intense

White Paper

Improving Performance in Computer to Plate Printing Using Semiconductor Laser Arrays

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Over the last 25 years, electronic typesetting and desktop publishing (DTP) have revolutionized the printing industry. Almost anyone with a computer and the right software can create and print professional materials. However to achieve the highest print quality, it is still necessary to use a commercial or industrial printer with advanced technology for delivering state of the art print quality standards.

In DTP, text is input using a word processor running on a desktop or laptop computer and then transferred electronically to a page layout package. The page layout software enables an editor to determine the precise appearance of the printed page. For most commercial and industrial printing, the page is then imaged onto printing plates that are mounted on a printing press. A single printing plate is used for monochrome and several plates for color (a minimum of 4 plates but usually 6 or more). These plates are imaged using computer to plate (CtP) systems, so CtP has become a key technology in almost every printing house. CtP printing is the de facto standard for the highest quality printing that can be achieved.

As recently as the 1970s, the preparation of printing plates was a craft industry, with compositors using hot-metal typesetters to cast lines of text. These lines of text were then set in a frame by hand to give the final page layout. This process remained essentially unchanged for almost a century. Automation began in the 1970s with photo-typesetting, a technology that used entirely photographic techniques to create an image on photographic paper. The images were then pasted up and transferred photographically to a printing plate. However, the present day combination of page layout software and CtP systems eliminates all of the hand composition stages.

CtP Technologies: Violet and Thermal

In a CtP system, the computer-generated page layout is transferred directly to the plate using modulated beams of light. In order to expose the whole plate, the beams are scanned over its surface. There are two CtP technologies: violet CtP which uses plates that are exposed by blue and violet light, and thermal CtP which uses plates that are exposed using near infra-red radiation. The layout of a thermal CtP system is shown in Figure 1. The plate is mounted on a rotating drum and beams from the print head are focused to a spot typically with a diameter around 10 µm using a combination of micro and macro optics. The plate is imaged by scanning the head laterally while the drum rotates.

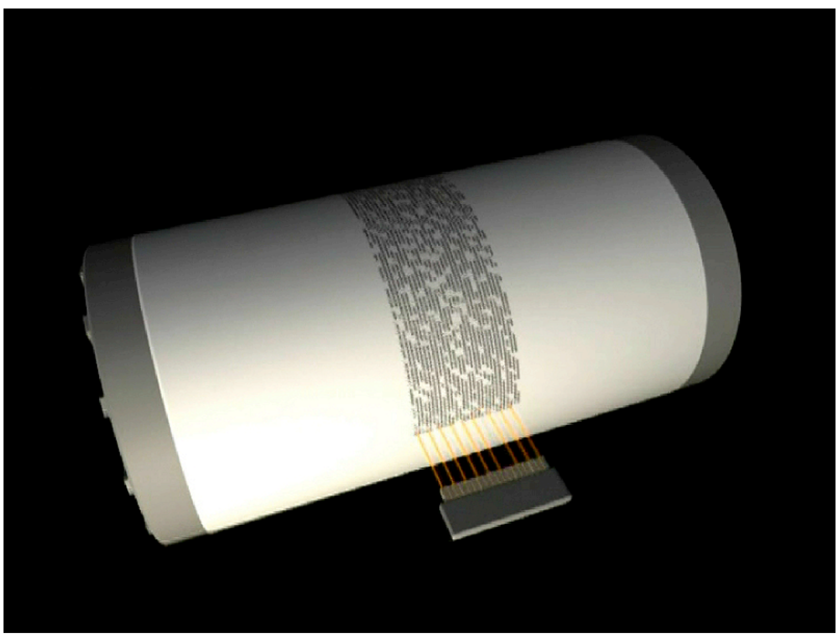


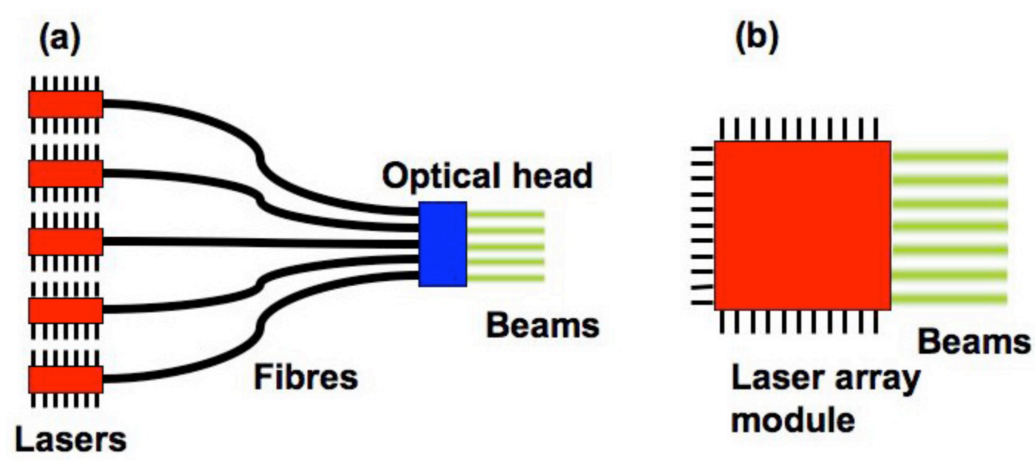
Figure 1. Schematic diagram of a print head imaging a CtP plate.

