Presented at Photonics West 2004 - Micromachining and Microfabrication Symposium
January 26, 2004, San Jose, CA, USA

Computer-to-plate printing using the Grating Light Valve™ device

Eiichi Tamaki[a], Yoshimi Hashimoto[1a], Omar Leung[b]
[a]Dainippon Screen Mfg. Co., Ltd. ,
Teranouchi-agaru 4, Horikawa-dori, Kamigyo-ku, Kyoto 602-8585, JAPAN;
[b]Silicon Light Machines, 385 Moffet Park Drive, Suite 115, Sunnyvale, CA, USA 94089-1208

ABSTRACT

A new class of commercial platesetters, called computer-to-plate (CtP) systems, has been introduced in the graphic arts industry in the past few years. As opposed to conventional systems that use an analog mask, these CtP systems employ direct digital imaging methods to generate patterns on metal plates used for offset printing. By eliminating this intermediate mask step, CtP platesetters enable users to transfer images directly from the computer to the plate, thus reducing cost and cycle time.

The Grating Light Valve™ (GLV™) is a diffractive MOEMS device that has been successfully implemented as the spatial light modulator in a commercial CtP platesetter for the graphic arts industry. The combination of high power handling capability, fast modulation rate, and large number of pixels on the GLV allows for increased printing speed. Properties of the GLV, such as analog gray scale, and pulse width modulation can be used to increase print quality.

In order to create images on the plates, infrared laser illumination is focused onto the GLV device, which reflects the beam with controlled intensity onto a photo-thermal medium. While offering advantages in quality and throughput, the high pixel count and form of the GLV presents some challenges in illumination and projection onto the printing plate. This paper will describe the system architecture and method of operation for a GLV-based optical write engine, and show performance and results.

Keywords: computer-to-plate, Grating Light Valve, laser imaging system, MEMS, light modulator

1. INTRODUCTION

In the graphic arts industry, the computer-to-plate (CtP) systems are becoming more widely used in recent years. The new platesetting systems use laser beams to directly write images onto printing plates rather than first exposing a film then transferring the image to the plate. The digital direct plate imaging method eliminates troublesome film processes and thus ensures a short turn around time and high image quality.

While film-based printing plates are sensitive only to ultraviolet light, most of CtP plates are designed to respond to near infrared laser exposures. The IR sensitive plates are also called thermal plates because reactions in the media are thermally activated. The thermal reactions require high energy; therefore, high-power (semiconductor) lasers are utilized to write thermal plates.

Because a high-power semiconductor laser (laser diode) emits a multi-lateral mode beam, optics with a high numerical aperture (N.A.) must be used to achieve the desired spot size. An external drum structure, allows a high N.A. optics however, this configuration has the disadvantage that a heavy large drum stands in the way of improving productivity due to mechanical constraints such as size and limited rotation speed.

[1] Presenting author, y.hashi@screen.co.jp

The GLV is an MOEMS device with a great number of addressable diffraction grating pixels constituting a linear array[1)]. Unique properties of the GLV allow it to meet market demands for higher productivity and higher image quality. This paper describes how the GLV device has been incorporated into a thermal CtP system.

2. PROPERIES OF THE GLV

A GLV pixel is made up of an even number of parallel doubly supported beams with a reflective surface called ribbons. Typical dimensions are shown in Fig. 1. When a GLV pixel is addressed with an electrostatic potential, alternate ribbons are deflected, creating a square well diffraction grating. This unique design gives a GLV-based thermal CtP system several advantages.

