euro countries, was judged as the catalyst for the collapse of the Euromarket and even the fall of the Euro as the common currency. The result of this was an almost complete stop of growth in the European Capex market, felt by all the European laser and system suppliers. Somehow Europe muddled through thanks mainly to the strength of the German economy and its leader, who played a key role in reviving Greece, Spain and Portugal from near collapse.

As this report was written the effects of recession were being felt and reported throughout the 27 country Euromarket and in the UK. Worse, the impact of this situation had spread to Central and Eastern Europe, two regions that had in 2011 been cited as among the strengths of the European laser market.

Compounding this problem was a new one in 2012, the softening of the roaring markets in China, which had been the driving force behind laser system sales growth in the preceding two years. All of a sudden, a lack of effectiveness in government handling of the domestic economy led to a secession of activity in that country's Capex market, especially in the 3rd quarter of 2102. No nation is an economic island any longer so China's problems spread to the rest of Southeast Asia and Japan, also dragging down the laser market. Again, as this report was written the new government leaders in China loosened their grip on imported capital equipment funding and the fourth quarter of the year looked to be in recovery.

In the U.S., a very good year in manufacturing ran counter to the bad international economic news. Exports were at a recent-times high and strength in the: energy, transportation, aerospace, agricultural/heavy equipment, and medical device industries presented a ripe market for industrial laser materials processing system sales. The economic future, however, was cloudy as the warring political parties argued over a solution to the "fiscal cliff" end-of-year budget problem, causing companies to restrict Capex commitments for the second half of the year. A fourth quarter slowdown in manufacturing output was accompanied by predictions of a flat to low growth 2013, reminiscent of 2012.

TABLE 3. Global laser system revenues ($M)

TYPE/YEAR	2011	2012	%	2013	%
CO_2	4100	4244	4	4300	1
SOLID STATE	1611	1665	3	1695	2
FIBER	1164	1350	16	1465	8
OTHER	200	216	8	240	11
TOTAL	7075	7475	6	7700	3

All the above led to visions of the 'fat lady' again as summarized in the low growth 2013 numbers in **TABLE 2** and **3**. Generally, industry participants and observers are opting for a reasonable growth first quarter, as 2012 backlogs are reduced, followed by three quarters of flat or low growth rate sales and shipments.

The Details

TABLE 1 is a snapshot of the industrial laser market since the end of the recession of 2008-2009; a period in which this industry defied the experts' predictions of a long, slow recovery, and led by

booming sales of solid-state lasers for face plate applications in hand-held devices and fiber laser for marking/engraving and sheet metal cutting, snapped back in 15 months to pre-recession revenue levels. Record shipments in 2011 set the table for a strong first half of 2012, even though the aforementioned economic problems should have stultified sales. **FIGURE 1** shows the history of industrial laser revenue in that now classic fishhook curve that illustrates how the post-recession revenue growth has significantly affected the CAGR since 1970 of 18.12%.

In all fairness, it should be pointed out that laser and laser system sales in 2008 set a record. After two international trade shows, the order books of most system suppliers were full, with backlogs extending into the second quarter of 2009. And then disaster in the shape of the recession of 2008/2009 trashed all the backlogs with cancellations and many project delays. It was the latter that produced some of the impetus for the rapid market recovery of 2010, proving a point that *ILS* has made many times: industrial lasers have experienced an illustrious growth rate since the early 1990s. Among the applications that these lasers serve are many that are themselves in a steep growth period: communications, transportation, medical and energy. And these laser applications are for the most part unchallenged by competing or advancing technologies. So when the recession ended that pent-up buying demand for the canceled or delayed orders, it gave an instantaneous boost to company backlogs, a situation that held for more than 15 months. In this period, the beginnings of the hand-held communications device business provided a boost to industrial laser sales with multitudes of solid-state and excimer lasers being directed into the manufacture of smart phones and now tablets.

The increased penetration of fiber lasers into markets (**TABLE 2**) held by other laser types continues, as that laser's high efficiency, compact footprint and low maintenance costs are proving attractive in buying decisions when the fiber competes directly with other laser power sources. In 2011, high-power fiber laser sales grew at a fast pace and began a serious penetration into the market for sheet metal cutting. This situation intensified in 2012 as evidenced by the dominant presence of fiber-laser-powered metal cutters at all the major trade shows featuring fabricated metal product processing equipment. Further support for the high-power fiber lasers' market growth is the appearance, in 2012, of a number of companies offering fiber lasers in the metal cutting sector: Amada/JDSU, Rofin Sinar, Hypertherm, and GSI Groups JK Laser. Also providing kilowatt-level fiber lasers for other cutting operations are Coherent, Miyachi, and SPI Laser, the latter part of the Trumpf group. In 2012, high-power fiber lasers are estimated to have taken up to 20% of the market from equivalent power CO_2 lasers.

Fiber lasers were the winner in the growth-rate race in 2012, showing a 16% increase in laser revenues, mainly at the expense of high-power CO_2 lasers, which lost market share by as much as an estimated 10–15%.

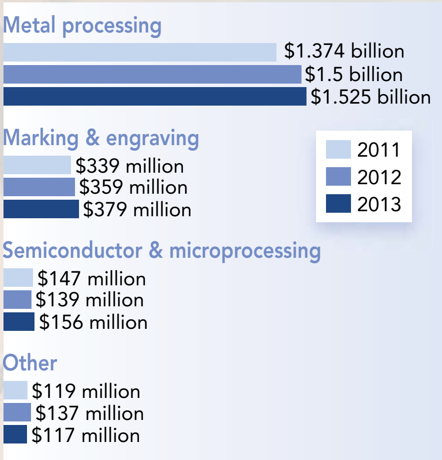
In the markets where fibers have been eroding sales of solid-state lasers, the fiber continued to be the laser of choice among marking system integrators; however, solid-state laser retained market share and actually increased this a bit in microprocessing applications, where it is preferred as a processing laser in the manufacture of hand-held communications devices.

Excimer and diode lasers, the latter a fast-growing product in the manufacturing world, continue to show strong growth that started in 2011 and increased their market share by 7% in 2012. They are finding niche markets where they are the lasers of choice in semiconductor and microprocessing applications and for the high power diodes in macro applications in the auto industry. New market entrants Teradiode and Direct Photonics are bringing a new vitality to the market as they introduce high power, up to 3 kW, products that are seen by many as the "ultimate" solution for on-line manufacturing operations.

TABLE 3, laser system revenues, shows the same trends as in **TABLE 2** since *ILS* assumes that most laser sales result in system integration. To support this assumption, one cannot find a very active market for individual laser sales to end users. To put this into perspective, *ILS* has identified more than 150 marking system and over 60 cutting-system suppliers that integrate lasers into their products. The former use more than 25,000 low-power lasers and the latter 5000 high-power lasers for a total of 51% of all lasers installed. *ILS* market estimates are for the basic laser system and do not account for ancillary material handling and other complementary processing operations.

System revenues have been growing at a slightly faster pace than laser revenues in the past few years as the

FIGURE 2.
Laser revenues by application sector



selling price of laser units has decreased because of increased competition in the marketplace, while the selling price for the laser system has not reflected this cost factor. Having said this, *ILS* is aware that the system market has seen selling price discounting, again as the competition heats up the market. Because the system numbers reported are based on empirical practices developed years ago, because integrators are loathe to share information and most of the large system suppliers are divisions of large corporations that do not break out laser systems sales, care is suggested when using these numbers. Many use this data to establish trend lines, as does *ILS*.

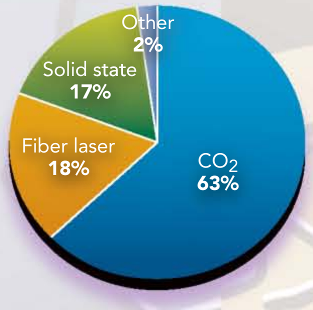
It should be noted that *ILS* has traditionally not included sales of excimer lasers used in photolithography in the reported system and application numbers. This application has been outside of those that *ILS* tracks. If system sales of the two main suppliers were to be included, they would increase the 2012 system total by about $800 million.

The sales of high-power laser metal cutting systems are a significant portion of total laser system revenues. In 2012, sales exceeded $5 billion or 60% of the total. As a consequence, any perturbations in the market for fabricated metal products have a major impact on the industry suppliers; thus this market is closely watched as an indicator of global manufacturing economics. This was very evident in 2012 when economic troubles in the Euromarket and in China, two major laser cutter users, had a noticeable 50% decline in the revenue growth rate for the system market.

TABLE 4. Metal processing ($M)

LASER/YEAR	2012	%	2013	%
CO_2	943	62	936	61
SOLID STATE	250	17	254	17
FIBER	267	18	285	19
OTHER	40	3	50	3
TOTAL	1500	100	1525	100

FIGURE 3.
Lasers for metal processing



2012 Total: $1.5 billion

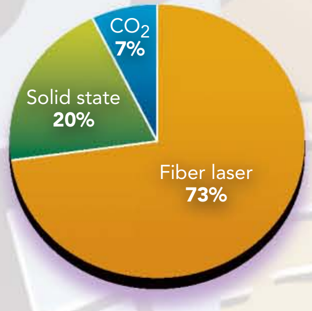
Applications segmentation

FIGURE 2 is a three-year summary of laser revenues broken down by applications in which they are used. It is obvious from this figure that Metal Processing (**TABLE 4** and **FIGURE 3**) is the largest segment, representing more than 70% of total laser revenues. That is why sheet metal cutting, a major portion of the Metal Processing market, is so important. Whereas this sector grew 6% over 2011 sales, it is estimated to only grow 2% in 2013, translating into a potential loss of at least $325 million in system sales, as the fabricating sector experiences a slowdown in 2013. Within the market segment CO_2 lasers dominate, but fiber lasers, which grew 30% in this sector at the expense of CO_2 lasers, are becoming a factor. In 2013, fiber lasers are estimated to grow 7% versus the 1% decline in CO_2 sales. Also contributing are the sales of high-power disk lasers from Trumpf, the world's largest industrial laser and system supplier.

