High-power NIR laser system benefits with TI's DLP® technology

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Industrial applications such as lithography, 3D scanning, 3D printing and medical systems have relied on DLP® technology for advanced imaging and exposure capabilities.

The digital nature of the DLP chipset has enabled system designs with fewer mechanical parts and less calibration maintenance. Industrial systems using high-power near-infrared (NIR) lasers can now benefit from DLP technology, including selective laser sintering (SLS) for 3D printing, dynamic grayscale marking and coding, ablation systems, and industrial digital printers based on direct photopolymer laser imaging.

This white paper describes the use of high-power NIR in industrial applications.

Selective laser sintering 3D printers

There are many types of 3D printing technologies, and they generally fall into these categories:

- **Fused deposition modeling**
- **Vat polymerization**
- **Sintering**
- **Jetting**

Each technology pairs with different material types like plastics, nylons, ceramics or metals; results in different object properties related to strength, elasticity and finishes; and is suitable for different build areas (centimeters to meters) and feature sizes (microns to millimeters).

Selecting a 3D printing technology often depends on the desired object properties. A second consideration then becomes whether you need to print one prototype or mass-produce multiple finished goods. In either case, you need fast printing speeds.

SLS 3D printers use high-power lasers to fuse together small particles of plastics, nylons and metals. You may opt for SLS additive manufacturing when needing to print more complex 3D geometries

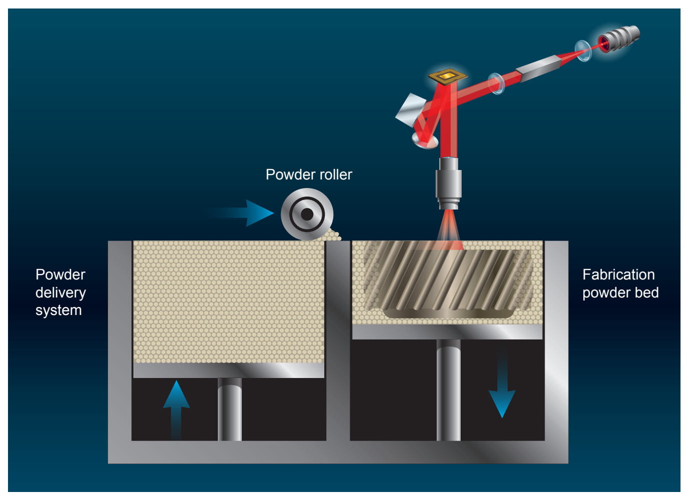

Figure 1: *SLS 3D printing process.*

such as interior features, undercut structures or thin walls. The sintering of powder materials often enables mechanical traits and strengths similar to injection-molded parts.

In SLS 3D printers, lasers move across a powder bed plane, sintering one slice of the object point by point. As shown in **Figure 1**, a roller adds another powder layer and the process repeats until a 3D object is produced. 3D printers may use high-powered carbon dioxide or NIR lasers to fuse plastic, nylon and metallic powders. Using a DMD as part of the exposure head enables the printer to expose a 2D area to NIR light, enabling it to print more complex images faster than with point-by-point laser steering. Given the fast switching speeds of DLP chipsets, the printer can vary the power per pixel in real time based on application needs or compensate for temperature discrepancies.

Laser marking – dynamic late stage customization and traceability

Laser marking involves a beam interacting with a film surface that is photo or thermally sensitive, thus altering the surface's properties or appearance. Laser marking can be used for printed circuit boards (PCBs), plastic bottles, medical devices, metal parts, cardboard boxes and more. Typical marking information or symbols include 2D matrix or QR codes, logos, sequential batch data and lot numbers.

While printing codes and symbols has been around a long time, the need for late-stage marking and traceable information is growing. In the medical and aerospace industries, regulations require the inclusion of printed information on every part. Digital marking solutions are flexible enough to send unique pattern or image information to each object late in the manufacturing process. Whether it's printing critical batch identification or fun custom tags, manufacturers can easily incorporate dynamic information and simplify print logistics for mass production.