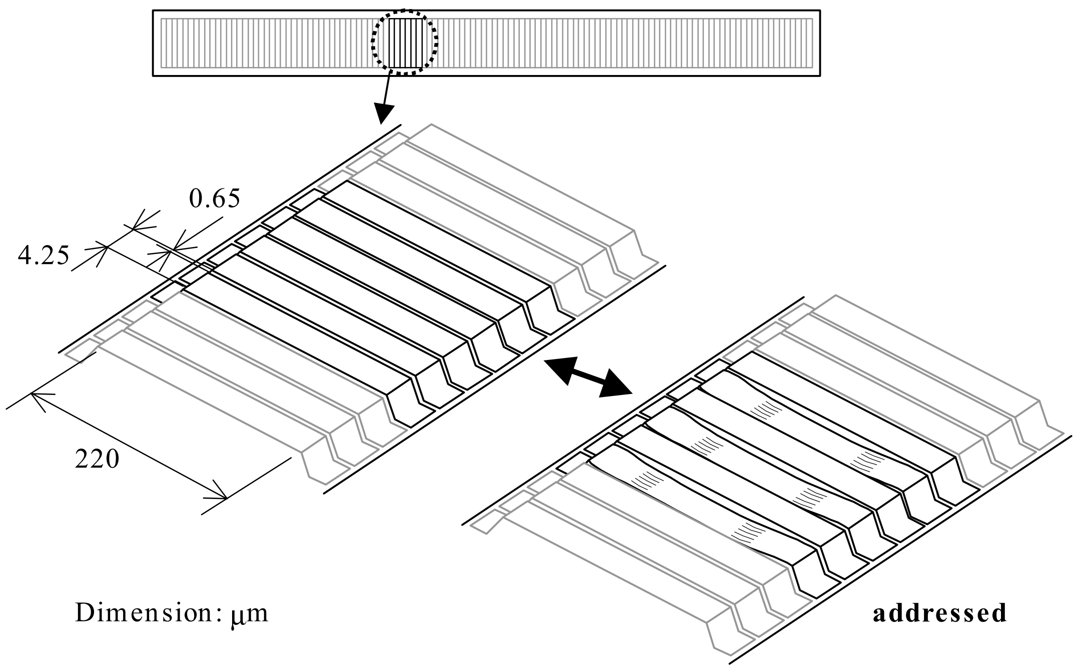

Fig.1. The GLV ribbon array is shown in the flat and deflected states.

2.1. Multiple elements

A GLV linear array is made up of thousands of parallel ribbons arranged at a constant pitch. Pixel size is determined by electrode design. The GLV used for thermal imaging has 6528 ribbons that are divided into1088 addressable pixels, each consisting of 3 active and 3 inactive ribbons. (The original design was made for HDTV displays, which required 1080 channels)[1-2)]. Compared with other methods for CtP plate setting, the GLV-based imaging optics provides more writing beams. This means that, compared with other methods, higher productivity can be achieved while maintaining, or even reducing, drum rotation speed.

2.2. High-speed switching

In general, writing speed is the product of the number of pixels and the switching rate of each pixel. Thanks to a deflection as small as 0.2μm (quarter the wavelength), the switching speed of the GLV device is several orders of magnitude faster than competing technologies. Pulse widths of less than 4 μs are typical with this device.

A two-dimensional array type of MOEMS device may have more total pixels than the GLV, but tend to have a lower potential writing speed because of slow switching. As mentioned, most of thermal CtP systems use an external drum, around which a thermal plate is wrapped. A multiple beam recording optics writes a line on the plate and as the drum is rotated, a swath is written onto the plate. While the drum is rotating, the recording head is slowly translated down in a direction parallel to the axis of rotation until the entire surface has been addressed. In this scheme, the swath width is practically determined by the column number of the modulator rather than the total number of pixels. The drum rotation speed is determined by the switching rate.

2.3. Gray level (Beam power control)

Up to 10 bits of gray are possible using the GLV by adjusting applied potential to control the modulation depth. Offset printing uses halftone dots to reproduce gray scale. Because of this, platesetters have only to generate binary dots. However, in order to ensure high image quality, the power of each beam may need to be precisely controlled. A sophisticated data dependent control of the modulation depth has been developed at Dainippon Screen to improve the image quality while maximizing the write speed.

2.4. High-power handling

High-power laser handling is critical for a thermal CtP system that uses a very intense (40W or more) laser source. One of the cutting-edge features of the GLV is its capability of handling very high laser power. Part of this is due to the basic structure of the GLV. The pixel's high effective reflectivity and durable silicon nitride composition are fairly robust to optical damage. As there are no transistors near the optically active area of the array, there are no photo-induced leakage effects that could disturb electronic performance of the driver circuits. Furthermore, the dimensions of the ribbons make the reflected light intensity insensitive to thermally induced distortions.

The other feature that increases the power handling capability is the thermal conductivity of device. At the microscopic level, it is known that much of the heat is transferred through the gas. The GLV is filled with a thermally conductive gas to maximize the heat transfer. The GLV itself is then mounted to a sink to remove the heat.

2.5. Seamless array

In a linear GLV array, each moving ribbon is always between two stationary ribbons. Thus, when adjacent pixels are in on state, there is no discernable boundary between the pixels. In terms of imager applications, this solid line shape does not require excess beam power to give energy to boundaries. Pixels with no boundary create exact images, for the on pixels and the off pixels have approximately the same dimensions.