TABLE 5. Marking ($M)

LASER/YEAR	2012	%	2013	%
CO_2	26	7	27	7
SOLID STATE	72	20	69	18
FIBER	261	73	283	75
OTHER	0	0	0	0
TOTAL	359	100	379	100

FIGURE 4.
Lasers for marking and engraving



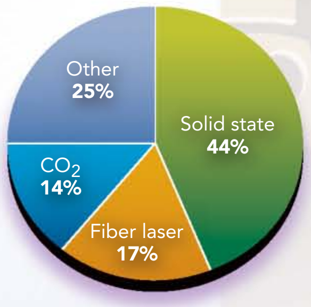
2012 Total: $359 million

Marking/Engraving (**TABLE 5** and **FIGURE 4**) is the second largest laser application in terms of revenues and the largest in terms of unit numbers sold. Solid-state lasers, lamp and diode-pumped, have steadily been losing market share to fiber lasers — a trend that is expected to continue as the fiber laser makers meet increasing competition from new fiber laser suppliers by reducing selling prices. Marking is as close to a commodity as any other industrial laser application. Some industry observers have

TABLE 6. Semiconductor/microprocessing ($M)

TYPE/YEAR	2012	%	2013	%
CO_2	20	14	22	14
SOLID STATE	61	44	64	41
FIBER	23	17	25	16
OTHER	35	25	45	29
TOTAL	139	100	156	100

FIGURE 5.
Lasers for semiconductor and microprocessing



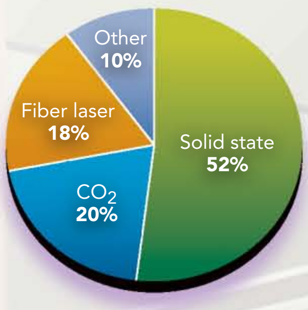
2012 Total: $139 million

compared laser markers to ink-jet printers in terms of: reliability, adaptability, low maintenance, and lowering selling prices. Laser marking growth is assured because more government and industry standards are in place to factor in laser as the marking source, especially in the area of 2D bar code matrix marking. Another target market is penetration into the ink-jet marking arena, where second and third harmonic wavelength lasers, with no consumables, are showing advantages in marking otherwise difficult to mark materials.

Laser activity in the Semiconductor/Microprocessing markets (**TABLE 6** and **FIGURE 5**) continued to lay the ground work for substantial revenue increases in the coming years as microprocessing is thought to be a growth area for the rest of the decade. This sector is home to one of the fastest growing laser types: ultrafast pulse, which produced a 60% growth in 2012 and looks to be continuing a double-digit growth for the next few years. Applications in the semiconductor segment range from micro-via drilling (where hundreds of units per year were installed in 2011 and 2012 in SE Asia) to laser scribing and ablation. Microprocessing applications include texturing and etching, applications that have sustained diode-pumped solid-state sales and, new to the scene, pulsed fiber lasers, at the fundamental and frequency shifted and single-mode wavelengths.

The ubiquitous "Other" laser category, **TABLE 7** and **FIGURE 6**, includes excimer lasers for annealing silicon in smart phone manufacturing and higher power solid-state, fiber and CO_2 lasers as the power sources for additive manufacturing processes, one of the future growth applications for laser processing. As these applications reach a visible market level, *ILS* tries to shift them into one of the more definable categories.

FIGURE 6.
Lasers for other applications



2012 Total: $137 million

TABLE 7. Other ($M)

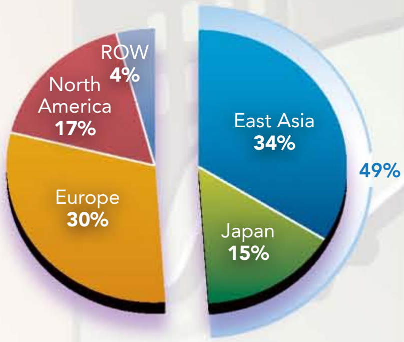
TYPE/YEAR	2012	%	2013	%
CO_2	28	20	27	23
SOLID STATE	71	52	61	52
FIBER	24	18	24	21
OTHER	14	10	5	4
TOTAL	137	100	117	100

Installations

So where do all the above-mentioned lasers end up? Using a variety of resources *ILS* can generate a view of where industrial lasers were installed in 2012. **FIGURE 7** is a projection of our analysis. Even though imports of laser systems into China slowed down in the middle of the year, the picture for 2012, taken on a global basis considering the slowing markets in Europe, will look similar to last year's *ILS* report.

In East Asia, China remains the largest user of industrial lasers and systems for materials processing. Supplied by dozens of domestic system integrators and most of the leading international companies, the demand for laser processing equipment continued, even though the economic brakes imposed by the central government slowed imported capital equipment for a good portion of the year. China is considered to be the largest market for laser marking and metal cutting systems, and East Asia to be the largest market for microprocessing and semiconductor processing equipment. As home to much of the production of smart phones, computers, and support equipment and tablets, East Asia is the major user of solid-state, excimer, and other lasers that produce the components for these products.

FIGURE 7.
Global system installations



2012 Total: $7.5 billion

European countries, led by slow-downs in Italy, Spain, and the Central European nations, slipped two points to 30%. Only the continuing strength of the German market kept this percentage from slipping even further.

The brightest performance in an otherwise slowing market was in North America, where manufacturing boomed in an otherwise slow economy. In the U.S., several industries, heavy users of industrial lasers, had a stellar year, and records were set for U.S. manufacturing orders during the year. The industries that seemed to defy global manufacturing slowdown are: aerospace, transportation, energy, agriculture and heavy equipment, and medical devices. Laser products used ranged from low-power laser marking units to high-power laser metal cutters and welders. As a result, North America gained a point over the 2011 share.

Forecast

The scenario as this report was being prepared has similarities to two past events. The first and least likely is the situation that developed when preparing the 2009 *ILS* report, where enthusiastic business results from two big laser shows, EuroBlech 2008 and Fabtech 2008, followed by the effects of the big market crash starting in December 2008, led to *ILS* projecting the first laser market decline in two decades. Little did *ILS* know then, but we grossly underestimated the decline, which went from the estimated low single-digit loses to mid-double-digits numbers as the world economies went into recession. The similarity was that EuroBlech and Fabtech this year were very upbeat shows with strong order placement immediately following each, a dichotomy because, except for the U.S., the global manufacturing economy was not very healthy. The difference between the two scenarios is that the financial disaster

of 2008/9 is not in the offing in 2012/13

The second similarity is the too-familiar market conditions today compared to one year ago when the 2012 report was being prepared. A very strong second half of 2011 led to substantial backlogs, which distorted forecasting for 2012. As stated earlier in this report, *ILS* took a conservative approach to forecasting the year, and time proved this correct. For this report, we have again taken a conservative approach, this time supported by manufacturing industry opinion of business in 2013. We do not expect to have to wait until the 'fat lady' sings.

Cautionary guidance remarks by the leading industrial lasers and systems suppliers paint a picture of a global manufacturing economy still in disarray as a consequence of unresolved economic issues in Europe and, as this was written, uncertainty in last year's bright light, the U.S. manufacturing sector, awaiting the fall-out from the U.S. government 'fiscal cliff' resolution.

The BRIC (Brazil, Russia, India, and China) nations have been targeted by several laser product suppliers as expanding markets in 2013. Conditions in China have already been cited. Brazil is a promising growth market, but it is in the throes of economic stagnation with inflation rising, fiscal reform still on hold, and little growth in the capital investment area. One domestic supplier to the medical device sector describes it as an economy running sideways. India, a giant population market, has similar problems with a government in disarray that is unable to cure economic discord, leaving manufacturers with uncertainty as to when and how to invest in capital equipment. Several international suppliers describe the country as a potentially good market for laser processing equipment, but the horizon for substantive growth seems to always move out of reach. The Russian market is thought by many European laser suppliers to be a fruitful market, developing more quickly under a manufacturing-oriented government. However, the prospects for this nation making a strong contribution toward capital equipment sales in 2013 remain marginal at best, and suppliers are looking at 2014 for some positive movement. *ILS* looks to the BRIC nation markets as a near term opportunity to expand sales of industrial laser products, acting as a relief valve for the slowing 2013 international markets.

As shown in **TABLE 2**, both carbon dioxide and solid-state lasers in 2013 are projected to experience a repeat of 2012, with little or no growth in sales revenues, resulting from the increasing inroads of fiber lasers into their markets and the sluggish world economies. On the CO_2 laser side, low power units should show a small gain, but a projected small (1%) decline, brought on by increased high power fiber laser sales will impact total CO_2 numbers. The flat market for solid-state lasers in 2013 is also expected from the incursion of fiber laser sales into their market sectors. The 2013 laser numbers directly impact the 2013 laser system revenue numbers (**TABLE 3**), which, at best, are expected to show very small increases from flat global markets.

Fiber laser, excimer, and diode laser revenues should enjoy modest growth (**TABLE 2**) as fiber lasers increase market share in the sheet metal cutting sector, from today's 15% to at least 20% in 2013, and excimer and diodes will experience growth through new industrial applications and markets that suppliers have developed. Increased laser sales produce equivalent revenue growth in the system sector, as shown in **TABLE 3**.

Overall 2013 revenue results should show a slight 2–3% gain over 2012. In and of itself, this is not a disappointment, as many suppliers told *ILS*, the laser equipment results will be in line with other capital equipment markets experiencing predicted flat growth in 2013. Application segments that will sustain and in some cases drive growth in 2013 are: metal processing (**TABLE 4** and **FIGURE 3**), which will represent about 70% of industrial laser revenues with CO_2 43% of total laser revenues and fiber lasers 13% of total revenues, together contributing 56% of total laser revenues.

Laser marking/engraving (**TABLE 5** and **FIGURE 4**) is an application that is driven by company and government regulations and standards for traceability and security, thus even in a slipping economy, this support for annual revenues will keep this application as the number two revenue producer. Fiber lasers will dominate the laser marking sector at about 75% of total laser marking revenues in 2013. Additionally, fiber lasers for marking will represent about 13% of all industrial laser revenues for 2013.