Although plate technology is continually developing, thermal CtP plates are considered to be more durable, giving longer print runs, and easier to handle as they are not exposed by normal daylight. Violet plates are sensitive to daylight and have to be handled in special ‘yellow rooms,’ where the blue and violet regions of the spectrum are excluded. Because they are sensitive, violet plates are generally exposed by rastering a single laser beam across the plate. Much more energy is required to expose thermal plates, so multiple beams of laser light are used. This requirement for multiple laser beams makes thermal CtP systems more expensive than violet systems. However, recent developments in laser integration are dramatically reducing the cost.

Diode Lasers in Thermal CtP

Industry standard thermal CtP plates are sensitive to radiation in the 800 – 850 nm spectral region. To write the plate quickly, multiple laser beams are generated with each beam individually modulated with information. There are several approaches for doing this. The modulation rates in a CtP system are relatively low at <10 Mbit/s and diode lasers can readily be switched on and off directly to provide the necessary modulation. One approach, therefore, uses multiple, directly-modulated diode lasers, with the light from individually packaged lasers coupled via multi-mode optical fiber into an optical head (Figure 2a). In this approach, each laser requires an individual gold-plated package with a precision fiber pigtail. The pigtails need to be assembled accurately in the head and each laser requires separate drive electronics on a card, inevitably mounted in a large electronic rack. The overall manufacturing process is expensive and the system is complex and bulky. Furthermore, the system specification may be limited because individual lasers are used. For example, the spacing between emitters is determined by the accuracy with which the fiber cores can be positioned and the minimum pitch is determined by the fiber diameter.

Figure 2. To write the CtP plate, multiple laser beams are generated with each beam individually modulated with information.



In a second approach, the light from a broad-stripe high-power semiconductor laser is homogenized to create a very uniform line of light. This light is then passed through an array of modulators. Different manufacturers use specific modulator technologies, with ferroelectric modulators and 'grating light valve' technology both being widely used. This approach has several advantages:

- Only one laser bar is required in each head,
- The homogenizer can be designed to accommodate failure of individual elements in the bar, and
- The spacing of the beams is determined by the very precise tolerances of the modulator array.

One disadvantage is that a significant fraction of the laser light is lost through inefficient coupling into the modulator. As a result, both the laser bar and the modulator array require water cooling.

In both the fiber coupled laser and modulator array approaches, the light beams are multimoded and obey the same laws of imaging as classical optics. In a CtP system, the plate is rotated in front of the scanning head at several hundred revolutions per minute. Because the drum is not perfectly centered or balanced and the plate is not perfectly flat on the drum, there are changes in the separation between the plate surface and the print head. In a practical system using classical imaging optics, autofocus systems are required to maintain high image fidelity, with the autofocus system tracking the changes in head to plate separation. Autofocus systems that can respond at the required speed are relatively expensive.

QWI Enabled Products Deliver:

- Long emitter lifetimes with no failure and little wear
- Cool facet provides high reliability
- Large elemental arrays up to 100 emitters for high yield and uniformity

Single Mode Lasers Overcome Limitations

Single mode lasers overcome many of these limitations. The single mode laser beam is governed by Gaussian rather than classical propagation and Gaussian beams have a significantly greater depth of field than classical propagation. The expensive autofocus mechanism can therefore be eliminated. Because the laser output is imaged directly onto the plate, very little light is wasted. Furthermore, recent advances in integration technology have made it possible to fabricate large arrays of single mode lasers. Such arrays combine the benefits of Gaussian beams with precision spacing of the beams, as the pitch of the lasers is fixed by lithography during manufacture. Because a single monolithic array is used, only one package is required reducing form-factor and cost (Figure 2b).

