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July : August 2010

Paint stripping advances

Diode laser hardening

Scribing consumer electronics

LASER ADDITIVE MANUFACTURING'S *rebirth*

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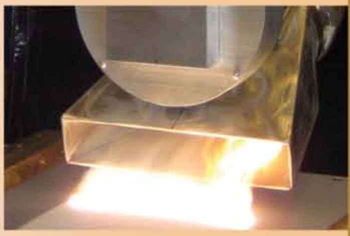
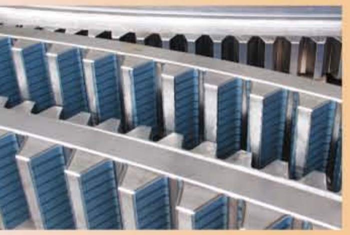
COVER STORY

Laser additive manufacturing is experiencing rapid growth as global companies adapt lean manufacturing practices.
Courtesy: Alabama Lasers





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INDUSTRIAL Laser Solutions FOR MANUFACTURING®

JULY/AUGUST 2010
VOLUME 25 : NUMBER 4

Features

Departments

Integrity 25th anniversary Excellence

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update

Patented laser engraved bricks solve problems

WEST PALM BEACH, FL - Bricks featuring personalized inscriptions are sold to supporters and then installed at the sponsoring organization. Traditionally, commemorative brick programs have been used by hospitals, zoos, libraries, parks, schools, museums, etc. More recently, programs have been offered by sports teams and venues as an alternative revenue source and unique method of fan participation.

Traditional engraving techniques (such as sandblasting and pantographing) suffer from problems that greatly limit program potential. Brick Markers® patented laser engraving processes enhance program potential by offering solutions to the following problems: an inability to produce highly detailed and complex images; loss of structural integrity; deterioration of fillers; poor warranties; and environmentally unfriendly products.

The inability to produce highly detailed images can greatly limit the fundraising potential of a program. The level of detail offered by laser engraving can be used to enhance revenue by differentiating contribution levels across a broad product line. For example, a zoo could offer various animal images tied to certain levels of giving (e.g., an elephant could denote a greater contribution than a monkey, etc.). Likewise, bricks featuring company logos are appealing to businesses since they offer high visibility, image enhancement, and advertising benefits. Additionally, laser engraving provides unsurpassed capability to produce arrays, a large picture that is assembled from individually engraved bricks and put together like a puzzle. As seen in **FIGURE 1**, the level of detail and complexity that can be achieved with laser engraving far surpasses that attainable with traditional techniques.

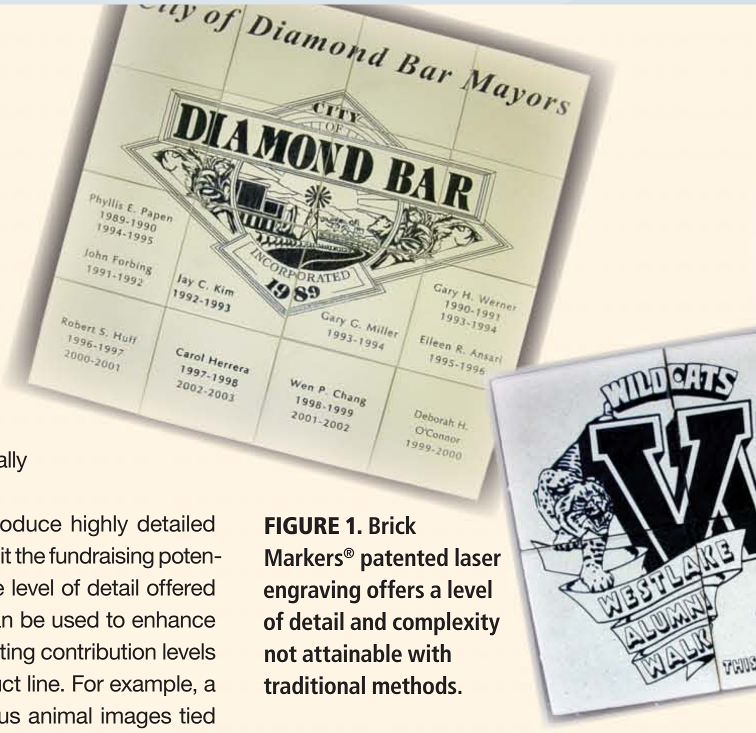

FIGURE 1. Brick Markers® patented laser engraving offers a level of detail and complexity not attainable with traditional methods.

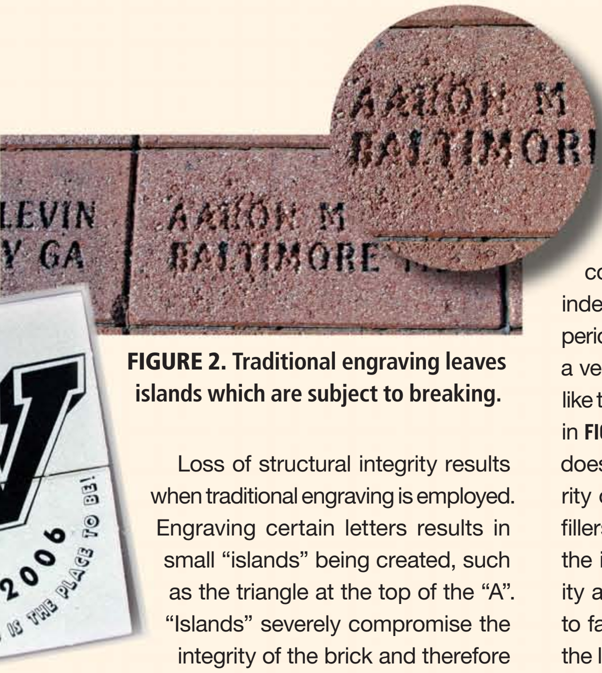

FIGURE 2. Traditional engraving leaves islands which are subject to breaking.

Loss of structural integrity results when traditional engraving is employed. Engraving certain letters results in small "islands" being created, such as the triangle at the top of the "A". "Islands" severely compromise the integrity of the brick and therefore the durability of the inscription. As can be seen in **FIGURE 2**, the loss of structural integrity leaves the "islands" subject to breaking as a result of freeze-thaw weathering and normal wear and tear. As the letters deteriorate, the inscription becomes increasingly illegible. Laser engraving doesn't produce "islands" or compromise the structural integrity of the brick. Consequently, legibility is never compromised due to "islands" breaking away.

Deterioration of fillers is a common malady of traditionally engraved bricks. To create contrast with the engraved surface and/or reduce problems associated with "islands", engravers typically utilize paint or epoxy filler. Paint creates contrast, but is subject to fading and peeling and does not protect the "islands". Therefore, paint offers a less satisfactory solution than epoxy filler. While the epoxy filler adds contrast and slows deterioration of the islands, this solution is also far from ideal. Sunlight results in the filler oxidizing and an associated loss of contrast. Different rates of expansion and contraction result in peeling and separation of the filler from the brick. As seen in **FIGURE 3**, deteriorating fillers result in an unattractive brick and increasingly illegible inscription. Laser engraving offers the ideal solution. The engraved portion of the clay brick is vitrified, producing a glass inscription harder than the brick. It uses no fillers and is not subject to fading, oxidation, peeling, or separation from the engraved brick.