Thermal transfer marking systems are similar to sintering in that a laser beam is steered point by point to produce a custom image on a thermally sensitive label or coating, as illustrated in **Figure 2**. However, laser printers with DLP technology use dynamic 2D NIR light patterns to thermally activate a substrate – imprinting an entire area in one shot rather than point by point. Since the micromirrors on the DMD switch very fast (in microseconds), print speeds can often meet production-line cycle-time requirements, even with complex and large codes or patterns. In addition, DLP technology enables grayscale imaging, which offers more variety for graphic printing.

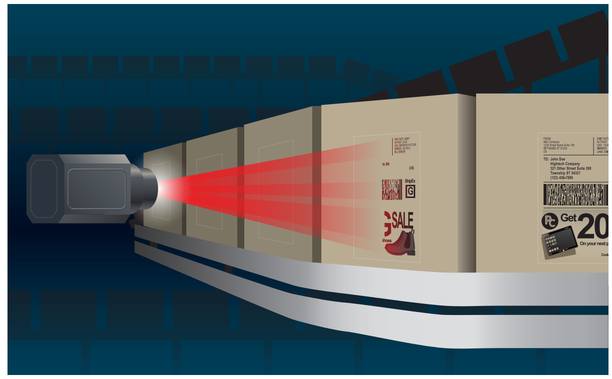

Figure 2: *Thermal transfer marking creates a gray-scale, custom label.*

Direct photopolymer laser imaging and engraving

Flexographic printing uses flexible photopolymer printing plates wrapped around rotating cylinders on a web press. The inked plates have a slightly raised image and rotate at high speeds to transfer the image to the substrate. Flexography inks can print on many types of absorbent and nonabsorbent materials. The rolls of material used in flexography allow large orders to run with few interruptions and can create continuous patterns, such as for soft product packaging. **Figure 3** shows examples of flexographic printing in packaging. Offset printing uses a similar image transfer concept but loads the individual sheets of paper or substrates one at a time.

The packaging market relies heavily on industrial printers for product labels, corrugates, folding cartons and flexible materials like snack bags,

Figure 3: *Flexographic printing.*

Figure 4: *Packaged goods with flexographic-printed labels.*

as shown in **Figure 4**. Digital printing solutions are competing with plate-based machines and are expected to become more popular. Digital printers can bring the benefits of customization regardless of batch size, along with faster print speeds and lower machine maintenance.

An interesting example related to the migration from plates to digital imaging is the PCB lithography market. Over the last 10 years, PCB lithography machines have transitioned from masks to digital-direct imaging for patterning fine features in the various resist build layers. DLP technology is a key enabler of digital lithography due to the DMD's combination of a large micro-mirror array, small feature sizes and very fast data rates, which translate to an imaging cycle in microseconds to meet the demands of printing hundreds of panels per hour.

Many of the same DLP technology benefits for laser marking apply to new digital printing system designs. For example, dynamic 2D NIR light patterns could directly interact with the cylinders or ink to produce real-time, customizable print images. A DMD also enables you to easily implement multibit-depth grayscale imaging by programming the micromirrors' on- and off-time. This is similar to display applications, but using faster pattern rates versus a typical projector rate of 60 or 120 Hz: 12,500 Hz in the case of TI's DLP650LNIR.

Digital plate making and computer-to-plate systems

In the print industry, physical plates are a critical part of the printer and define the content published on a given media. Print plates are used in various printers, including flexographic and offset printers. The analog process of creating plates involves a polymer base, negatives of the content, ultraviolet exposure and washouts.

In recent years, the move to digital plate making – the process by which images are etched directly onto the printing plate using computer-guided lasers – has gained popularity. The digital process enables the production of plates in less time, with more consistency and fewer defects, resulting in lower costs. From a performance perspective, digital printing can also improve registration and edge-print repeatability.

Using a DMD as part of a guided-laser exposure system adds the ability to expose a 2D area of laser light, allowing faster plate production and the ability to incorporate more complex images that include grayscale.

DLP chips offer multiple system benefits

The DMD is a micro-electromechanical system (MEMS) at the heart of DLP technology. A DMD contains an array of highly reflective aluminum micromirrors that can spatially steer light. In the case of high-power laser applications, DMD features can bring many benefits.