Manufacturing QWI Enabled Laser Arrays

Photonic integration is delivering enormous benefits across the printing industry. For the first time it is possible to manufacture large monolithic arrays of high-power semiconductor lasers. Quantum Well Intermixing (QWI) is one of the new technologies paving the way. QWI is a fundamental integration technology applied to semiconductor wafers after the epitaxy is completed. The technology is a physical semiconductor process in which the atoms inside the semiconductor are controlled in a very precise and systematic way such that the bandgap of the semiconductor can be increased. QWI enabled laser arrays have long passive waveguides at the facet regions of the laser cavity. Being passive, these waveguides do not absorb light, so the facets remain cool and the lasers are capable of delivering high power. A further advantage of the passive waveguide is that the beam is very stable in terms of its direction and spot size. QWI, therefore, delivers high single-mode laser power with excellent image quality. Photographs of a laser array with QWI passive waveguides in the facet regions are shown in Figure 3, with each laser emitter capable of delivering up to 250 mW of single mode optical power simultaneously.

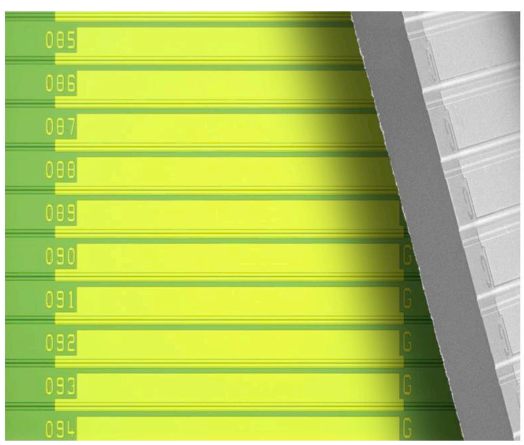


Figure 3. QWI enabled laser array with passive waveguides in the facet regions.

The Future is Bright for Laser Arrays in CtP

Quantum Well Intermixing (QWI) is a fundamental integration technology that is bringing new standards for semiconductor laser performance, reliability, and manufacturability. The disruptive nature of this revolutionary QWI laser technology is being used to manufacture large arrays of high power, single mode lasers for the first time. These arrays are dramatically changing the dynamics of CtP systems – a key system in commercial quality electronic typesetting and desktop publishing.

QWI enabled lasers deliver revolutionary improvements in CtP systems including:

- **Smaller Form Factor, More Flexible Packaging** from the integration of passive regions at the facets of laser emitters, arrays, and bars. This allows for the development of small form-factor, cost effective, and extremely versatile optical printing heads.
- **Revolutionary Print Head Reliability** and reducing common problems related to Catastrophic Optical Mirror Damage (COMD)
- **High Yields Mean Lower Costs, Ready Availability** when large arrays of up to 100 single-mode lasers can be integrated onto a single chip with excellent laser parametric uniformity. This guarantees virtually unlimited availability of high performance, lower cost print heads.
- **Exceptional Uniformity, Beam Control, & Brightness** through the combination of QWI and innovative epitaxial designs produces lasers with the high brightness needed to meet the demanding needs commercial color printing.

The passive regions bring two other critical benefits to laser arrays. First, they allow the mechanical tolerances to which the laser is manufactured to be relaxed, allowing large element arrays (of up to 100 emitters) to be made with high yield and high uniformity. Second, the cool facet leads to outstanding reliability. The combination of optical performance, yield, and reliability is absolutely critical in enabling integration to be used in the printing industry.

Outstanding Yield and Reliability

In order for laser arrays to be viable, the laser manufacturing process must have a high yield and every element must perform within a tight electrical and optical tolerance. This represents a major challenge, as some CtP systems need several hundred mW at 8xx nm in a single transverse mode from each element. The array faces the same reliability and yield issues as single lasers, but magnified by the fact that there may be up to 100 elements in the array. A typical yield at chip level for a high-power single mode laser is around 60%, so if this were maintained across an array of 10 lasers, the yield would be $0.6^{10} = 0.006$, which is less than 1%. In order for the array yield to be 60%, the individual laser yield needs to be >95% for an array of 10 lasers and >99.5% for an array of 100 lasers. QWI enabled passive waveguide integration allows these yields to be achieved.

In addition, CtP requires every contiguous laser element in the array to function within the tight power specification over a long operational lifetime. No redundancy of laser elements is possible, so failed, defective, or degraded lasers in the array cannot be accepted. End-of-life of the module is therefore determined by the first failure of any element in the array. This requirement sets an exceptional challenge. In order to calculate the mean time to failure (MTTF) of a system, a statistical approach is often used that assumes failures are random, distributed, and independent; hence the failure rate in an *n*-element array is be expected to be proportional to the number of elements in the array. Passive waveguide laser arrays have proven to be very robust and reliable, with over 8 million hours of emitter lifetime with no failure and negligible little wear-out, despite the high optical power densities present at the facet.