3. DISCUSSIONS ON REFLECTANCE OF THE GLV

3.1. Spectral reflectance

The reflectance of GLV pixels depends on the incident wavelength. The results we had on the first GLV samples revealed that the reflectance at wavelengths from 800 to 830nm was relatively low and very sensitive to wavelength variation. As aluminum reflectivity does not vary strongly at this wavelength range, we attribute this wavelength sensitivity to the GLV device structure.

The design of the GLV device allows some of the incident light to pass through the gap between ribbons and reflect from the underlying substrate. The wavelength dependence results from the interference of the reflected light from the aluminum surface and the substrate. It is therefore sensitive to the distance from the ribbons to the electrode, and the phase intensity of the light reflected from the substrate. Since the distance is constrained by electrostatic and mechanical requirements, we focused on optimizing the performance by modifying the optical properties of the electrode.

To improve the spectral reflectance, the thicknesses of the various layers comprising the lower surface were changed. Figure 2 depicts cross-sections of simple (a) and improved (b) GLV pixel structures. The optimized multi-layer structure matches the phase of the reflected light in the undeflected state, thus enhancing the reflectance. Figure 3 shows spectral reflectance curves before and after this improvement. Obviously the reflectance between 800nm and 850nm has greatly increased. The new substrate structure is thought to be optimal, considering the aluminum surface reflectance (85%) and the GLV phase relationship. This type of layer modification can be done to customize the efficiency for a wide range of wavelengths.

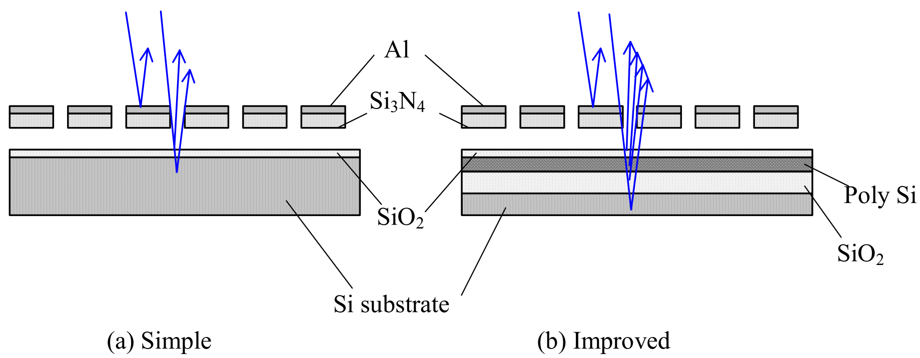

Fig.2. The electrode can contribute to the efficiency of the GLV. Layer thicknesses and properties of the multi-layer electrode were modified to optimize reflectance and phase.

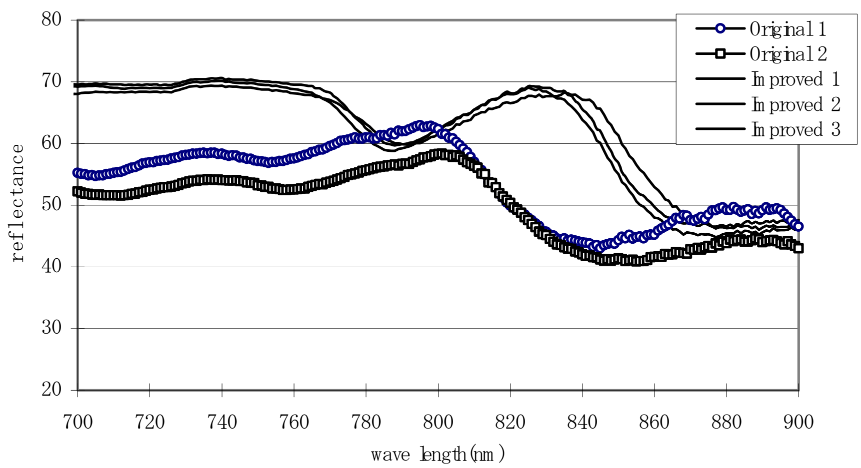

Fig.3. The dependence of efficiency on wavelength.