Microprocessing applications revenues in 2013 (**TABLE 6** and **FIGURE 5**) will show the largest increase (12.2%) over 2012 sales, with diode-pumped solid-state lasers and ultra-fast pulsed lasers producing over 40% of the revenues in this category. This sector is one of the most active in terms of advanced laser material processing technology, and it is the target for fiber laser suppliers in Europe and Asia.

On a final note, *ILS* has been working to reduce the size of the "Other" category by shifting applications into others. Thus, the 2013 revenue number for other applications in **TABLE 7** and **FIGURE 6** will show a 17% decrease.

In summary, the 2012 market for industrial lasers and systems came in just about where *ILS* had predicted, well below the double-digit numbers of non-recession years, but in the minds of many suppliers, satisfactory given world economic conditions. Entering 2013, projections from industry suppliers, even the powerhouse duo of Trumpf and IPG Photonics—both strong double-digit revenue growth producers—were for a mixed year in manufacturing ranging from flat to low single-digit growth. Most laser and system suppliers, having survived the past recession by trimming their operations, opted to continue this practice in 2012 and most will do so in 2013 as well. There is no sentiment for market loss through the appearance of new non-laser competition, so the industry is prepared for an anticipated strong fourth quarter in 2013, followed in 2014 by a return to double-digit revenue growth.

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technology report

Laser welding of copper

COPPER'S SPECIAL PROPERTIES CALL FOR STRATEGIC REMOTE TECHNIQUES

DIRK HERRMANN AND PETER HERZOG

The industrial demand for complex components made of copper is increasing as they are necessary for electric drives used in the automotive industry as well as for energy transportation systems in the field of regenerative energy sources. Also, modern battery technology uses copper components for interconnection and current transport. An adequate joining technique is required to produce such components and assemblies, For automotive industry production the joining technique must be fully automated, highly reproducible, and reliable. It should also be fast and flexible without changing the properties of the welded parts.

These requirements are best met by remote laser welding, which provides the opportunity to weld several seams in different orientation and of different geometry in a few seconds within one chamber. There, the laser beam can be moved dynamically in three dimensions with variable speed and laser power. With this enormous flexibility, the welding process can be exactly adjusted to the geometry of the joint.

At Wieland-Werke AG in Ulm, Germany, copper components for the automotive industry have been joined successfully by laser remote welding in a serial process for several years. One example, shown in **FIGURE 1**, is components used for electric engines in hybrid powertrains. As one of the biggest producers of semi-finished copper products worldwide, Wieland covers the whole supply chain of these components. Production starts at the foundry, which ensures the quality of the copper, and continues in the extrusion of bars and wires or rolling of strips and sheets.

From these semi-finished products, parts of complex shapes are formed by stamping, bending, drilling, and milling. Next, these parts are automatically clamped together in a corresponding device and laser welded. To give an example, one of the components has 17 welds: one is an 8 mm long butt joint in 2 mm thick copper, and the other 16 welds are overlap joints where 0.8 mm thick copper is welded on 2 mm thick copper. All 17 welds are done in one run which lasts less than 5 seconds.

Source: ZF Sachs

FIGURE 1. Application example: component for electric engines in hybrid powertrains.

Challenges

Compared to the joining of steel, which in numerous cases is done by remote laser welding, welding of copper poses additional challenges [1]. Three major facts must be considered:

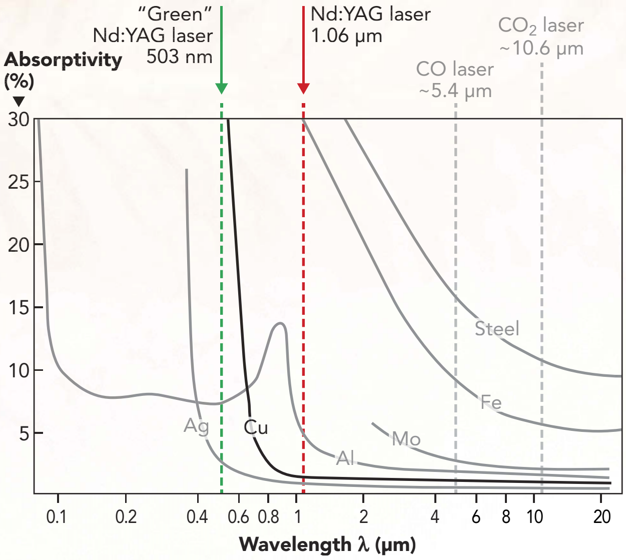

FIGURE 2. Absorption ratio of different materials at infrared and green wavelengths [2].

1. Low absorptivity of infrared laser radiation on the copper surface at room temperature,
2. Low viscosity of the copper melt, and
3. High thermal conductivity of copper.

The absorptivity of different metals given in **FIGURE 2** [2] depends on the wavelength of the radiation. A Nd:YAG-laser, which is commonly used for welding, has a wavelength of 1064 nm. As the diagram shows, the absorptivity of copper at this wavelength is 2–3%. Thus, 97–98% of the energy of the laser beam is reflected on the copper surface and does not cause heating of the material. Therefore, a special strategy is needed at the beginning of the process.

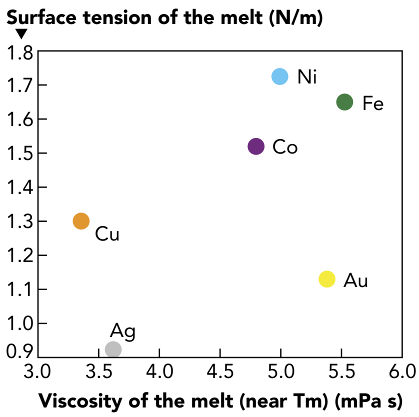

FIGURE 3. Surface tension versus viscosity of different metal melts [3].

At first sight, the solution might be to start with very high laser power. However, this frequently leads to overshooting and a blow out of the melt because the absorptivity increases with rising temperature, and it suddenly jumps up when the melting temperature is reached. To avoid a blow out, the process must be started with low laser power, which is linearly increased in the first millimeters of weld to its full value.

In order to get a regular and flawless weld seam, the melt pool should be smooth and even near the solidification line. But at the front of the melt pool, the laser continuously creates waves and streams. These pool movements can best be damped by a melt that has a high viscosity. **FIGURE 3**, a map of surface tension versus viscosity for different metal melts [3], clearly shows that viscosity of a copper melt is significantly lower than those of iron and steel melts. This means that any kind of melt movement in a copper melt is transported throughout the whole melting bath, which causes high turbulences. The morphology of weld seams in copper is therefore often not as regular as in steel. In addition, the low viscosity also impedes a good filling of the welding gap. In order to increase the seam quality, a long and oval melt pool should be established in which the melt turbulences may calm down in the rear part right before solidification. This is hard to accomplish considering how fast copper solidifies.

Thermal conductivity is a main factor in laser welding of copper. The higher it is, the faster the heat is conducted into the adjacent material and turbulences are frozen, resulting in irregular seam morphologies. Heat conductivity also defines the achievable welding depth. In order to melt deep into the material, a high energy density is required. This means that a high laser power of several kW must be focused to an area of 0.15 to 0.05 mm² to weld copper of several millimeters in thickness.

Processing maps

When it comes to laser welding, the easiest and most effective parameters to vary are laser power and welding speed because welding depth increases with laser power and decreases with rising welding speed. These interactions can best be illustrated by plotting the two parameters against each other. **FIGURE 4** shows a schematic sketch of such a plot where, in the upper left corner, at high laser power and low welding speed, the welding depth is the highest. Correspondingly, in the lower right corner of the map, at low laser power and high welding speed, the welding depth is the lowest. Starting from this approach, Wieland created processing maps by measuring the depth of seams welded with systematically varied parameter combinations. With these maps, they can easily discover a power/speed combination that is suitable to weld a given thickness.

In addition, the investigation revealed that there are three main boundaries limiting the process window. The first one is the threshold between heat conduction welding and deep penetration welding. In **FIGURE 4**, it is indicated by a line at low laser power that slightly increases with welding speed. In order to benefit from the advantages that the laser offers, deep penetration welding should be the preferred working technique. It provides the possibility to create narrow and deep welds at minimum heat input. So, the objective is to use a power/speed combination that is above this line.

The second boundary is situated in the zone of high laser power and low welding speed. Welding with power/speed combinations that are beyond this line is connected to melt blow outs and the formation of holes and pores within the weld seam. The reason for this is the high amount of impacting energy at low welding speeds

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together with the circular instead of oval shape of the melt pool. As high speed videos of the process reveal, the melt pool swells, forms a big hump and finally explodes, blowing out the melt and leaving a hole in the seam. The resulting holes and pores are detrimental to the strength and the electrical conductivity of the weld seam.

The third boundary exists at very high welding speed, where humps of melt may periodically occur at the surface of the weld seam. This phenomenon is also observed in laser welding of steel and is commonly known as humping. For laser welding of copper, humping has less importance because the applied welding speeds are normally too low.

The area that lies within these three boundaries is the process window. Welding within the process window enables the creation of sound joints with seams of regular shape and depth at high reproducibility. The difference between welding inside and outside of the process window is illustrated in **FIGURE 5**, which shows snapshots of high speed videos of the welding process. The videos were taken by the Institut für Strahlwerkzeuge of Stuttgart University (IFSW).

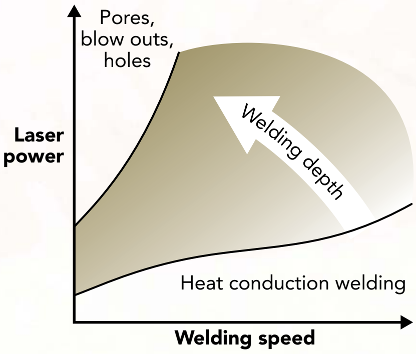

FIGURE 4. Processing map with process boundaries. The shaded area is the process window.