Poor warranties are typically offered by engravers employing traditional techniques. Such warranties are vague. For example, the warranty might state that the engraving "will remain legible". Items with poor contrast or missing filler could indeed be legible — at least for a period of time. But this seems like a very low standard. Would you like to be the proud owner of the brick shown in **FIGURES 2** or **3**? Because laser engraving does not compromise the structural integrity of the brick and does not use paint or fillers, it has become the "gold standard" of the industry. It offers unsurpassed durability and can be confidently guaranteed not to fade, chip, oxidize, peel, or separate for the life of the surface of the engraved brick.

Environmentally unfriendly products are often the end result of traditional engraving and fill methods. Laser engraving is the ultimate "green" technology and uses no solvents, paints, plastics, or volatile organic compounds.

Given the many advantages of laser engraving, it would be easy to think of it as unaffordable. However, laser engraving's superior image detail, permanent and maintenance-free inscription, unparalleled warranty, and environmental advantages are available at a price competitive with traditional engraving methods.

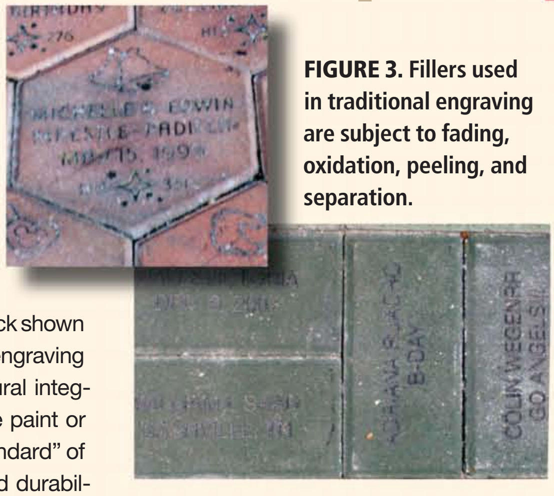

FIGURE 3. Fillers used in traditional engraving are subject to fading, oxidation, peeling, and separation.

This article was prepared for *ILS* by Sharon Rieck, president and owner of Brick Markers® USA. Her company is the sole source of the exclusive patented Vitralase® and Vitrix® laser engraving processes. To contact a sales representative in your area go to http://www.brickmarkers.com/findarep.htm or call (800) 634-8948.

COVER STORY

conference report

Laser Additive Manufacturing Workshop 2A

PAUL DENNEY

LASER ADDITIVE MANUFACTURING HAS FINALLY BECOME A PROCESS OF INTEREST FOR A NUMBER OF INDUSTRIES

The term "laser additive manufacturing" covers a wide range of processes. It can range from depositing a "patch" on a damaged or worn steel part to the fabrication of functional micron-scale parts in exotic materials for medical applications. Having been involved in laser "additive manufacturing" for over 25 years, I find it somewhat humorous that today's design and sustainment problems have finally caught up with this "new" solution. While there have always been proponents of the technology for niche applications, with recent improvements in lasers, digital modeling and control, and re-thinking by companies with respect to "repair" versus "replace," additive manufacturing has finally become a process of interest for a number of industries. As designs and cost reduction efforts push manufacturers and operators, it is probable that laser additive manufacturing will become even more broadly used.

The Laser Institute of America (LIA) held its second Laser Additive Manufacturing (LAM) workshop in Houston, TX, on May 11 and 12, 2010. Designed to gather those involved in the wide areas of laser deposition of materials, this workshop drew 50% more attendees than last year's inaugural event, including representatives from more than 11 countries. The participants held interests ranging from the use of lasers to repair/refurbish components to "digital" fabrication of functional components.

The LAM workshop began in 2009, when it was noted that a noticeable percentage of papers appearing at ICALEO were focused on the use of lasers to deposit materials. Unlike ICALEO, which has multiple tracks over four days and is more academic in nature, the LAM workshop had the objective of being more application-oriented with participation by those that use or would like to use the technology.

LAM was launched March 3-4, 2009 in San Antonio, TX, a location selected because of the number of facilities located in Texas involved with laser cladding for the oil/gas/energy industries (**FIGURE 1**). There were a number of concerns about starting a new conference/workshop during what many considered to be the worst economic environment since the Great Depression. However, the workshop was well attended, suggesting

010 SUCCESS

FIGURE 1. Large hydraulic road laser clad with powder. Courtesy: Alabama Laser

FIGURE 3. Dual hot wire laser cladding. Courtesy: Alabama Laser

that the topic was timely even in a down economy.

The LIA was very pleased with the 2010 LAM, which grew 47% versus 2009. This may be attributed to the workshop developers emphasizing their commitment to providing both end users and manufacturers with the practical knowledge and information needed to use lasers productively and profitably (**FIGURE 2**).

Keynote speaker Dr. William “Bill” Steen of Liverpool University, Liverpool, U.K., commented that LAM was well organized with an extraordinary level of friendliness among the participants who were highly motivated to move their businesses forward. Dr. Steen said, “Regarding the technology, significant advances have been made in developing high efficiency and high quality cladding, with tentative adventures into 3D manufacture. This is obviously a subject that is growing and will become a large industry.”

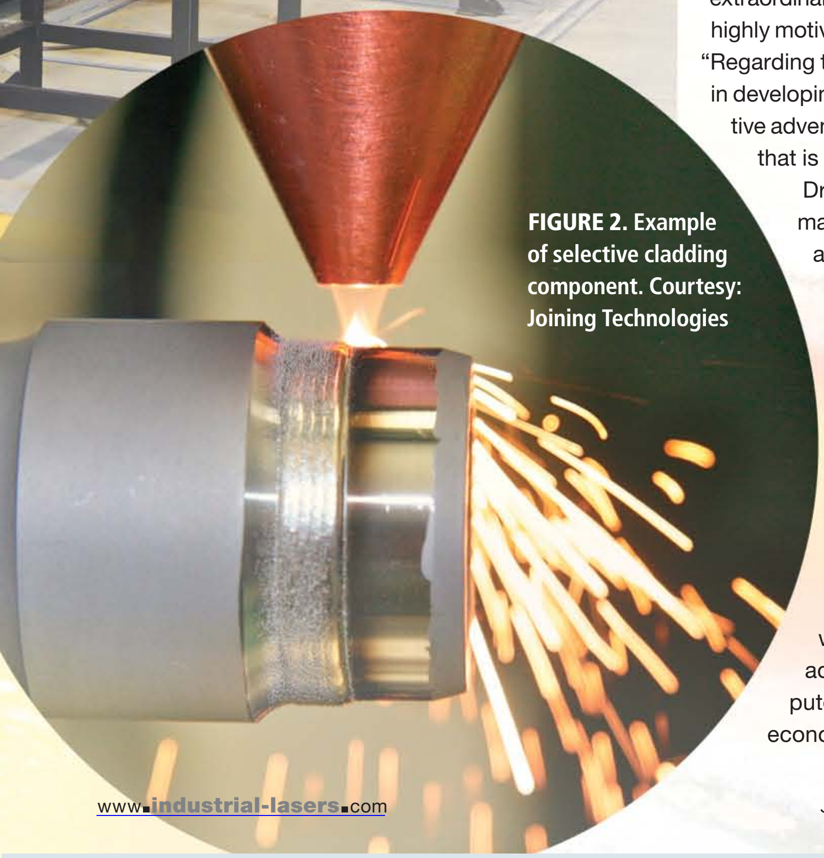

FIGURE 2. Example of selective cladding component. Courtesy: Joining Technologies

Dr. Ingomar Kelbassa of RWTH Aachen University, Germany, remarked that “this year’s LAM workshop is the one and only workshop/conference I know which is absolutely focused on processes such as LMD [laser metal deposition] and SLM [selective laser melting]. LAM is industry driven, and the main forum for experience exchange in that specific field of application.”