The DLP650LNIR DMD, shown in **Figure 5**, supports a high optical power-handling capability of 500 W/cm^2 across 950-1,150-nm NIR wavelengths. The device provides the ability to vary optical power at the pixel level and introduce high-speed 2D patterns in a single exposure for faster imaging. In addition, dynamic mirror programming can compensate for any process shifts that may occur,

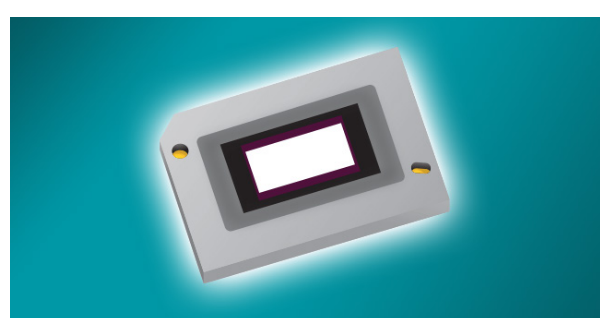

Figure 5: *DLP650LNIR .65-inch WXGA high-powered DMD.*

such as attenuating power or exposure levels to overcome surface non-uniformities.

Steering 1 million points of light simultaneously

Having an x-by-y array of mirrors helps bring more programmability and flexibility to your laser exposure systems. The ability to expose a 2D area of laser light in one shot enables complex image printing that's faster than point-by-point laser-steering systems. Using optical image-compression techniques in combination with the DLP chipset can increase or vary the power per pixel based on application needs. The DLP650LNIR has 1280 x 800 (or over 1 million) micromirrors for spatial light modulation. The mirror size is 10.8 µm, which enables print features in the sub-50 µm resolution without image demagnification.

NIR wavelength support

DLP technology can be combined with various light sources and is compatible across ultraviolet, visible and NIR wavelengths, illustrated in **Figure 6**.

The DLP650LNIR DMD can be used with light sources in the 800-2,000-nm range but is optimized for 950-1,150 nm, where it can handle 134 W/cm^2 of input power. NIR lasers are widely used across sintering, marking, coding, digital printing and ablation markets, since a number of powders, inks, media, substrates and thermally sensitive coatings interact in this wavelength region. The DLP650LNIR can add advanced illumination, exposure and thermal control to these applications.

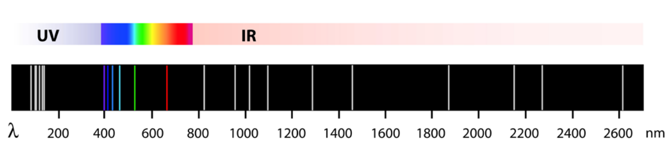

Figure 6: *DLP technology spans 363-2,500 nm wavelength capability.*

Dynamically program patterns and images

The micromirrors on a DMD switch very fast – in microseconds. The DLP650LNIR pairs with the

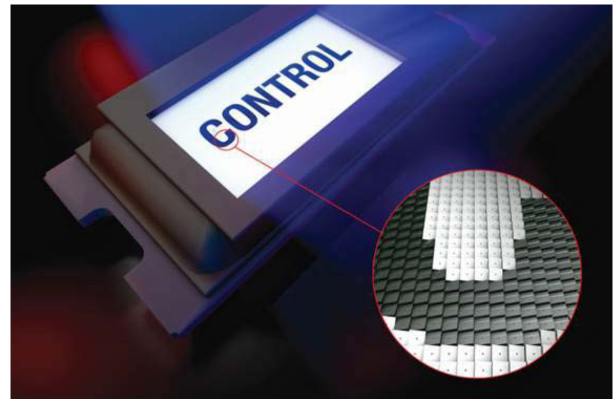

Figure 7: *Individual mirror control for adaptive patterns.*

DLPC410 controller, DLPR410 programmable read-only memory and DLPA200 driver for a complete chipset that offers 12,500-Hz binary pattern rates. Fast pattern rates enable you to program and deliver custom, complex graphics in real time on the production line. You can also adapt patterns, as illustrated in **Figure 7**, for advanced printing techniques or in-line image correction.