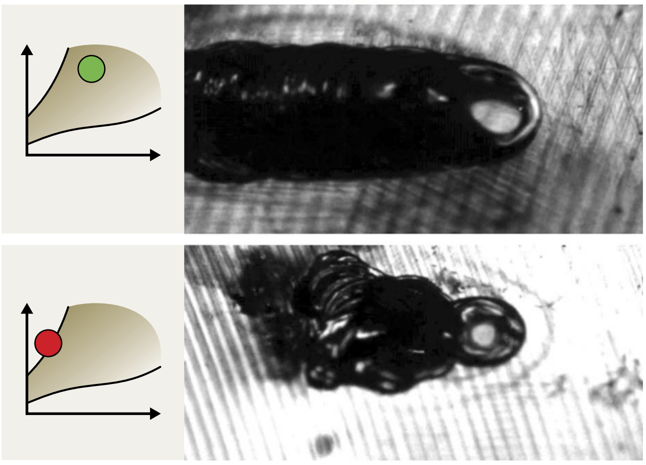

FIGURE 5. High speed video snapshots of a perfectly welded seam (above) and a seam with pores and blow outs (below). Videos taken by IFSW.

Quality of weld seams

Weld seams in copper are usually softer than the base material. Unlike iron, copper is not an allotropic metal and phase transformations, like the formation of hard martensite in steel, do not occur. The molten copper solidifies to a coarse microstructure that is characterized by columnar grains. In the heat affected zone, the work hardening condition of the base material is decisive for the microstructural evolution: in strongly work-hardened copper, recrystallization takes place; in soft copper, a slight grain growth happens.

An important fact to consider is whether the welded type of copper contains oxygen or not. In the presence of hydrogen, oxygen containing copper may embrittle when heated up to temperatures above 1000 K. The copper oxides, which are primarily located at the grain boundaries, are chemically reduced by hydrogen to Cu + H_2O, which is connected to an intense volume expansion [4]. The resulting steam puts high vapor pressure on the grain boundaries and generates intercrystalline cracks. Therefore, using a shielding gas is recommended when oxygen-containing copper is welded. However, in laser welding, the time in which the copper melt is in contact with the atmosphere is short and the content of hydrogen in dry air is low. From Weiland's experience under these circumstances, it seems possible to do laser welding in air without producing hydrogen-induced cracks. But doing so results in an oxygen-contaminated weld seam that afterwards must not be heated up to temperatures above 800 to 1000 K.

New developments in laser welding copper

In order to improve the absorption of laser radiation, experiments with green lasers were done. As **FIGURE 2** shows, the absorptivity of copper for the green laser is much higher than for the infrared laser. In a research project named "CuBriLas," which was funded by the German Ministry of Education and Research, several companies and research centers worked together in order to improve the laser welding of copper by using a green laser. The CW-laser used was a prototype made by Trumpf Lasertechnik GmbH and had a power of some hundred watts. For the Wieland applications, it turned out the power was too low because in pure copper welding, depths of about 0.4 mm maximum were achievable. Nevertheless, the investigations clearly proved that energy dissipation is better with

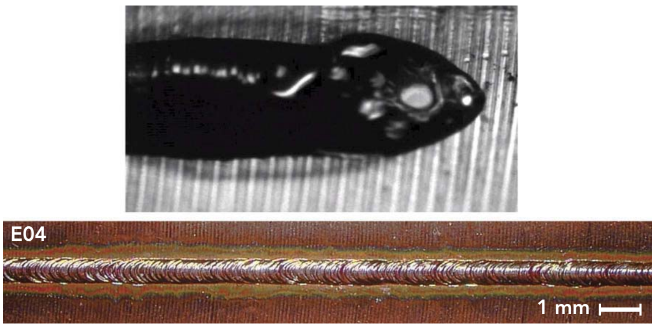

FIGURE 6. Welding with two laser beams (infrared + green). Snapshot of a high speed video and corresponding weld seam. Video taken by IFSW.

a green laser. Using the same power, the green laser welded deeper than the infrared laser [5].

An interesting approach to improve the welding process is to combine the advantages of the infrared and the green laser. Together with the IFSW, Wieland did some experiments to evaluate this approach. In the experimental setup they welded with two laser beams, letting the green laser lead and the red laser follow (see **FIGURE 6**). As the absorptivity of green laser light on solid copper is very good, the task of the green laser in this setup is to heat up the surface to the melting temperature. The following infrared laser then couples directly into the melt and provides the necessary welding depth due to its high power. Benefits of this strategy are a better stability of the welding process, an increased welding depth, and a homogeneous and reproducible energy coupling [6]. Regarding the processing map of power and speed, the process window is expanded at both boundaries, as illustrated in **FIGURE 7**.

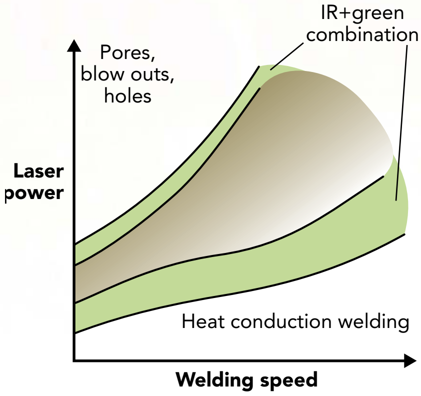

FIGURE 7. Expanding the process window by infrared+green laser combination process. The shift of the threshold at low laser power is given in [5].

Summary

In the past, laser welding of copper has been considered as hardly applicable. However, with today's understanding of the process and with modern laser technologies it is possible to produce joints of high quality in a fast and fully automated serial production. The special attributes of copper — low absorptivity, high thermal conductivity, and low viscosity of the melt — must be taken into account.

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application report

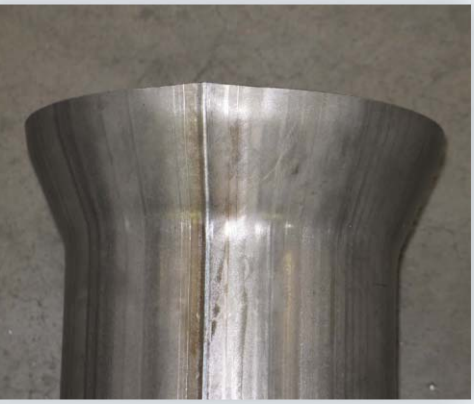
Laser welding repla

CZECH COMPANIES MARKET

LASER PROCESSING SYSTEMS

TOMÁŠ MUŽÍK, STANISLAV NĚMEČEK, AND TOMÁŠ ATTL

In the Czech Republic, the towns of Plzeň (Pilsen) and České Budějovice (Budweis) are well known thanks to the production of beer. But these towns are also part of a country that is known for its reputation in the production of heavy machinery and automobiles. Car manufacturers Skoda, TPCA, Hyundai, and Tatra are located in the country, with KIA and VW in neighboring Slovakia. Tool shops and automotive subcontractors are located in almost every town and village. This manufacturing sector growth is promising, with the economic crisis definitely over and many companies now investing again. Generally, the economic situation is stable and much better than in southern EU countries that are still experiencing problems.



Laser welded mild steel tube after "cone test." During this test, a cone is pushed into the tube and it must withstand defined diameter increases. Results like this mean excellent quality.

Since 2008, Matex PM, the laser job shop and system integrator, has focused its services on the automotive and heavy machinery sectors, offering laser surface hardening, welding, and additive manufacturing capabilities. The company currently runs three robotic laser systems in two subsidiaries and operates its own R&D center for quality assurance and development of in-house process development.

Together with ATTL s.r.o., a machinery builder from Prague, the companies offer large lines for the production of tubes and various profiles. Some of the profiles are mechanically formed, but most of them are longitudinally welded. Usually these production lines consist of a set of forming rolls that take steel from a coil and form it into a desired profile. In the middle, there is a welding system where the profile is precisely aligned, welded,

ces TIG

Production line for laser welded stainless steel tubes. The input of the steel plate into the forming rolls is shown in the middle; laser source is on the left.

and sometimes pre-heated or annealed. At the end, profiles are automatically cut in desired lengths and transported to storage. The tubes and profiles produced are used mainly in industries such as automotive, construction, or machinery.

Conventionally, welding is done by induction coil or tungsten inert gas (TIG). The joint efforts of Attl and Matex PM produced a new approach – laser welding, a process that offers many technological and economic advantages, but some challenges, too. Let's take a look at them.

1. Speed of welding

Usually the most important parameter of such production lines is production speed, which is limited by the welding process and by the cutting at the end. Consider the most common weld seam configuration: butt joint with a thickness of 1 mm. With laser welding, it is easy to reach weld speeds of 10 m/min, which is much higher than that from conventional TIG welding, but lower than that from induction welding. However, the laser can reach these speeds even on thicker materials; it depends on laser power and the investment budget. Currently, on one line being installed, speed is over 20 m/min.

2. Heat input / power consumption

The biggest difference between conventional welding and laser welding is the much lower total heat input in the case of lasers. This results because the laser beam produces a narrow weld seam with fast energy transfer from the beam into the material. We estimated the energy input into the welded material at 1 mm thickness of high-strength steel. In the case of the laser, it is about 15 J/cm, while with TIG, it is at least 60 J/cm, and with metal active gas (MAG), it is 85 J/cm.

This estimate is important for the calculation of running costs (see opposite page) and has important consequences on the mechanical properties of the weld seam, which are usually much better in the case of lasers, but the fast cooling of materials or welding speeds that are too high can cause unexpected problems, too.

3. Weld seam properties

A weld seam made by any technology has three basic zones – molten zone, heat affected zone, and transition zone in the basic material. Laser welding makes the seams narrow because of fast cooling rates, an advantage because this produces low distortion and low heat degradation of the basic material. However, fast cooling can be a problem when welding high-carbon steels, especially when a subsequent cyclic load is expected. In this case, the heat affected zone can be too hard and it can be prone to cracking.

This problem can be solved by careful technology development — by the proper selection of the laser source and the setting of focus size and other welding parameters. In some cases, even pre- or post-heating is necessary. Therefore, laser welding is able to weld "problematic" steels better than any other technology.

High-strength steels that are interesting for lightweight car construction are welded by laser, preserving their strength and plasticity, contrary to conventional welding, which destroys the special microstructure of these steels and downgrades their mechanical properties to levels of common mild steel.