The Plenary chair, Dr. Jim Sears of the South Dakota School of Mines & Technology, arranged three speakers. Dr. Steen gave the first one, an overview of the technology. Steen has been involved in laser materials processing for almost five decades. His presentation was titled “Some Thoughts on Laser Additive Manufacturing”. Dr. Steen mentioned that while laser cladding had been around for a long time, advances such as low cost and easy-to-operate computers are making precision manufacturing possible and economical.

A second presentation by Dr. Kelbassa, titled "Additive Manufacturing, Repair and Salvage of High-Value Aero-Engine Components by Laser Metal Deposition and Selective Laser Melting," reviewed a number of advances that have been made in Europe in aerospace such as the repair of blade integrated disks (BLISKS) and nozzle vanes (NGVs), which are important components in today's advanced jet engines.

FIGURE 4. Single hot wire laser lead. Courtesy: Alabama Laser

The final plenary presentation was by Dave Abbott of General Electric Aviation, who focused on progress being made in the establishment of standards for additive manufacturing especially through the ASTM F-42 committee. This committee, created to standardize various aspects of additive manufacturing, has begun with creating definitions so that people can communicate with common meanings for terms that may be used in additive manufacturing.

An additional 20 papers were presented, ranging from materials used for deposition to the types of lasers and optics used for additive manufacturing to examples from various industries that are using LAM. The material presentations included presentations by powder manufacturers such as North American Hoganas and presentations by Alabama Laser (Wayne Penn) (**FIGURES 3** and **4**) and Preco (Joel DeKock), who both use wire as the additive material. Presentations on laser and optics systems included dedicated equipment for inside bore cladding by Paul Colby of Xaloy and laser processing heads for cladding and heat treatment from Scott Heckert of II-VI. On the second day, there were a number of presentations that related to specific applications. Dr. Sears presented on work he has accomplished on "scaffolding" for bone growth into prosthetics. Dr. Rich Martukanitz presented on a number of Navy applications for laser cladding/repair.

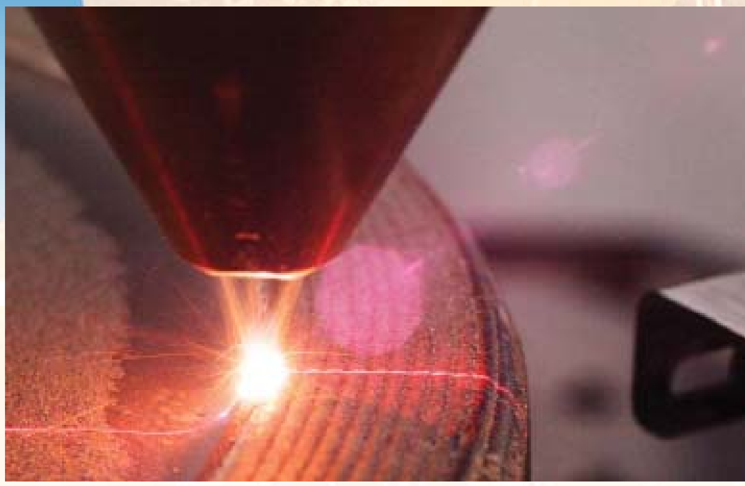

FIGURE 5. Example of surface cladding of component face. Courtesy: Joining Technologies

"The LAM is the only venue dedicated solely to additive or direct manufacturing," stated Dave Hudson, president of Joining Technologies (**FIGURE 5**). "As such it brings together an interested group of competitors and educators to enthusiastically discuss advances in the field. Any potential user of the technology needs only to sit and listen in order to gain insight collected over decades by the world's leaders in additive manufacturing. Joining Technologies is proud to be a member of this group and will continue in its efforts to advance the technology by their continued sponsorship of LAM."

In addition to the technical presentations, 22 exhibitors were present, including laser manufacturers, integrators, research organizations, laser cladding service providers, and powder manufacturers. There were also 13 sponsors that made the workshop possible and a success. With the success of LAM 2010, the LIA staff has already begun to plan for LAM 2011, which will be held early next year.

Paul Denney is director of the Laser Applications Laboratory at the Connecticut Center for Advanced Technology. He can be reached at pdenney@ccat.us.

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application report

Slice and dice: LASER MICROMACHINING *for* CONSUMER ELECTRONICS

VICTOR DAVID

MORE EFFICIENT LAPTOP SCREENS, HIGHER CAPACITY FLASH MEMORY STICKS AND FASTER COMPUTER PROCESSORS ALL RESULT FROM THE REPLACEMENT OF MECHANICAL CUTTING METHODS WITH LASER MICROMACHINING

Over the past few years, notebook computer battery life has tripled; the capacity of memory cards has increased while their cost has declined; and computers, smart phones, and other digital devices have become ever faster and more powerful. While many factors have contributed to these improvements, the increased use of laser micromachining is a common enabling theme. Consequently, the demand for laser micromachining in the electronics industry has probably never been stronger.

Bright LEDs for long battery life

The use of efficient LEDs instead of inefficient cold cathode lamps as the backlight source in liquid crystal displays has dramatically extended battery lifetime in laptop computers and reduced energy consumption in televisions. As a result, the LED industry is experiencing unprecedented growth.

LEDs used in flat panel displays are based on gallium nitride (GaN), which is grown and patterned as thin (a few microns total) layers on a sapphire wafer. Sapphire is ideal because it provides a lattice match for the GaN and is also transparent. This is important because some of the light escapes the LED by partially passing through the edge of the sapphire substrate. Sapphire is also a fairly good thermal conductor, which helps in heat sinking the LEDs. But unfortunately, sapphire is a notoriously difficult material to cut, second only to diamond.

In practice, LEDs are patterned in bulk on sapphire wafers measuring 2 inches in diameter with a typical thickness of about 100 microns. Thousands of LEDs can be produced on each wafer because the final LED chip may measure only 0.5 mm x 0.5 mm or even less. The LEDs are then physically separated in a process called singulation.

Traditionally, singulation was carried out by scribing (partial cutting) with a diamond saw wheel, followed by physical snapping. But today, most LED manufacturers have switched to laser scribing, again followed by physical snapping using a pressure edge (see **FIGURE 1**). Here a focused, pulsed UV beam partially cuts through the sapphire. Typically several passes are used to cut through approximately 30% of the wafer thickness (see **FIGURE 2**). Conventional physical snapping follows.

Laser scribing has become the preferred method for several reasons. First, by focusing the beam down to a spot size of a few microns or less, the laser scribe can be much narrower than a saw cut and with significantly less edge damage (cracking and chipping). This means that LED devices can be packed closer together with narrower gaps, called streets. The high quality edge also eliminates the need for post processing, which is impractical on such tiny devices. All this translates into

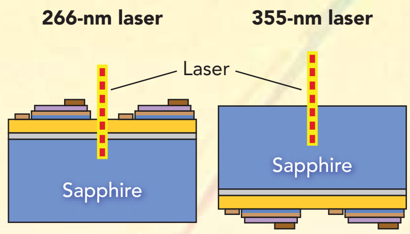

FIGURE 1. Bright LEDs are created on a thin sapphire wafer and then separated (singulated) by laser scribing followed by physical snapping with a pressure edge.