3.2. Polarity dependence

We have also found that the reflectance depends on the incident light polarity. Figure 4 shows typical reflectance curves of 0^{th} order light at 808nm along a GLV array. As shown in this figure, the GLV pixels reflect light polarized perpendicular to ribbons (S-polarized) more effectively than light parallel with ribbons (P-polarized). (The incident beam impinges on the GLV at a certain angle in the plane determined by the ribbon and the normal to the GLV surface). Unlike electro-optic modulators, which can be affected by crystal anisotropy, this phenomenon is due to the ribbon structure.

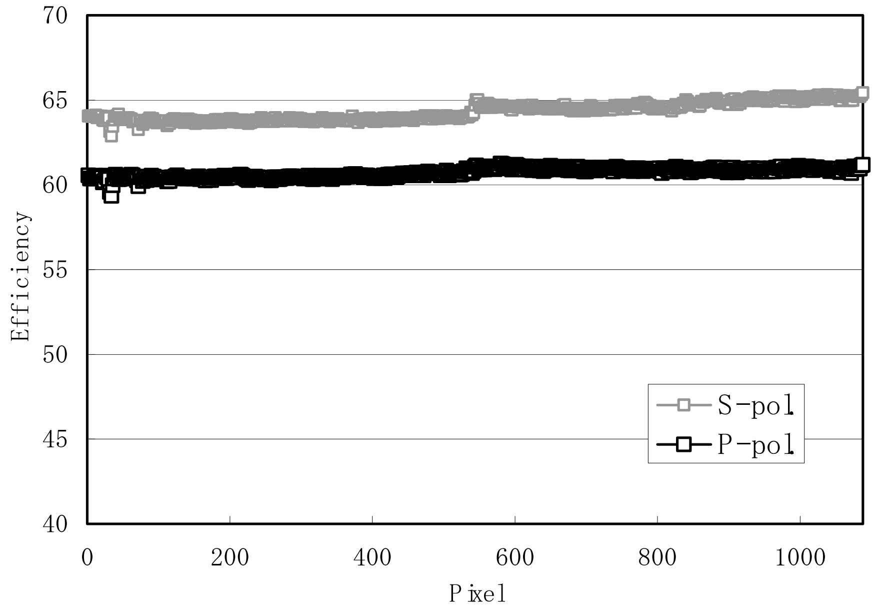

Fig.4. The dependence of efficiency on polarization

Figure 4 suggests we use S-polarized incident light to get the GLV function optimally. The incident polarization should be modified if necessary. However, the reflectance of P-polarization is typically lower than that of S-polarization only by 4-5 %. To get higher intensity, it is reasonable to combine two laser beams of orthogonal linear polarization on a common axis.

4. IMAGER DESIGN

4.1. Imaging with 0^{th} order beam

For display applications, $\pm 1^{st}$ order diffracted beams are used to create an image on a screen. While this maximizes the contrast ratio, we have chosen to use 0^{th} order (non-diffracted) beams as signal beams. One of the reasons is that high resolution print applications need reduction optics, where the numerical aperture (NA) is larger in the image space than in the object space. To avoid a shallow depth of focus, the NA in the object space should be small. The other reason is high efficiency. While only 81% of the diffracted light energy is directed into the $\pm 1^{st}$ orders in an ideal square-well diffraction grating, 100% of light energy is reflected on an ideal mirror plane.

To direct the 0^{th} order beam to an image plane, the incident beam needs to hit the GLV at an angle in the plane whose normal is parallel with the GLV array.

4.2. Number of ribbons

The basic GLV pixel is made up of 6 ribbons, or 3 active-inactive ribbon pairs. For the CtP application we combine two GLV pixels, or 6 ribbon pairs for each writing pixel. The resulting writing pixel is 51 μm in width, which is used with 5:1 reduction optics to image up to 544 discrete 10 μm spots onto the plate. While the larger pixel size reduces the number of pixels and requires optics with a shallower depth of field to get the desired spot size, this larger area allows us to minimize the laser intensity on the GLV.

A further advantage of combining two GLV pixels is that 6 ribbon pairs give higher contrast than 3 pairs. Figure 5 shows a theoretical intensity curve of diffraction by 3 pairs of ribbons. Because a slit that passes 0th order beams has a finite width, some of diffracted energy cannot be filtered out. Use of more ribbon pairs generates less diffracted energy in the vicinity of 0th order, thus rendering higher contrast (See Fig. 6).