4. Weld seam quality

Another question is weld seam quality and its stability during long-term production. Generally, laser welded seams have much higher quality, low surface distortion, low oxidation, etc. Weld spatter on the root side is limited even without the use of protecting gas from below. Weld root quality is one of the most important arguments for laser welding.

However, it is much more complicated to set the laser process correctly, as this process runs quite fast in a small spot so there is no chance to manually react to process fluctuations or imperfections. The equipment suppliers have to make the welding system as robust as possible so that it is stable and able to keep the right setting for long periods, even in a harsh industrial environment.

Installing a seam quality checking system is a great advantage as it can check the weld seam geometry and/or the welding process stability. Usually such systems have

Laser welding station.

Profile for separating glass plates in windows, welded by a single-mode fiber laser.

to be taught how the weld looks when everything is OK, which takes some time. But then, the operator has 100% on-line quality checking, which is a great advantage and sometimes a “must-have”.

5. Protecting gas

The laser welding systems described use common argon gas from the upside only. Helium or a mixture of gases have some advantages, but with much higher costs. This may look like a minor issue, but gas prices have a high impact on total running costs of different technologies and even of different laser systems.

Root protecting gas is not necessary on common mild or stainless steels.

6. Running costs

When comparing welding of round tubes of mild steel at 1.5 mm thickness, summarizing the costs for energy and protecting gas and not including the costs of amortizations, staff, and service costs, the following are obtained:

Type	$/m of weld seam
HF coil welding	$0.75
TIG welding	$2.0
Plasma welding	$3.0
CO_2 laser welding	$1.5
Fiber or diode laser	$0.3

High frequency (HF) coil welding is a standard technology for production of common construction tubes. It has quite low running costs and very high welding speed of about 80 m/min. But the weld seam quality is limited, heat input is high, and a complicated power source with an extremely heavy power line is needed.

TIG and plasma welding are used where a higher quality of weld seams is needed, usually on stainless steel. TIG technology is limited mainly by speed, especially on thicker materials. Consumption of protecting gas is an important factor, doubled when root protection is necessary.

As can be seen, there is a substantial difference between CO_2 and fiber or diode laser, mainly because the latter two do not need “laser gas,” and the fiber-guided lasers are about two times more electrically efficient. The fiber and diode laser beams are more efficiently absorbed by metals; consequently, lower laser power is needed for the same productivity with much lower service costs. There is one reason why CO_2 lasers are used – they have, in some special cases, somewhat better weld seam quality.

7. Problems

There are also some problems and limitations for the line producers and for the operator — they have to understand laser safety. They cannot observe and align the process directly like a conventional system.

The laser process is sensitive to proper alignment and servicing of the laser optics and precision machinery. Improper settings or a variation can cause poor weld seam quality, which might not be found during production.

Building a completely new production line takes a long time, with high investment, where the price of a laser welding cell is not the most important cost. There are a lot of older systems based on TIG welding – could they be changed to laser welding, too? The answer is in most cases, yes, it is possible to change the conventional TIG welding technology in the middle of the line and replace it with a laser system. Then, much higher production rates can be achieved, limited probably only by the speed of cutting at the end of the line. Typically, a conventional system with a speed of 0.5 m/min can be upgraded to 3 m/min with no problems. No pre- or post-heating is necessary and neither is a root protecting gas. Weld seam quality is even better than by TIG, and mechanical properties of the seam are greatly enhanced.

Laser welding of tubes and profiles has a promising future because there is a high demand from the automotive industry for these products, where the laser is better than conventional welding of tubes welded from zinc-coated sheets, profiles from high-strength steels, tubes to be processed by hydroforming, etc. Manufacturing lines producing outstanding quality, reasonable prices, and very low running costs are now available to users.

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market report

The industrial laser market IN TURKEY

LASER EXPORTS AND GOVERNMENT SUPPORT CONTINUE TO GROW

KORAY EKEN

A diversified economy, proximity to Europe, the Middle East, and Central Asia, integration with foreign markets, the external anchor of EU accession, solid economic management, and structural reform are the drivers of Turkey's long-term prospects. Since the crisis of 2001, the country has had one of the most successful growth performances in the world with economic expansion for 27 consecutive quarters between 2002 and 2008 due to increases in productivity, becoming the 17th largest economy in the world.

The machinery industry, crucial to the industrialization of all countries, has been the driving force behind Turkey's industrialization process, with rapid growth based on high value-added products and contributions to other sectors. As a result of this, the machinery industry has been more successful than other branches of the manufacturing industry, and the number of exports has constantly been above the average of the exports for Turkish industries overall. In terms of the value of the machinery produced, Turkey ranks sixth in Europe.

The machinery industry in Turkey has been growing at a rate of nearly 20% per year since 1990. Machinery production started to take up an increasing portion of the country's exports and, in 2011, exceeded $11.5 billion (8.57%) of total exports ($134.9 billion), which was an increase of 22.8% over the year before.

For the country's 100th anniversary in 2023, the machinery industry was given the ambitious export target to reach US$100 billion of exports with a share of 2.3% of the global market. The Turkish machinery industry was projected to have a compound annual growth rate (CAGR) of 17.8% by 2023, when the sector's share of Turkey's exports was expected to be no less than 18%.

SMEs

The growth of the Turkish machinery sector is backed by highly competitive and adaptable small and medium-sized businesses (SMEs), which form the bulk of industrial production. Turkish SMEs offer a young, dynamic, and well-trained labor force combined with a professional workplace attitude. In order to meet the financial needs of SMEs, there are some incentives granted, including exemption from customs duties, VAT exemption for imported and domestically purchased machinery and equipment, credit allocation from the budget, and credit guarantee support. Similarly, The Small and Medium Sized Industry Development Organization (KOSGEB) makes significant contributions to strengthening SMEs by various support instruments in financing, R&D, common facilities, market research, investment sites, marketing, exports, and training. In 2011, KOSGEB spent $208.3 million on this support.

As a result of the increase in the share of machinery sectors in total industrial exports containing high technologies, R&D expenditures have recently begun to rise. In 2010, R&D expenditures totaled $6.5 billion, which constituted 0.84% of GDP. In order to increase and encourage R&D activities, government institutions provide many incentives for R&D.

Industrial Laser Solutions has been tracking the significance of the Western Asian region, and specifically Turkey, as an increasingly important laser market. As an example, IPG Photonics has opened a new office in Istanbul, Turkey, to provide local support and service for the company's fiber lasers in Turkey and nearby countries. This demonstrates IPG's commitment to the region, which will enable the company to provide prompt and direct technical support to the numerous laser cutting OEMs in Turkey that use their high performance fiber lasers.

History of laser processing in Turkey

The history of laser processing in Turkey began with cutting applications in the 1990s, when imported cutting machines, specifically products from European machine manufacturers, were installed in automotive and defense industry companies. Today, lasers for cutting are still prevalent. Until 2010, CO_2 lasers dominated as kilowatt-level tools for 2D cutting of both thin and thick metals. Then, fiber lasers came on strongly.

Trumpf and Rofin-Sinar are leading suppliers for CO_2 lasers, while IPG dominates for fiber lasers, especially for marking and kilowatt lasers. Other large suppliers such as SPI Lasers and Rofin-Sinar also offer fiber laser products.

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There are many companies that integrate laser systems by using the above subsystems. Some of them also export the products that they integrate to the US, India, Germany, Russia, and Brazil. Durmazlar (Bursa, Turkey – http//tr.durmazlar.com.tr), Ermaksan (Bursa – www.ermaksan.com.tr), Nukon (Bursa – www.nukon.com.tr), Servenom (Kayseri – www.servonom.com.tr), Coskunöz (Bursa – www.coskunoz.com.tr), and Ajan (Izmir – www.ajamcnc.com) have the major share of Turkish laser revenues, with Durmazlar being the largest laser cutting machine integrator in Turkey. Durmazlar, beginning with CO_2 laser cutting machines, has produced kilowatt fiber laser cutting machines for the last several years. This company now produces more than 40 cutting machines a month, 10 of which are now kilowatt fiber laser units. Today 50,000 Durma machines contribute efficiency to different industries worldwide.

Ermaksan is another leading machinery company, producing more than 3000 machines annually, mostly integrated with CO_2 lasers. They now offer kilowatt fiber laser machines as well.

Nukon implemented fiber lasers and exported the first of the four machines produced. The company will make a €3 million investment to reduce the present production process from 60 days to 15 days.

Servenom was founded in 2007 and started its production life with CNC laser cutting and marking and CNC plasma metal processing machine production. It is aiming to be one of the preferred brands of the world in its sector. With its €200 million turnover, Coskunöz started activities parallel to the Turkish manufacturing industry in 1950 and is now one of the leading industrial groups. Ajan was founded in 1973, and in the last few years has been focusing on sheet metal cutting and forming.

In 2005, Turkey's laser exports totaled $480,000 (23 lasers), while laser imports were $45.2 million (740 lasers). These rates gradually increased each year except in 2009, when the effects of the global economic recession hit, and the import rates declined to $46.9 million from $81.6 million in 2008. The rates recovered nearly all their losses by the end of 2010.

Nevertheless, the export rates were not affected by the recession, increasing from $7.6 million to $17.7 million that year. In 2011, the total number of Turkey's laser exports was about $27.8 million (126 lasers). When compared with export numbers, laser imports were higher with a total of $104.3 million (1,630 lasers). However, it is believed that import and export numbers are higher with lasers that import or export as a part of systems with different, even sometimes wrong, HS Codes (an international standard coding of trade products).

TURKEY FIBER LASER PIONEER

FiberLAST (Ankara), was the first industrial company involved in fiber laser R&D activity in Turkey. It was founded in 2007 to design, develop, and manufacture fiber lasers in Turkey. Supported by a group of university-based collaborators, FiberLAST's R&D team has developed its own proprietary fiber lasers. The company develops and produces fiber lasers with the collaboration of Bilkent University and Middle East Technical University (METU). While the main focus is on industrial systems, the company may also develop fiber laser systems for special customer needs and academic and scientific applications. FiberLAST has attracted considerable government R&D funding to date, having signed research contracts with KOSGEB (a government organization for supporting small and medium size entrepreneurs) and TUBITAK (The Scientific and Technological Research Council of Turkey). FiberLAST has the ability to follow academic improvements and apply them to its products and to develop proprietary and innovative products worldwide. With these approaches. its developed fiber laser technology is already in the market for marking applications.