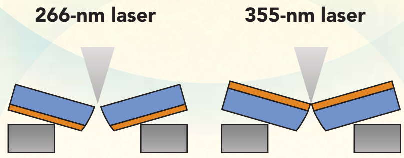

FIGURE 2. In LED singulation, a 266 nm (or 355 nm) pulse UV laser is used to scribe through approximately 30% of the total sapphire wafer thickness, followed by mechanical snapping.

higher yields and therefore lower unit cost. In addition, tight focusing enables fast scribing at lower laser powers, thus minimizing the cost of implementing lasers.

What laser characteristics does scribing require? The most common laser singulation method is front side (the device side) scribing using a 266 nm, Q-switched DPSS laser. One of the most important laser parameters is beam quality because a low M^2 ensures good edge quality and allows minimum LED separation. Basically, M^2 is a number that describes how tightly a laser beam can be focused; a perfect Gaussian beam has the theoretical minimum

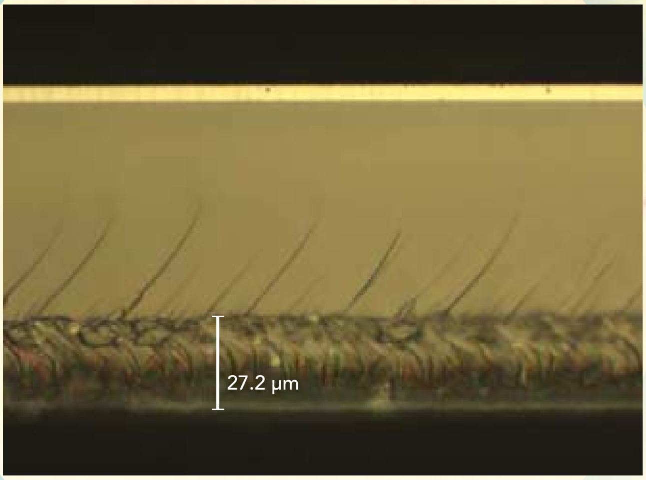

FIGURE 3. As silicon wafers for memory chips get thinner, the maximum sawing speed gets successively slower. In contrast, maximum speed for laser cutting gets considerably faster.

focused spot size defined by $M^2 = 1$. For all real lasers, usually $M^2 > 1$. (Many LED manufacturers use the Coherent AVIA 266-3 principally because of its $M^2 < 1.3$ rating). Other key laser parameters are reliability, pulse-to-pulse stability, and an average power of at least 2.5 W to achieve target throughput rates. Alternatively, a few manufacturers scribe from the backside of the sapphire using a 355 nm laser; this wavelength produces some minor debris so cutting from the backside keeps this away from the LEDs themselves. Here, beam quality is even more important as sapphire is quite transparent at 355 nm and can only be machined at this wavelength by using a high focused intensity to drive nonlinear absorption. Popular models for this method are either the AVIA 355-5 or 355-7, again because both have an M^2 value of <1.3. In addition, a few LED manufacturers are investigating the use of hybrid picosecond lasers such as the Coherent Talisker, where a 532 nm wavelength should produce equivalent results to nanosecond pulses at 266 nm.

More memory in less space

The capacity of SD and microSD memory cards has been steadily increasing over the past several years, yet the physical size and shape of these cards necessarily remains the same. Plus, the unit cost per MB has dropped dramatically. The two primary factors that have enabled this are greater circuit density through advances in microlithography and the use of physically thinner wafers so that more can be vertically stacked together within a given sized package.

At present, typical memory wafer thickness is currently 80 microns or less; 50 microns is considered cutting edge; and 20-micron wafers are being investigated at the R&D level. For economies of scale, these wafers are up to 300 mm in diameter. Since silicon is a crystalline material, a 300 mm x 50 micron wafer is incredibly delicate and easily chipped or broken by mechanical contact. And, with a typical post-process value of well over $100K, breakages must be avoided during the singulation process.

Traditionally, singulation involved multiple passes with a diamond saw wheel. But at 80 microns thickness, the saw must be slowed to an uneconomical rate using low cut pressure to avoid chipping, cracking, and breaks (see **FIGURE 3**). This has created tremendous opportunities for lasers. Many chip producers have now switched to cutting with a Q-switched 355 nm DPSS laser. Like the saw, laser cutting has to be done in multiple passes to minimize thermal damage, which is removed by subsequent post-processing. For this reason, the single most important laser parameter is a very high pulse repetition rate. Specifically, the typical scan rate is 600 to 750 mm/sec in order to achieve an overall cut rate of about 150 mm/sec with around five passes. Plus, this application needs very good edge quality that requires 50% pulse-to-pulse spatial overlap. Coherent therefore developed a very high repetition rate laser just for this thin wafer application (the AVIA 355-23-250), which combines a 250 kHz pulse rate with power output >8 W to deliver sufficient cutting power per pass. There is also growing interest in process development using hybrid picosecond lasers since the shorter pulse duration produces much less heat affected zone (HAZ), eliminating the need for post-processing.

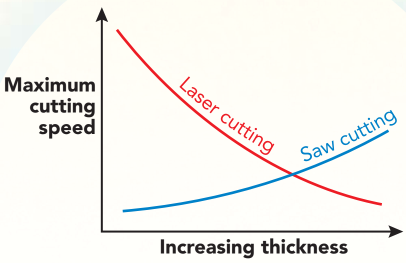

FIGURE 4. With so-called low-κ materials, mechanical sawing can cause major damage to the integrated circuits.

Faster computers and phone applications

As integrated circuit features shrink, the insulating gaps between circuit interconnects become narrower. Traditionally, the insulating material used in these gaps is silicon oxide. But, higher circuit speeds require lower impedance lines, which means using materials with a lower dielectric constant, i.e., higher resistance. Thus, there is an interest in switching to so-called "low-κ materials," that is, materials with a lower dielectric constant (denoted κ).

Low-κ can be achieved by using traditional silicon oxide, but at lower porosity. In addition, entirely new materials are being considered, again often with increased porosity to increase the air content and thereby further lower their κ value. As with memory chips, these fast processors are created as thin epitaxial layer objects

that are densely packed on a large silicon wafer. The problem here with singulation is that low-κ materials are all soft. Thus, traditional diamond sawing can cause considerable damage, including delamination, to the circuits (see **FIGURE 4**). However, these are thicker wafers than memory devices, so laser sawing is not quite economically practical at this time.

As a result, a hybrid process is now becoming the preferred method. Specifically, a 355 nm, Q-switched DPSS laser is used to cut through the soft epitaxial layers to create crack stops. This is then followed by mechanical sawing through the wafer itself. Two versions are currently used as shown in **FIGURE 5**. For wafers designed with wide streets between the individual circuits, the laser may be used to make narrow scribes down either edge of each street, in a single pass. With narrower streets, several beams in parallel may be used to make a single scribe that is wide enough to accommodate the saw blade cut. The former is more commonly used as it requires less laser power for a given throughput, i.e. lower processing costs. Key laser parameters here are beam quality and high repetition rate. A typical laser for this application is the AVIA 355-23-250 which provides the requisite 30 microjoules per pulse and $M^2 < 1.3$. Moreover, it can deliver these specifications at a repetition rate of 250 kHz, which supports 200 mm/sec scribe rates with 50% pulse-to-pulse overlap.