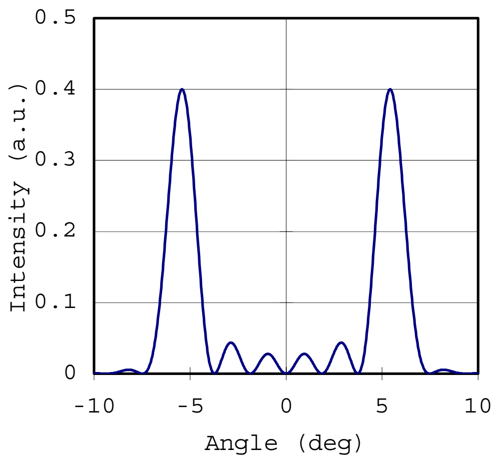

Fig.5. The intensity as a function of angle for 3 deflected ribbon pairs at 808nm illumination.

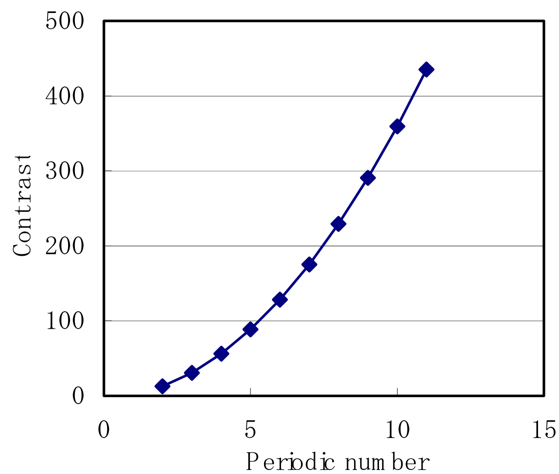

Fig.6. Extinction ratio of 0th order beam

4.3. Illumination optics

For thermal applications, it is necessary to use very high power lasers such as laser bars, which have multiple emitters. While the nature of the GLV device imposes a limit on etendue in one direction, the geometry of the array permits efficient coupling of multiple laser beams. Although linear illumination optics often uses slow-axis collimator (SAC) lenses[1)], we have chosen to use a fly-eye lens array to integrate beams from emitters[3)].

Figure 7 shows a typical intensity distribution that our illumination optics creates on a GLV array. As shown in this figure, our optics gives much the same power to every pixel of the GLV array, which is approximately 28mm long.

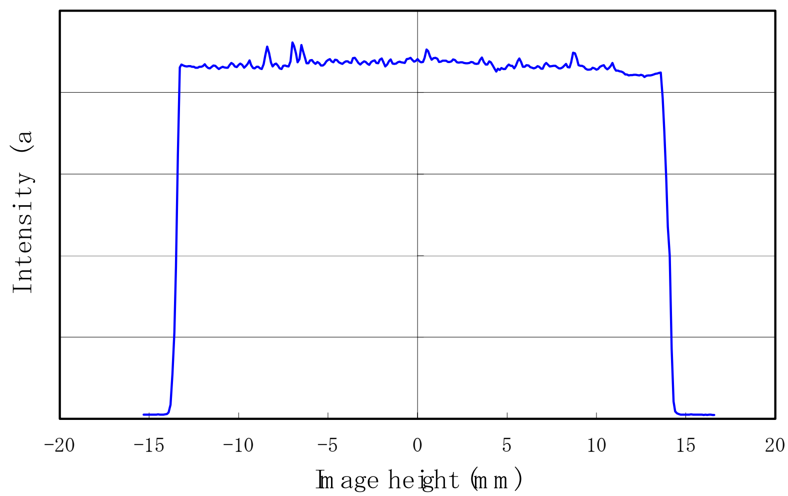

Fig.7. Illumination profile of the line of illumination along the length of the GLV.

Because our illumination optics eliminates SAC lenses, there are no limitations to emitter intervals. With an increase of output power, a laser bar tends to have more emitters at a narrower pitch. For example, 19 and 49 emitters on a laser bar are located at an interval of 500µm and 200µm, respectively. Our specially designed illumination optics avoids technical difficulties in fabrication and adjustment of very small SAC lenses.

4.4. Use of two laser bars

As mentioned above, we can use two lasers of orthogonal polarization to nearly double the writing beam intensity because the GLV reflectance does not heavily depend on the incident polarization. Figure 8 is a schematic configuration of an illumination module with two laser bars. The laser beams from one of the bars pass though a half-wave plate, which rotates the polarization by 90 degrees. These rotated laser beams are then combined by a polarizing beam splitter with the beams from the other bar and are focused onto the GLV.