Important industries

Turkey has taken significant steps in the defense industry during the last 20 years. Being a foreign-dependent country in the past, today Turkey develops and produces its indigenous products through

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national opportunities. In the strategic plan for 2012–2016, presented by the Undersecretariat for Defense Industries, the aim is to reach $US2 billion for defense exports. Thus, there is a strong demand for defense companies to involve laser technology in development and production.

According to the Turkish Industrial Strategy Report covering the period between 2011 and 2014, the overall strategic aim of the country was determined as "increasing the competitiveness and efficiency of Turkish industry and expediting the transformation to an industry structure which has more share in world exports, where mainly high-tech products, with high added value, are produced, which has qualified labor and which at the same time is sensitive to the environment and the society." In order to achieve this aim, "increasing the weight of mid- and high-tech sectors in production and exports" is one of the basic strategic objectives that have been delineated. Energy, food, automotive, information, and communication technologies, "laser and optical systems," and machinery production technologies are defined as the primary areas that will be focused on this objective.

The Supreme Council for Science and Technology (SCST) is the highest ranking Science-Technology-Innovation (STI) policy-making body chaired by the Prime Minister, who has the decision-making power for national STI policy. At the 23rd Meeting of the SCST in 2011, it was emphasized that high-value-added sectors that improve economic welfare, provide technology improvement and increase competitiveness, with continuing R&D, have to be considered important sectors that increase competitiveness and provide sustainable development of Turkey. The optical sector is viewed as one of these powerful sectors.

Although the situation in the laser industry has improved quickly through interest in fiber lasers for the cutting sector and defense industry, Turkey had no laser production, importing all laser modules from abroad. Even without the data for the defense industry, the import of lasers was about $100 million. Thus, optic and laser technology was announced as a strategic technological area that will be supported by the government. For example, with government support, FiberLAST (Ankara - www.fiberlast.com.tr) was founded in 2007 as the first industrial company involved in R&D activity in the fiber laser area. The company designs, develops, and manufactures fiber lasers in Turkey (see sidebar "Turkey fiber laser pioneer").

As can be seen by this report, Turkey has become a vibrant market for industrial laser systems, and the country has also developed an expanding base of system suppliers that is making headway into many international markets. An incipient domestic laser activity has begun, which will start to supply the needs of system integrators.

KORAY EKEN *(eken@fiberlast.com.tr), CEO at FiberLAST, compiled this view of Turkey's industrial laser market for ILS.*

application report

Laser welding of polymers

EXTENDING THE PROCESS LIMITS BY NEW TECHNOLOGIES

ANDREAS RÖSNER AND ALEXANDER OLOWINSKY

In the beginning of the 1990s, the laser welding of polymers was considered an emerging unconventional technology suitable only for niche applications. Today, after more than a decade of significant research effort, laser transmission welding is a well-established joining technology, and it even seriously challenges processes with an older "tradition" for plastic joining, such as adhesive bonding or ultrasonic welding. For components with a suitable design, the weld seams produced by this versatile technology are closer to perfection than the weld seams produced by any other plastic welding method.

The laser welding of polymers offers the unique advantages of: contactless processing without leaving any traces on the joining components; no particles released in the welding area; and generation of a reduced heat affected zone [1, 2]. Moreover, it is the most precise of all welding methods. Therefore, for many applications—especially in electronics—laser welding has become the dominating joining technology. This process also gains more importance in medical device manufacturing. The main advantages are the non-contact and vibration-free energy input, the precise control of the deposited energy and thus the related reproducibility and low thermal load of the parts. The decreasing costs for laser source and beam guiding system are enhancing these advantages and making laser welding even more competitive compared to other joining technologies.

By the broad acceptance of laser transmission welding in the market and thus the already existing know-how of users and equipment suppliers, new requirements coming from the parts to be joined arise as the conventional way of laser transmission welding reaches its limits.

A comprehensive approach—starting from the laser source, beam guiding, beam shaping and irradiation strategy to interaction mechanisms with the material—paves the way for these new applications and their requirements. Significant effort was made to study the laser welding of dissimilar materials leading to valuable know-how on this topic. As a result, different compatibility matrices were published. Furthermore, the latest advances in the field of material development allowed, through the use of adapted additives and pigments, the welding of a broad range of colored polymers and the welding of different color combinations as well. As shown in **FIGURE 1**, based on these possible color combinations, a complexity scale for the transmission laser beam welding could be determined and solved over the years.

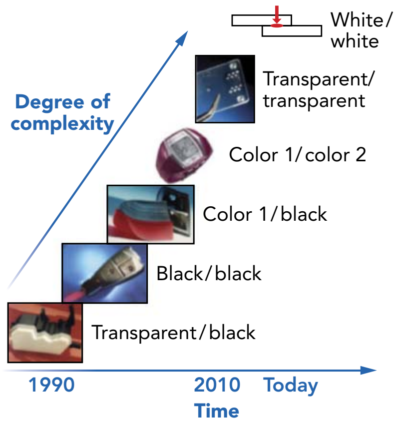

FIGURE 1. Degree of complexity for the transmission laser beam welding of thermoplastics [3].

Note that the complexity degree for the welding of the transparent/ transparent or white/ white joining configurations reaches the highest levels, and currently there are very limited practical solutions for such situations. While a laser absorber can be compounded for the welding of different color combinations with the color of the parts, there are currently no laser absorbers for the welding of transparent components. Several products from different companies are available on the market for the welding of transparent polymers such as ClearWeld, Lumogen, etc. Nevertheless, a particular slight coloring of the parts (light brown, yellow, or green, depending on the used product) cannot be avoided. To weld white material, the request for a high transmission of the laser transparent part restricts the amount of white that appears so that a high degree of white cannot be reached.

New laser wavelength

Different types of laser sources can be used for polymer welding. By the principle of laser transmission welding, the wavelength of the laser is one of the most important criteria when selecting a laser source because the optical properties of the polymers depend on the wavelength. CO_2 lasers emitting at 10.6 µm are rarely used for welding as polymers show strong absorption in this wavelength range. Only thin material can be welded because almost all radiation is absorbed at the surface. However, these lasers are used for cutting. Nd:YAG lasers emitting at 1064 nm have better beam quality than diode lasers, which is why Nd:YAG lasers are often implemented in marking systems. Diode lasers are the most preferred laser source for polymer welding: High efficiency, lower costs/W, compact design, high robustness, and the ability to be fiber coupled are the most attractive advantages [1]. Beside the standard wavelength range, between 0.8 µm and 1 µm, new wavelengths in the area between 1.5 µm to 2 µm have been developed. By analysis of the optical properties, especially the absorption and the scattering coefficient [4] and adaption of the laser wavelength on the one hand and an adaption of the material on the other hand, the process limits can be extended. The following two different applications show the implementation of the described technology, both by adapting the laser wavelength and the material.

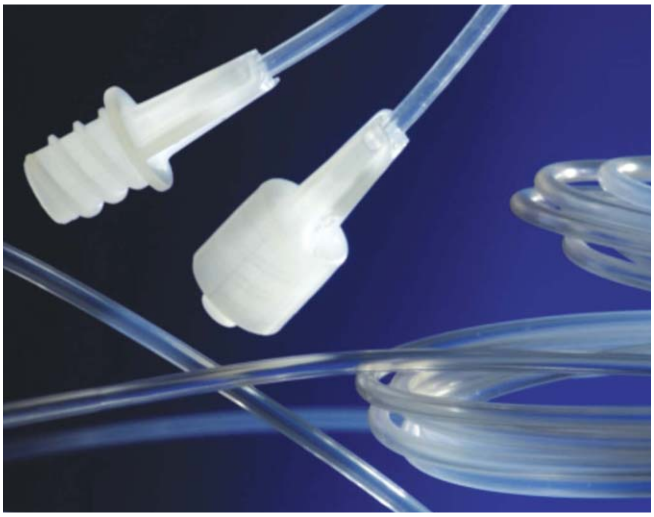

FIGURE 2. Infusion tube with laser welded connectors without an IR absorber.

Medical industry

The necessity of using an infrared absorber to deposit the laser energy in the joining area has prevented transmission welding from many applications on medical components. **FIGURE 2** presents an application where the tube end of an infusion tube and a tube connector, both consisting of additive-free polypropylene (PP), needed to be welded together. Choosing a laser source with suitable wavelength bands can be exploited in order to allow for welding without using an absorber. In the absence of an absorber, both joining component partners have equal optical properties, hence the laser radiation is no longer absorbed at their interface. Nevertheless, to deposit the laser energy into the joining area, optics with high numerical aperture (NA) are used. In the focal area, the focused beam has the highest intensity, which is set to a value sufficient to melt both joining partners at the interface. Outside the focal area, the material remains solid due to lower intensity of the beam.

The measurement of the optical properties reveals a sufficiently high intrinsic absorption of PP at 1.7 µm wavelength due to the dominating C-H-Group. Using a high-power diode laser emitting at this wavelength, both parts of the infusion tube could be welded together successfully with a process time of below 10 sec. The resulting seam is invisible from the outside and characterized by a high strength and media tightness. This process is mainly used for medical applications that often demand transparency of the components and offers a lower cost because the absorber is not used (**FIGURE 2**). In addition, in medical fields as well as in food packaging, the use of an absorber is usually connected with costly and time-consuming NDA-approval procedures which can also be saved by omitting the absorber.