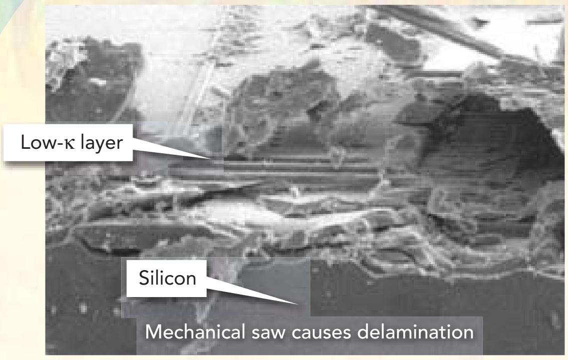

FIGURE 5. Chips using low-κ materials use laser scribing down the street between the chips. The laser scribes act as crack stops enabling high speed sawing with no damage to the circuitry.

Conclusion

In conclusion, the shrinking dimensions of electronic components, together with a shift in materials, continue to make laser scribing an ever-more attractive and economically viable process. Plus, laser manufacturers have worked to improve the performance, reliability, and cost of ownership characteristics of their products to even further broaden the range of tasks for which they are applicable.

Victor David is senior product line manager with Coherent Inc. www.coherent.com.

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application report

ADVANCES IN LASER paint stripping

STAN REAM

NEW POLYGON SCANNER DOUBLES PAINT STRIPPING EFFICIENCY

Paint is everywhere in our lives, and it has a multitude of uses. We paint surfaces for their protection and for their appearance. We paint objects to make them more obvious or less obvious. And, of course, paint can become art. But paint doesn't last forever. It can peel, erode, flake, crack, or become unwanted for a variety of reasons. In many cases, the removal of old paint is a critical step in the long term preservation of infrastructure assets, such as bridges, storage tanks, rail cars, etc. Sometimes we just want a new color on our painted surfaces. Imagine, for instance, the paint removal challenge that an airline faces when it acquires a competitor's fleet of aircraft.

Paint removal can be accomplished in variety of ways, but the dominant two methods are media blasting and chemical removal. Sand is certainly the most common media for the blasting solution, and painted steel surfaces are the most common application for it. We've all seen the tents around bridges during repair and repainting. For softer substrates, such as aluminum, media blasting is carried out with plastic beads, walnut shells, starch, or even CO_2 pellets. Alternately, chemical paint stripping is widely used on aircraft and off-aircraft components. The chemicals used for paint stripping have been improved over the years, but they remain toxic and hazardous in various degrees. Additionally, media blasting and chemical paint removal techniques both multiply the amount of hazardous waste that must (or should) be managed, and they present a variety of worker hazards. For these reasons, some aircraft may be flown out of the U.S. to conduct paint removal in more environmentally lenient countries, where worker safety may not be as high a priority.

Alternative paint removal techniques

The Air Force has been pursuing alternative paint removal techniques for decades. Their needs are strategic, and their aircraft present some unique paint removal "business cases". Thus, the Air Force has been the driving force in the investigation and development of laser paint stripping technologies. A number of Air Force projects from the 1980s demonstrated the potential of laser paint stripping and identified the implementation challenges to come. As lasers became more "industrialized," the development of laser paint stripping technologies continued, resulting in several installations of laser de-painting facilities at Air Force bases. The current Air Force laser paint stripping installations serve as demonstration and production facilities, even as the fundamental paint stripping technologies continue to evolve.

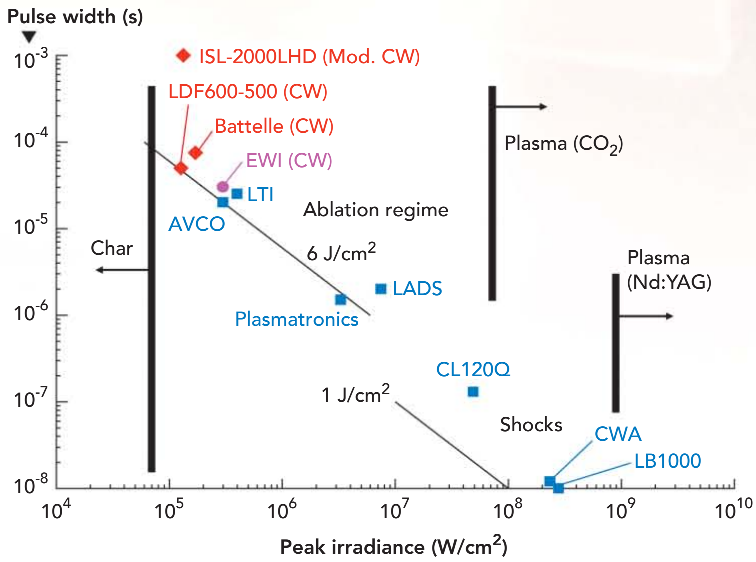

FIGURE 1. The substantial range of peak power and interaction times over which laser paint stripping has been accomplished.

Most of the early, large area, laser paint stripping development was carried out with CO_2 lasers of one type or another. Continuous wave, TEA laser, and e-beam pulsed lasers were among those evaluated. The far-infrared wavelength of these lasers is attractive from the standpoints of absorption by the paint and substrate damage resistance, but the beam delivery complexity of CO_2 lasers encumbered some of the potential applications. Nevertheless, the multi-kilowatt power capability of these CO_2 lasers established attractive benchmarks for paint removal rates and efficiencies. So, when robust, multi-kilowatt, fiber-delivered (1.06-1.07 micron), laser power became available in recent years, additional research was undertaken to evaluate this candidate wavelength regime.

The physical mechanisms of laser paint stripping have been described in a number of ways, including vaporization, ablation, combustion, multi-photo absorption, shock removal, etc. **FIGURE 1** shows the substantial range of peak power and interaction times over which laser paint stripping has been accomplished. The "bottom line" here is that there are many physical mechanisms/interactions that can be applied, but some are easier to implement and more affordable than others. Regardless of the mechanism, one fundamentally important requirement is that the laser power be delivered in an intense, short period, in order that the delivered energy remains primarily contained in the removed paint and not transmitted or conducted to the substrate. This requirement can be fulfilled with a pulsed beam or with a rapidly scanning beam, both of which can successfully limit the local interaction time of the beam with the work.

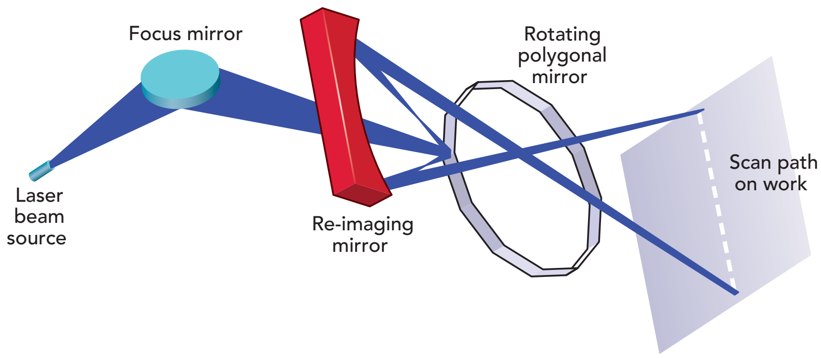

FIGURE 2. The fundamental elements of the patent-pending Edison Welding Institute (EWI) scanner design.