Digital controllers offering high bit depth

DLP mirrors can produce 8-bit grayscale images like the one in **Figure 8** with rates greater than 1,000 patterns per second. This gives you digitally controlled grayscale capability that is not common in point-by-point laser systems. Controlling pixel and pattern duration settings means that the on-time for each pattern can control the amount of light hitting a substrate or material. This translates to printing high-dots-per-inch graphics, preheating a powder bed for more even sintering, or delivering a highly accurate pattern for ablating a defect. DLP technology brings both temporal and spatial light control capabilities, which open a dramatic new set of tools for industrial printing, marking, coding and sintering tools.

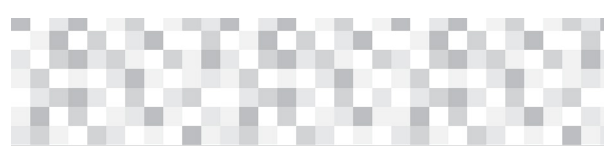

Figure 8: *DLP technology enables 8-bit grayscale images.*

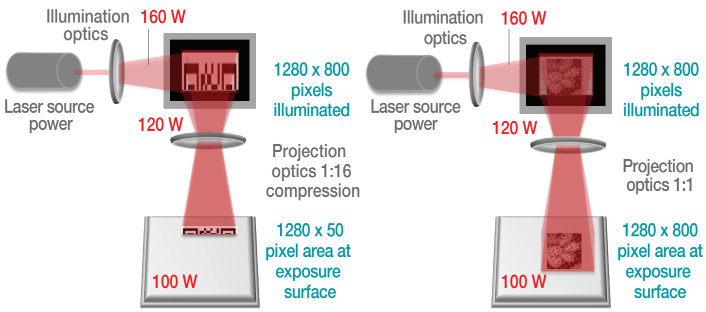

Figure 9: *Optical compression as a means to attenuate power per pixel including a QR code (a) and a grayscale image (b).*

Key considerations to jump-start your NIR system design

When integrating high-power illumination with DLP technology, managing the DMD's temperature is very important. Light engine designs should keep the mirror array temperature at or below 70°C and the backside of the DMD package at or below 30°C. In the case of high-power lasers, liquid cooling of the backside of the DMD is a key requirement in the system design. If you are trying to maximize the power output, you also need forced airflow across the front of the DMD. For more information about thermal design considerations, see the "DLP Products thermal design guide: focus on high power NIR laser illumination" application note.

When starting a design, you typically know the power of your laser source, as well as the energy you need to expose or interact with the intended material. When incorporating DLP chips into the design, there are places where light efficiency losses will occur. The main locations will be the input illumination optics, DMD and output projection optics.

As an example, a design might lose 25% of the light in the DMD and 17% in the output optics. If a design starts with 160 W of incident power on the DMD, 120 W would leave the DMD and 100 W of energy would leave the projection optics and hit the substrate or surface. Spreading 100 W of energy across 1280 x 800 pixels equates to 0.1 mW per pixel.

These are just estimations that will depend on specific optical engine designs, but they are meant to offer guidance on how to determine power per pixel. You can calculate efficiency for each DMD using the respective device data sheet, along with data from the "Wavelength Transmittance Considerations for DLP DMD Window" application note.

Image compression is a powerful technique that can increase the power per pixel, as shown in **Figure 9**. For example, designing the output optics with 1:16 compression to spread 100 W across 1280 x 50 rows of mirrors at the material surface (rather than 1280 x 800 rows) increases the power per pixel by 16 times to 1.6 mW. There are any number of image-compression combinations, depending on your unique end-equipment design specifications and required power at the surface. You will need to evaluate several system considerations and trade-offs when pursuing a high-power NIR system design with DLP technology.

Related websites

- DLP products advanced light control parametric table.
- DLP650LNIR, DLPC410, DLPR410 and DLPA200 chipset data sheets.
- DLPLCRC410EVM and DLPLCR65NEVM evaluation modules.
- TI E2E™ Community DLP products forum.
- "Mounting Hardware and Quick Reference Guide for DLP® Advanced Light Control Digital Micromirror Devices."
- "Introduction to 12 Degree Orthogonal Digital Micromirror Devices."