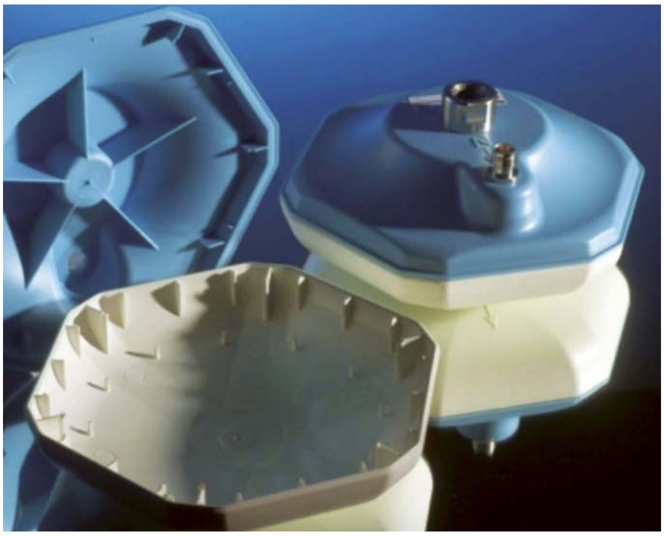

FIGURE 3. 3G-C antenna housing (navXperience) ASA/ABS polymer material (Treffert), welded with 1.5 µm fiber laser radiation in REMOTE and TWIST overlap welding configuration.

Electronic industry:

3G-C antennas are active high-precision electronic systems developed for signal reception from satellite-based navigation systems (**FIGURE 3**). A tight sealing of the housing is necessary, since it is exposed to rough environmental influence. Experiments with standard wavelengths (0.8–1 µm) failed due to high absorption at the surface, leading to decomposition and marking on the surface (**FIGURE 4**).

An adaptation of the laser wavelength along with the material optimization made by Treffert (Bingen, Germany) leads to an enormous increase of the relevant optical properties. The lower white joining partner has sufficient absorptivity in this wavelength range, which in turn means that a good weld seam quality can be achieved even when using colored polymers with high reflectivity in the visible spectral range. By using a laser wavelength of 1.5 µm instead of 0.94 µm, the degree of transmission of the blue part is raised from 48% to 63%, and the degree of reflection is decreased from 53% to 30%. A decrease in the process-relevant scattering is also achieved, which means that the intensity in the welding area is higher. For the absorbing white part, the degree of reflection is decreased from 73% to 32%, which means that the absorption is raised. Overall, this means that 30% more laser power reaches the weld, and 120% more laser power is absorbed in the weld area as well. Therefore, the new laser wavelength allows for a stable welding process and a pressure tightness of 2.5 bar.

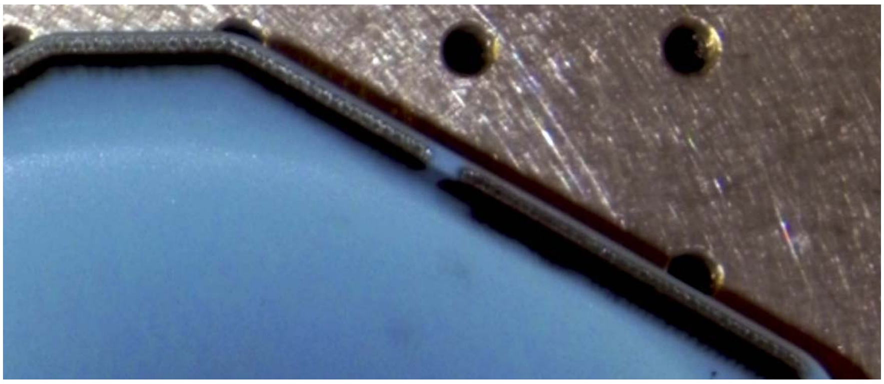

FIGURE 4. Decomposition of the surface by welding with 1 µm wavelength.

Using a welding station assembled at Fraunhofer ILT, the antenna's top and bottom shell are relatively positioned and clamped, and the focused laser beam is deflected along the weld contour using a galvo scanner head. To avoid spots with high radiation intensity, the focused laser beam is moved along the weld seam with a superimposed circular oscillation (TWIST method). With this technique, the increasing industrial user demands regarding weldability of colored instead of standard transparent/black combination can be achieved. Applications are expected in the field of consumer goods and medical components where a carbon black pigmentation has to pass for different reasons.

Summary

The results show that the use of new laser systems along with material development can enhance the flexibility of laser transmission welding. The variation of different colors has gained more flexibility and the limits of the process that demands a transparent and absorbing component are expanded, since the visual and laser wavelength are decoupled. This gives new design possibilities for the part construction engineers because the visual transparent part doesn't need to be the upper joining partner and the white part can be either the top or the bottom joining partner. ✺

Acknowledgments

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technology report

Beam profiling's role in **laser**

NO TWO LASERS ARE CREATED EQUAL

JOHN MCCAULEY

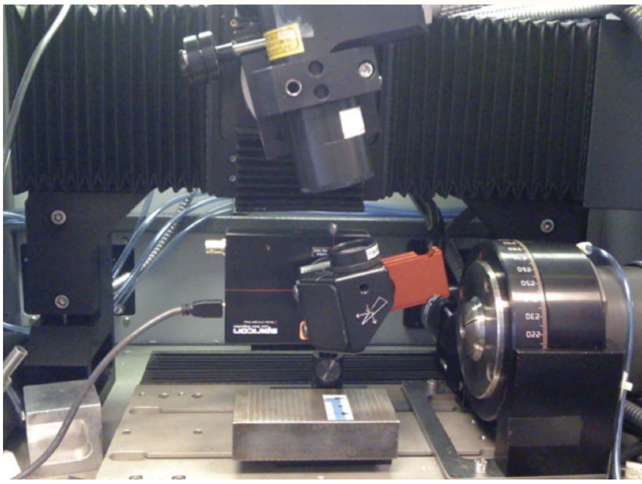

FIGURE 2. Beam profiler on a laser welding system.

H. JAMES HARRINGTON, an American author, engineer, entrepreneur, and consultant in performance improvement, has been credited as saying, "Measurement is the first step that leads to control and eventually to improvement. If you can't measure something, you can't understand it. If you can't understand it, you can't control it. If you can't control it, you can't improve it."

Even though Harrington was speaking specifically of improving the quality of a person's work performance, the same is true when it comes to maintaining a quality laser process. Quantitative and qualitative measurements of a laser's performance are the first steps to understanding how to control the laser, with the measurement data obtained being used in several ways.

Companies that use laser processes in manufacturing are tasked with controlling their laser at every step in the process. First, the development of process parameters is a crucial part of the manufacturing process because it is where quality meets quantity. If the behavior of the laser is not understood and controlled, the end user could eventually experience decreases in both quality and quantity of work. Second, once that developed parameter set is transferred from the applications lab to the work cell, it is vital to understand how the affected laser system performs, even if it is an identical laser with an identical set of process parameters. Third, the qualification of that system before it is delivered should involve some kind of factory acceptance test. Establishing a baseline of laser performance at this phase is important, and in some cases required, so that if something happens to the laser or process, such as movement of the system, it can be returned to normal. Finally, once the laser system is employed, it must be maintained. Maintenance activities can alter the system's performance. Only with laser measurement tools and techniques can you fully understand how the laser behaves at every step of the laser system's life cycle.

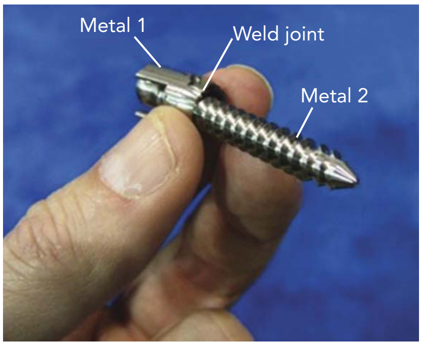

FIGURE 1. A representation of the laser welded part.

However, laser measurement is still not universally applied. Conversations about laser measurement at a facility that does not have a program in place to support their laser products ultimately yield questions such as: "What does laser power measurement or beam profiling do for me?" or "How can I use the data that I get from a beam profile?" Sometimes it's difficult to communicate the answers to these questions without an example of where they've been applied.

The evolution of a laser process validation program

Earlier this year, a company that supplies, among other services, laser welded parts to the biomedical industry, had an issue arise with an in-house laser process. The company had been experiencing increased expansion in its manufacturing processes related to most of its medical devices. One of the keys to its successes was establishing a solid reputation in the industrial community as a vendor that supplies the highest quality parts to some of the larger medical device manufacturers across the country.

Early on, the company decided to learn about laser monitoring on a laser welding process that joins two dissimilar metals of the implantable device shown in

process validation

FIGURE 1. For this joining process, they utilized a lamp-pumped Nd:YAG laser with free-space optics operating in a repetitive pulse mode, which was integrated into a small glove box workstation used for manual welding. Already having an established set of laser parameters for this process, they decided it would be best to start by monitoring energy per pulse readings. However, at the time, there was no real laser quality assurance program in place, and the readings were simply used to get a feel for how the laser was performing day-to-day.

Since that time, this company's reputation and commitment to quality allowed them to establish new relationships with additional medical device manufacturers and increased quantities ordered by their current customers. This success resulted in the opening of an additional facility in a nearby town, which has an established medical device manufacturing community. As the quantities of parts being processed increased, the company also purchased an additional, identical laser system.

Soon after employing this laser with the same process parameters, the company discovered that welds were cracking (luckily, during a quality inspection and not after providing the part). This indicated that too much heat was being put into the weld. How could this make sense with identical laser parameters being applied to identical laser systems? It was clear to the company at that point that a more comprehensive laser measurement program was needed for its processes.

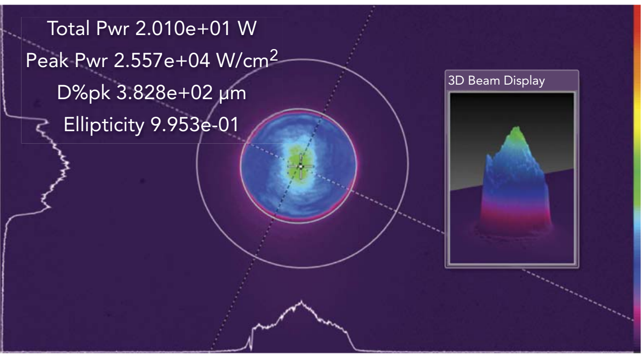

FIGURE 3. Beam profiles on Laser #1 at process parameters: 0.5 kW peak, 9 Hz, 5 ms pulse, and 400 µm spot size.