Considering that continuous wave laser power is usually more powerful, affordable, and robust than pulsed laser power, it is not surprising that the use of a beam scanner to produce the required, short interaction time with the work is an attractive solution. Indeed, this is the solution that the Air Force and others have been pursuing in the last few years. Galvo and servo-motor-driven scanners have both been evaluated for this purpose, but the former has achieved the greater success. Of course galvo scanners have achieved their greatest success in the low power marking applications, but galvos face some significant limitations in the multi-kilowatt regime, where laser paint stripping is most attractive. As the laser power increases, the galvo scanning mirrors become heavier, and the scanning speed and acceleration decrease. Typical maximum scanning speed for continuous, high-power, large area, galvo scanners is in the 10 m/s range, which results in a longer-than-optimal interaction time with the work surface. High power galvos also tend to be heavy and require long focal lengths to accomplish required scan widths. For these reasons and others, the Edison Welding Institute (EWI) and Craig Walters Associates undertook a joint project to develop a polygon scanner for high power laser paint stripping.

Polygon scanners

Polygon scanners had been investigated for laser paint stripping as early as 1986, but very little attention or improvement effort had been devoted to the technology until the recent EWI effort began. The fundamental elements of the patent-pending EWI scanner design are shown in **FIGURE 2**. The specific deployment shown here utilizes a fiber-delivered beam, but alternate solutions have been designed for CO_2 laser input. The EWI scanner has only one moving part, the polygon itself, which rotates at a constant velocity and produces a unidirectional, essentially constant velocity path on the work surface. With only a modest rotational speed, the polygon scanner can produce a surface scanning velocity exceeding 50 m/s. This high scanning speed permits a short interaction time of the beam with the work surface and allows very high laser power to be utilized. EWI's polygon scanner (**FIGURE 3**) has performed a multitude of paint stripping trials using 10kW of fiber laser power, and higher power testing is underway.

Large area paint stripping results with the EWI scanner have exceeded expectations. Comparisons of "normalized stripping rate" with previously reported, benchmark, laser paint stripping efforts (**FIGURE 4**) clearly illustrate this point. The metric here (normalized stripping rate) is essentially a measure of laser paint stripping process efficiency; specifically it is the volume of paint removed per amount of energy delivered. Considering further that the EWI scanner has applied the highest and most efficient laser power to date for paint stripping purposes, this advancement is indeed remarkable. The net result of this total applied laser power and the improved paint stripping process efficiency is that the EWI polygon laser scanner can remove paint nearly three times faster than any other reported laser paint stripping technology.

Additional serendipity was realized in the daunting area of effluent removal. As it turns out, at the high scanning speeds available with the polygon scanner, the incremental effluent evolution during each scan is able to be swept away with a modest, vacuum-induced air flow. This had been an area of considerable concern, since other programs using galvo scanners for high power paint stripping had reported significant effluent capture issues. Not only is the effluent removal highly manageable with the EWI scanner, but the resulting solids in the effluent appear to be completely "dry" rather than the sticky agglomeration that others have reported. Much study remains to be performed in the overall effluent management area, but it is reasonable to conclude that this version

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of laser paint stripping produces an absolute minimum of solid waste.

The benefits and advantages of the EWI polygon scanner technology for large area laser paint stripping are numerous and worth summarizing.

- Highest paint stripping power capability
- Can be used with multiple laser wavelengths
- Smaller, lighter, and more robust than other scanners
- Can be provided in a hand-held version
- Aero window eliminates need for consumable transmitting windows
- Highest reported laser paint stripping process efficiency
- Highest reported laser paint removal rates
- Facilitates efficient, complete, effluent removal
- Facilitates good sensor access for process control

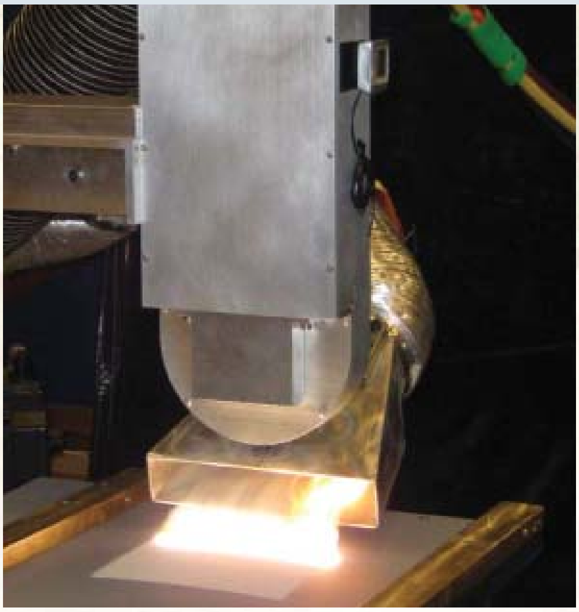

FIGURE 3. EWI's polygon scanner has performed a multitude of paint stripping trials using 10kW of fiber laser power, and higher power testing is underway.

In the overall scheme of a potential laser paint stripping facility, the scanner itself may be a small component. Still, the above advancements in the core laser paint stripping process technology are essential for the creation of stronger business cases for specific applications. For instance, the higher stripping efficiency and the lighter weight of the polygon scanner mean that the motion systems required for large paint stripping jobs (airplanes, ships, etc.) can be faster and lower cost. And, given the higher effective paint stripping rates of the polygon scanner, the overall productivity of a paint stripping facility can be higher. For these and other reasons, this enabling piece of laser paint stripping technology substantially enhances the business cases for a multitude of potential applications.

Additional development needed

As encouraging as these results are, several areas of required, additional development remain to be satisfied. Most important among them is the need for development of a process control technology. Specifically, it is essential that the laser scanner "system" be capable of monitoring and controlling the laser paint stripping process so that the right amount of paint is removed from the right location. Many solutions for this control requirement have been conceived; some have been patented; and some have been applied. Candidate control solutions for application to EWI's polygon scanner technology are under investigation, and success in this area is considered to be attainable in the near future. Continuing advancements in sensors, cameras, and computing power make this essential task much simpler and more affordable than in the past.

In summary, it is reasonable to conclude that all the required elements for successful, industrial, laser paint stripping application have been developed or are within our reach. Much work remains to be done, but the path forward is clearer today than ever before.

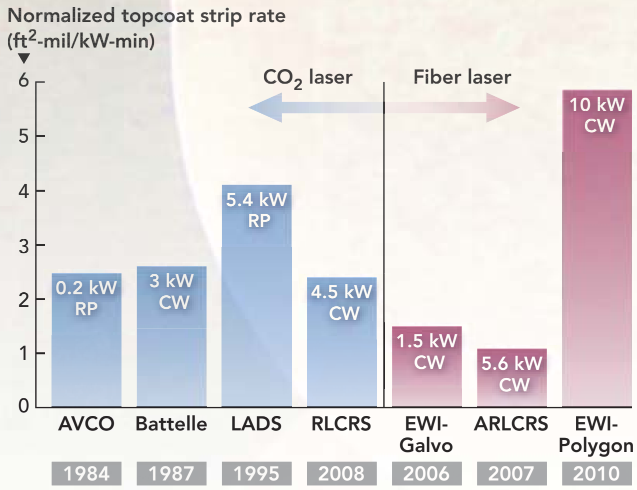

FIGURE 4. Comparisons of "normalized stripping rate" with previously reported, benchmark, laser paint stripping efforts.