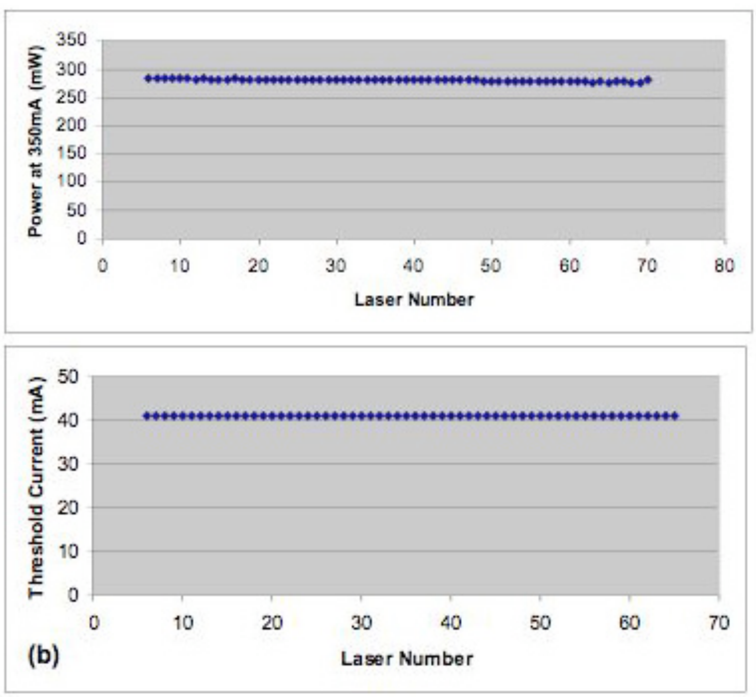


Figure 4. Monolithic laser array technology gives outstanding image quality at the highest resolution printing.

Improving Print Performance:
Laser Array Modules for Next Generation CtP Systems

The monolithic semiconductor laser array is only one part of an integrated module. In order to build an imaging head, the laser array has to be built into a compact module with drive electronics, micro-optics, and bulk optics. In order to produce a single package with a small form-factor, the digital processing and drive electronics are incorporated into compact printed circuit board within the head, which may make use of an application specific integrated circuit (ASIC). The electronics allows each laser element to be addressed individually.

In order to optimize the image, the laser beams need to be conditioned carefully using optical elements. The beam from a single-mode semiconductor laser is emitted from a small aperture, typically ~1 µm high × ~2 µm wide. This means the beam diverges strongly, unlike the beam from many other types of laser. Typical divergence angles are 20° to 30° in the vertical direction (the so-called fast axis) and 6° to 12° in horizontal direction (the slow axis). The fast axis can be collimated by a single cylindrical lens running the full length of the array, but, to keep the beams separate, the slow axis must be corrected individually for each element in the array. This can be done using an array of micro-optic lenses whose pitch matches that of the lasers. The conditioned beams can then be imaged as a group onto the plate using a series of bulk lenses.

The packaging of the module also presents significant challenges. In a high power printing module, there is interdependency between the laser and package. Consider, for example, a 100 element module with each laser operating at continuously at its maximum power of 250 mW. The optical output totals 25 W, but the laser will dissipate around 30 W in heat. The electronics also introduces a comparable heat load into the module. The laser parameters vary quite strongly with temperature, with the uniformity of beam profile, spot position, and optical power across the array all being affected. The choice of carrier material (thermal conductivity, thermal expansion coefficient, and mechanical finish), the solder material, and the assembly process have to be carefully optimized, otherwise hot spots and thermal expansion differences give rise to undesirable variations in uniformity and, ultimately, affect reliability.

All of the above issues have to be considered to achieve the required print performance. Monolithic laser array technology has proven to be very robust with excellent device to device uniformity. This uniformity gives outstanding image quality at the highest resolution printing. The single mode threshold current and power characteristics of each channel in laser array of 60 elements are shown in Figure 4.

About Intense

Intense is a world-leading supplier of High Power Lasers (HPLs) and individually addressable laser array modules that operates from two international centers of excellence: Intense Ltd. in Glasgow, Scotland, and Intense-HPD in North Brunswick, New Jersey.

From digital imaging to defense and industrial applications, Intense is bringing about a revolution in the way diode lasers solve evolving customer needs. Intense's QWI enabled laser diodes, arrays, bars, and stacks deliver:

- Superior brightness, and exceptional uniformity and beam control,
- High yields, lower costs, and increased reliability, and
- Compact, flexible, modular designs.

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