With these particular pulsed Nd:YAG welding laser systems, the user can change four different laser settings to get different results: laser peak power (laser energy with respect to the duration of the laser pulse), pulse width (or pulse duration), pulse repetition rate (frequency of the pulses), and spot size.

It is also worth noting that the lamp time between Laser #1 and Laser #2 was about the same (around 500 hours) at the time of these tests.

The technique that was used for these measurements consisted of determining the laser's average power with an Ophir thermopile sensor and meter and measuring the laser's spot size and shape with a Spiricon high-resolution camera and beam attenuation device, as pictured in **FIGURE 2**.

Simple experiments provide quick solutions

First, baseline average power and spot size measurements were established and recorded on Laser #1, the laser that was producing good parts. **FIGURE 3** shows the 2D and 3D beam profiles with some of the calculated results.

Second, measurements of Laser #2 at the same process parameters were taken, keeping all of the same software and optics settings of the beam profiling system. **FIGURE 4** shows the 2D and 3D beam profiles with some of the calculated results. Using Laser #2 at the workpiece with the same process parameters, the output average power was measured at a 35% increase from Laser #1's. The spot size remained about the same. The power density measurement, however, showed a 15.6% increase from that of Laser #1. Both visually and mathematically, it's easy to see that there are differences between the two beam profiles and laser power measurements from what are supposedly two identical laser systems with the same laser settings.

Since the beam analysis system was set up, the company made some changes to Laser #2's parameters to attempt to achieve a set of measurements similar to that of Laser #1. In the span of about 10 minutes, it was discovered that decreasing Laser #2's peak power and the pulse width settings created an image and set of measurements that were closer to that of Laser #1's. The results of changing these

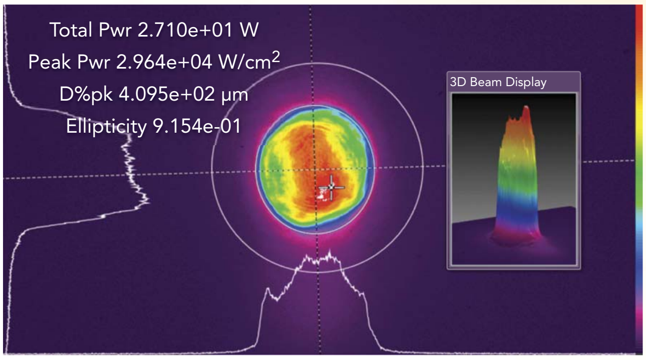

FIGURE 4. Beam profiles on Laser #2 at same process parameters: 0.5 kW peak, 9 Hz, 5 ms pulse, and 400 µm spot size.

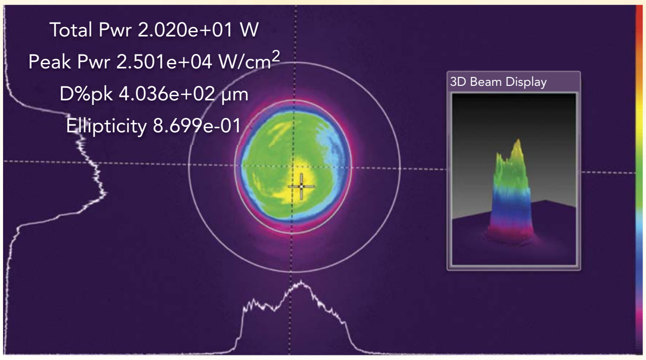

FIGURE 5. Beam profiles on Laser #2 at modified parameters: 0.48 kW peak, 9 Hz, 4 ms pulse, and 400 µm spot size.

settings are shown in **FIGURE 5**. Again, visually and mathematically, the results of those two minor changes in the process parameters are apparent. Using these modified process parameters has brought the beam profile closer to that of the laser that is producing acceptable parts. The customer was then tasked with verifying that the new parameters yielded desirable results.

Be armed with the right tools

These three pictures tell the story that no two laser systems are created equal. To be clear, the laser manufacturer should not be considered at fault for providing a defective product. There are many variables that can affect the quality of a laser system's components. Because of this, those who are responsible for ensuring quality in their laser processes, and those responsible for protecting the integrity and reputation of their companies, should arm themselves with the right tools and know for sure that their laser processes are consistent from batch to batch, from day to day, and even from one laser system to the next. The only way to know this for sure is through a comprehensive laser characterization program.

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4 Lasers & Photonics Marketplace Seminar, San Francisco, CA; www.marketplaceseminar.com/index.html

12-13 LIA's 5th annual Laser Additive Manufacturing Workshop, Houston, TX; lia.org/conferences/lam

20-21 International Conference on Turbomachinery Manufacturing, Aachen, Germany; www.ictm-aachen.com/

20–23 Indometal, Jakarta, Indonesia, www.mdna.com

28 Laser Safety Officer Training, San Diego, CA; www.lia.org/store/course/LSOCA0213

MARCH
11-15 Laser Safety Officer With Hazard Analysis Training, Phoenix, AZ; www.lia.org/store/course/LSOHAAZ0313

12-13 Industrial Laser Applications Symposium (ILAS), Nottingham, UK; ailu.org.uk/laser_technology/events/2013-03-13/ilas2013.html

13-14 Micro.Nano.Mems - The Ultra Precision Manufacturing Expo, Rosemont, IL; www.micronanomems.com

18-21 International Laser Safety Conference (ILSC), Orlando, FL; laserinstitute.org/conferences/ilsc/conference

19-21 Laser World of Photonics China, Shanghai, China; http://www.world-of-photonics.net/en/laser-china/start

APRIL
10-12 Photonix Expo & Conference, Tokyo, Japan; http://www.photonix-expo.jp/en/

MAY
14-16 BLECH China, Suzhou, China; blechchina.com

JUNE
10-14 Laser Safety Officer With Hazard Analysis Training, Niagara Falls, NY; www.lia.org/store/course/LSOHANY0613

24-28 Fundamentals of Laser Assisted Micro- & Nanotechnologies (FLAMN-13), St. Petersburg (Pushkin), Russia; www.lastech.ifmo.ru/FLAMN13/

25-27 Laser Safety Officer Training, Indianapolis, IN; www.lia.org/store/course/LSOIN0613

OCTOBER
7-11 Laser Safety Officer With Hazard Analysis Training; Miami, FL; www.lia.org/store/course/LSOHAFL1013

15-17 WESTECH, Los Angeles, CA; www.westeconline.com/2013/public/enter.aspx

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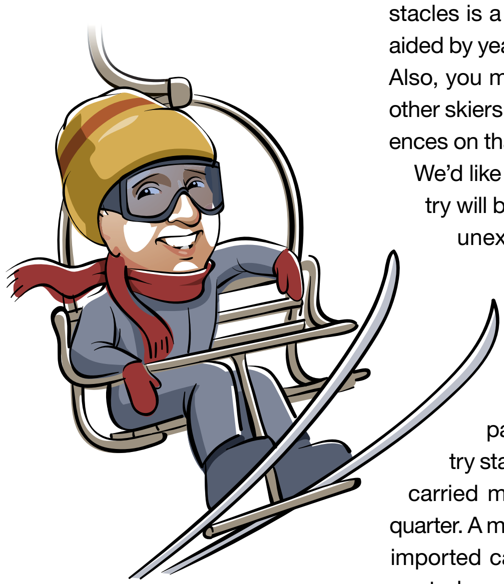
my view

The course looks gnarly

2013 FORECAST:

BUMPS



Starting a new year can be a little like skiing a trail for the first time. If you're lucky and the lift is adjacent to the trail you have chosen, you can get a look at it and file away information on where to turn or where to change the direction of your descent. But for the most part, it is a real-time activity with no forewarning. Depending on your level of expertise, adjusting to changing slope conditions or unexpected obstacles is a relatively straightforward procedure aided by years of experience in similar situations. Also, you might have received some hints from other skiers on slope conditions and their experiences on that trail.

We'd like to think that this year the laser industry will be a smooth run, with any bumps and unexpected obstacles well within our expertise. That's usually far from reality. However, we do know a little bit about the first quarter because the die has already been cast with backlogs from the last quarter of the past year. For example, the laser industry started 2012 with a healthy backlog that carried many suppliers well into the second quarter. A major bump, the freezing of the Chinese imported capital-equipment market, was unexpected, and some suppliers were unprepared. Add to this the also unexpected obstacle caused by a political spat between China and Japan that impacted the sales of Japanese capital equipment into this large market, and cost some suppliers a 20% loss in business. That's a mogul you didn't see coming.

The ongoing economic distress in Europe has been such a dragged-out affair that it is now just a series of small ripples we are equipped to handle. The same holds true for the "fiscal cliff" mess in Washington, which, by the time this is published, should be over. At best, its effects will be just a bigger ripple that only affects the U.S.

During the period it took to prepare my report in this issue, I sought the wisdom of many who make their living in the industrial laser sector. If I was schussing into uncharted territory, I valued the opinions of others making the same trip. Like a downhill skier, each had his own anecdotal contribution, but most took refuge under that worn-out descriptor 'uncertainty'. Prodding them to stretch their thinking over the next terrain drop, I managed a consensus on a flat-to-low growth 2013, ending with an uptick as the groundwork for a more prosperous 2014 was laid in the last quarter.

I've been doing these forecasts for about 28 years, starting in the predecessor to this magazine, *Industrial Laser Review*. A broader audience was exposed to my analysis through the Marketplace for Lasers seminar organized 25 years ago by sister publication *Laser Focus World*, whose Editor-in-Chief, Conard Holton, joined me in a search through the *LFW/ILS* library to find some of the early reviews I published.

I thought you might be interested in the total number of industrial laser units sold in 1986, a steep decline year for capital equipment sales (see **TABLE**), compared to those in Table 2 (see p. 8) of this year's report. That was then, but this is now, with unit sales having grown 27 times over 1986 numbers. If you look at the curve in Figure 1 of this year's report, you'll notice that it bears a resemblance to a ski slope. Do you think skiing was on my mind as I slalomed through this first My View of 2013?

Materials processing laser sales

	1985	1986
CO_2	1250	1300
SOLID-STATE	1400	890
TOTAL	2650	2190

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