Acknowledgments

The Edison Welding Institute (EWI; www.ewi.org) gratefully acknowledges the contributions and collaboration with Dr. Craig Walters, co-developer of the EWI polygon scanner and widely-recognized leading expert in laser paint stripping technology, who can be reached at CWALASERS@cs.com. EWI also acknowledges the contributions and collaboration with Wayne Trail Technology (Bob Lewinski at Bob.Lewinski@waynetrail.com) and II-VI Incorporated in the production of EWI's prototype scanner. Finally, EWI is grateful for the financial assistance from the Air Force (through CTC) in support of the initial demonstration of EWI's polygon scanner technology.

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Geoff Shannon, PhD
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FIBER LASER WELDING: TECHNOLOGY, CAPABILITY AND APPLICATION OPPORTUNITIES

The fiber laser has unique properties of brightness, beam quality, flexibility and cost of ownership that open up a range of application opportunities as a welding source. The laser technology of fiber lasers will be briefly covered with the main focus of the webcast being an overview of the welding performance and application scope of the fiber laser. This will be related to application examples for both sub kilowatt and multi kilowatt power levels, covering both ferrous and non ferrous materials. In addition, some system integration and operational considerations will be presented.

DR. GEOFF SHANNON specializes in the development of lasers and applications for existing and new markets. Shannon has a BEng in Mechanical Engineering and PhD in Laser Welding Technology from the University of Liverpool. His 20-year career in laser technology has centered around applications research and development as well as new product development of lasers and systems.

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Laser surface treatment not only for aut

TOMÁŠ MUŽIK

CZECH JOB SHOP WANTS TO BRING LASER HARDENING TO MORE INDUSTRIES

The town of Plzen (Pilsen) in the Czech Republic is well known for its excellent beer, Pilsner Urquell. However, there is also a group of heavy industry factories; the Skoda concern, large machine tools, steam turbines, electric locomotives and even ship parts are produced here.

The Czech Republic (and Czechoslovakia before) has always been a country of heavy industry with its production range similar to Germany, Sweden or Finland. After 1989, massive growth in the automotive industry came. Car producers Skoda, TPCA, Hyundai, and Tatra are located in the country, with Kia and VW in Slovakia. Toolshops and other subcontractors are located in every town and even in most villages.

In 2005 Tomáš Mužík and Stanislav Nemecek left a university research center and founded their own company, MATEX PM, offering laboratory analyses and expert work for industrial partners. Late in 2008 the company invested in laser technology and transformed into a laser job shop. Because laser metal sheet cutting and car body welding were already widely available in the region, the company focused on laser surface hardening and laser welding.

The company's key equipment is a 3.6 kW diode laser, fiber coupled with optics mounted on an industrial robot. Application development and process optimization are done in-house because the company has operated well-equipped laboratories for many years.

Laser surface hardening is an old technology, first developed in the 1970s, and there have been a few excellent applications, primarily in the automotive industry, but broad commercial success, until recently, has been more difficult. Because the laser hardening technology seems like a new process to many, MATEX's main challenge has been to show the economical advantages of the process. It is frustrating because hardening is usually the last production operation, many times on very expensive tools. In today's tight economic times, it is somewhat easier to bring something new into large factories; but even then, nobody wants to be the first customer. And any ideas about support or joint R&D projects are not subjects for discussion.

Induction vs. laser hardening

Most often MATEX is asked to replace induction or flame hardening, so let's take a closer look into the technological differences.

Generally, to transform hardened steel or cast iron, the material has to meet three conditions: 1) reach austenitizing temperature above Ac3; 2) achieve rapid cooling down from it to obtain martensitic transformation; and 3) have certain amounts of dissolved carbon in the material (as the main parameter influencing final hardness).

Both conventional technologies bring heat to the surface and let it penetrate into the material in the first step. In the second step, rapid cooling from the surface requires assistance, usually by water-based liquid.

A laser beam produces the surface heating also, but much faster, so that it doesn't penetrate so deeply. A steeper temperature gradient heats the surrounding material less, resulting in lower distortion with a smaller heat affected zone. Then, in the second step, cooling is produced by conduction into the underlying cold material by a self quenching process.

The total amount of energy applied is lower in the laser hardening process, which offers valuable benefits such as better surface quality and lower part distortion. However, the main technological superiority is in cooling from below, which

omotive

FIGURE 1. Segments for cutting tool with hardened blades.

means the cooling rate is almost constant over the hardened depth, avoiding the occurrence of surface cracks. Additionally, the transformation to a martensitic structure starts from the base material, so the crystals grow epitaxially.

Induction or flame hardening is hard to control, especially on complex shapes and the process is still based on experience and subjective adjustment. Laser hardening has to solve a similar problem: temperature-based control. In real world applications, power-based control cannot be used because of differences in reflectivity, angle of surface irradiation, differences in the base material temperature, and its thickness. Power control is accomplished by an on-line measuring pyrometer and suitable computer software. The best choice is a "two color" pyrometer which is less dependent on surface emissivity. Pyrometer optics have to be built into the laser optics "on-axis" to insure that the incoming IR signal comes from the whole laser irradiated area. This allows the temperature to be held within a few degrees during the hardening process on commonly machined surfaces.

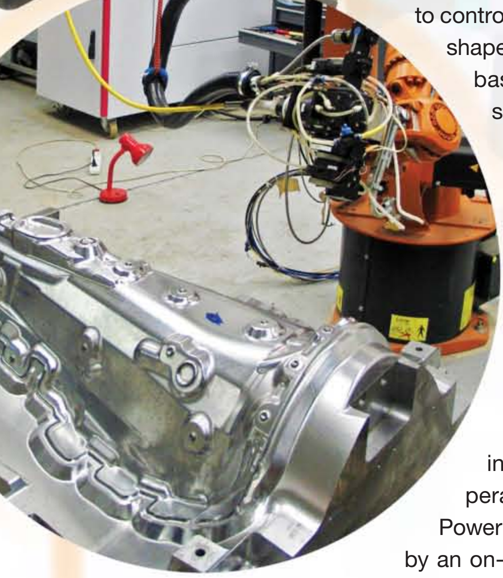

FIGURE 2. One bigger cutting/forming tool.

The process is not only controlled by set temperature, but also by the travel speed of the laser spot. For laser hardening, a rectangular laser spot with homogeneous power density is mostly used to prevent surface melting, even when sharply contoured edges are hardened.

showcase

Tools for the automotive industry

Many of MATEX's customers are tool producers for the automotive industry that make tools used for cutting or pressing of plastics and metal parts in mass production. There are many such tool shops in the area, mostly subsidiaries of global companies.

MATEX gets the tools just after their milling; after laser hardening, the tool goes back to the tool shop, where it is aligned, checked, and mounted to a frame. Or the tool may be finalized, tested for some time, then dismounted from the press, and sent to the company for laser hardening.

After customer acceptance, the tool is transported to a production site somewhere in Europe. All this takes only a few days and these tools may be used to form parts for Audi, BMW, VW, Opel, SEAT and other cars.

Basically, four types of tools are laser hardened for the automotive industry.

1) Cutting edges (pinch) for plastic materials. Such tools can consist of a lot of segments or one big piece that weighs tons. They are used for forming hot plastics and cutting them in one step by press. Plastics can contain reinforcing filler such as glass fibers, and cladding is applied to their surface. All this has to be cut perfectly, so sharp and hard blades are necessary (see **FIGURES 1** and **2**).
2) Cutting parts for metal sheets, mostly made from smaller segments that are not as sharp as for plastics. They are made from different materials that were traditionally hardened in a vacuum oven. Laser hardening of cutting edges is much faster and cheaper with lower distortion. Laser-hardened tools are proven to cut at least 2 mm thick metal sheets. Thus, the highest possible depth of hardening with low distortion is requested, if possible.
3) Round shapes for metal forming/drawing are mostly made from nodular cast iron. Much higher surface hardness is reached by means of laser hardening, assuring better wear resistance and longer lifetime of the tool. Good surface quality without cracking and stable results are achieved (**FIGURE 3**).
4) The moving parts of the tool, which slides side on side, are laser hardened instead of nitrided. Shallow hardening depth is needed, as perfect surface quality and no dimensional changes are expected. These parts are up to 200 kg in weight and very precisely machined from all sides of their complex 3D shape. Usually, they are equipped with cooling channels, ended by a brass cap or screw.

FIGURE 3. Metal forming tool made of nodular cast iron with hardened edges.

FIGURE 4. Laserhardened tooth wheel segments.

MATEX has developed a process to harden these tools with fitted caps. The induced heat is so small that they remain tight. This is a great advantage for the tool producers because no dismounting is needed.

Unfortunately, there is no mass production in tool hardening, where each tool is different. They have complex shapes, so programming of the robot's path limits productivity. Off-line programming software based on 3D models is the solution.

Another challenge is the size and weight of the tools. There are two ways to compensate: either invest in powerful manipulation technology or harden larger parts at the client's site. This is possible with new compact fiber guided lasers and smaller robots. Recently, MATEX took the second option and moved its equipment to a nearby forging plant, where two guidance rails of hammer heads were hardened. Each part weighed 40 tons and a total of more than 60,000 cm^2 was processed flawlessly during a 72-hour period. It is possible to harden such hammer parts even when mounted without disassembling the hammer. This brings a vast saving of time and labor.

Other machinery parts

Many other applications for heavy industry clients are performed, for example, hardening of the tooth wheel, where the competition is induction hardening. If the batches are of smaller sizes, with high batch quantities, there is no chance for the laser, but the company finds success processing larger wheels where laser hardening is faster, cheaper and without risk of surface cracking. The largest wheel processed was about 8 m in diameter, delivered in eight segments. The wheel works in a huge coal harvesting machine (**FIGURE 4**).

Hardening of turbine blades for steam turbines is also a growing job. Laser hardening produces better results than other technologies; moreover, it is flexible, perfectly controlled, and reliable. Also very promising is hardening of straight cast iron parts such as lathe beds, which allow for simpler construction and increased lifetime of big machine tools.

The toolmaking industry for automotive applications drives the technology forwards as it always needs new solutions, shorter terms, lower prices, and better quality. Laser hardening already has a stable market position in this sector. However, this job is changing rapidly as new materials and new production processes come. An open mind and close cooperation between production engineers in industry and laser job shops are necessary to achieve new ideas and successful solutions.

Ing. Tomáš Mužík is director (CEO) and 50 percent owner of MATEX PM (www.matexpm.com/en/index.htm).

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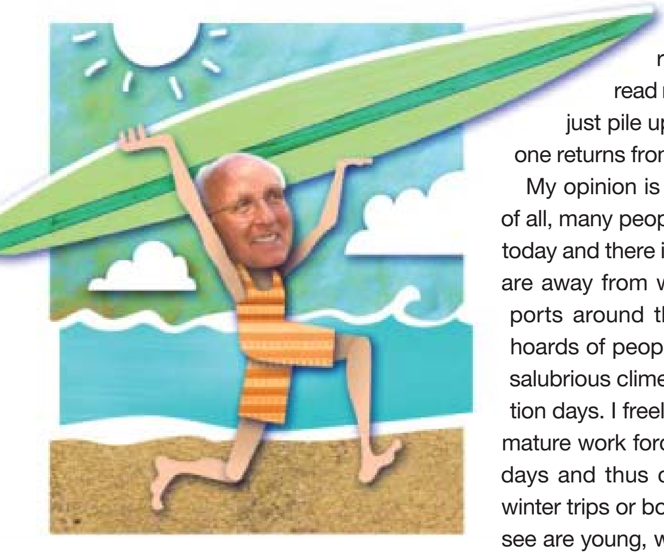
my view

The golden days of summer

RIDING A 50-YEAR LASER WAVE

Here in the Northern Hemisphere, these are supposed to be the "doldrums" of summer, with our minds on vacation trips or just lolling around sipping cool drinks and not over-exercising our brains. For those of us with air conditioning at work and home, these two months are bearable, but the glorious weather outside draws our thinking to pleasure rather than serious work, so it is a chore to focus on business.

In the publishing business, it has traditionally been a time of slow advertising sales as the long-held theory is that readers are too involved with recreational activities to read magazines, and the issues just pile up to be read, or not, when one returns from vacation.



My opinion is this is a lot of bunk. First of all, many people stagger their vacations today and there is no set period when they are away from work. Just look at the airports around the winter months where hoards of people head for warmer, more salubrious climes on pre-scheduled vacation days. I freely admit that today's more mature work force has extended vacation days and thus can schedule summer or winter trips or both, but many of the folks I see are young, which gives little credence to this theory as a whole.

Of course the production lines keep humming, except for those companies that schedule an annual shut-down. Even in the plants, those not on the line tend to stagger their vacations, so the "decision makers" are around all summer.

I looked at the *ILS* reader metrics for the July/August period last year and found little change in the number of web site visits and page openings.

To further my argument, there are countless conferences, workshops, and trade shows in these months, none on a grand scale I admit, but still scheduled on the premise that "if we hold it, then they will come." I'm involved in one in South Korea in mid-August.

My point is, you're reading this, so you are either checking your e-mails and get the digital version, or you are at work and checking your snail mail daily. I know that my blog readers are checking this out because I get my most caustic comments in response to things I said in the summer months last year. I'm just joking because the comments I receive tend to be complimentary and positive, but these still occurred mostly during the nice-weather months last year.

So we worked very hard to make this issue of *ILS* a good one with four features and one Update item all focused on applications. We do this because we know that you are looking for this information regardless of the weather and to prove this I'll let you know what the metrics for this issue are compared to the preceding 12 months, when they are available.

Just a word about the 50th anniversary of the laser. *ILS* did not set aside a special issue for this. I did a technology highlights feature in the January/February issue, and I have posted many news items about this on the web page, www.industrial-lasers.com.

I was a young research staff member working to build ruby laser crystal growing furnaces in that period just after Ted Maiman's breakthrough of the first working laser in 1960. It was an invigorating time as industrial and commercial research labs raced to be first with the latest laser development. Friday staff meetings were abuzz with the latest news, picked up by word-of-mouth, as that was before the Internet. For me to have been a very small part of those "early" days was a memory that I especially treasure as we celebrate the golden anniversary of this most significant achievement.

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