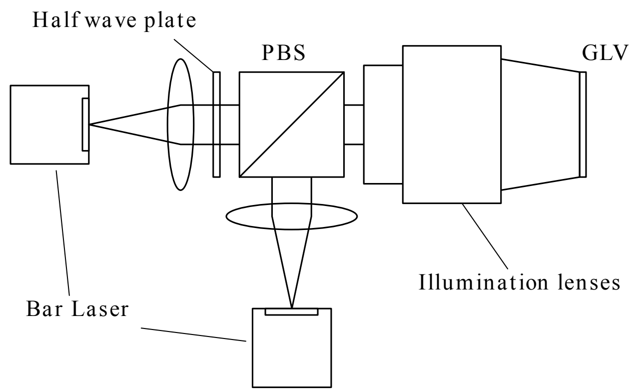

Fig.8. Schematic of double laser illumination system.

5. THE GLV-BASED PLATESETTERS

Such laser imager manufacturers as Dainippon Screen have extensive expertise in creating an image with a linear (acousto-optic) modulator array[4)]. In the meantime, Silicon Light Machines has found that scanned linear architecture is well suited to high resolution video displays[5)]. Since we started our joint project, we have worked on development of a linear GLV module that has been optimized for thermal imaging applications.

Figure 9 shows the GLV module used in thermal CtP systems. Shown in Fig. 10 is the GLV-based very large format platesetter developed by Dainippon Screen. Thanks to as many as 512 writing beams, this most advanced platesetter can image plates with high throughput without rotating a large drum at excessively high speed.

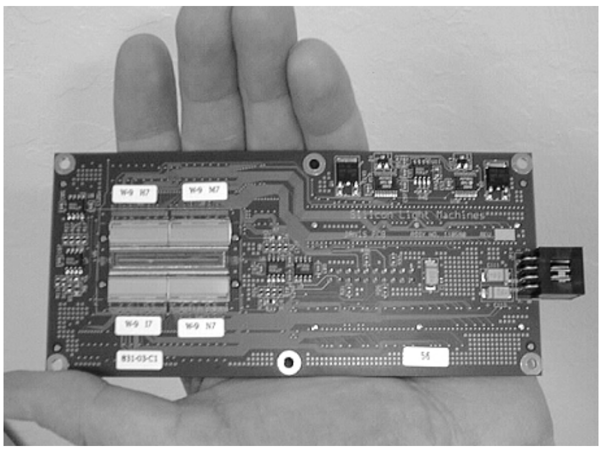

Fig.9. The GLV module

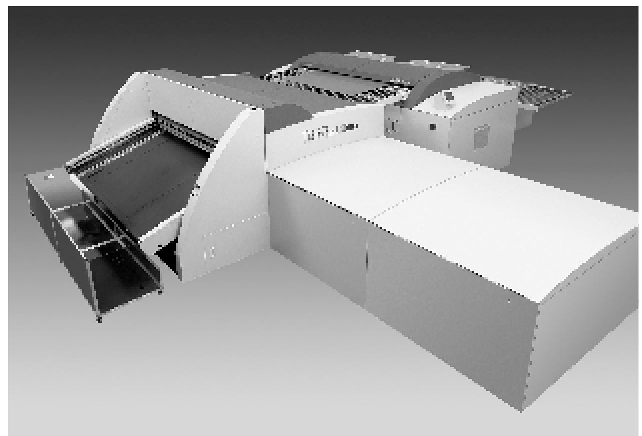

Fig.10. Dainippon Screen very large format platesetter (PlateRite Ultima)

6. SUMMARY

We described the features and technology behind a new class of CtP thermal platesetters based on the GLV. Among other spatial light modulator technologies, the GLV technology offers the best performance for thermal CtP applications. Thanks to its unique design, the GLV device meets all the requirements: high-speed switching, high-power handling, precise beam power control, and exact beam shape.

Imager technology was also described. The fly-eye lens array creates a uniform illumination beam without the use of a SAC lens. Polarization combining of the laser beams allows for a beam at nearly twice the power of a single laser bar. Additionally, Dainippon Screen has developed a data dependent technique to improve quality by using the gray level capability of the GLV.

With the advanced GLV technology, the latest thermal CtP systems have a number of advantages over existing systems

REFERENCES

1. D. T. Amm and R. W. Corrigan, *Optical Performance of the Grating Light Valve^{TM} Technology*, Presented at Photonics West-Electronic Projection Display V, 1999.
2. D. T. Amm and R. W. Corrigan, *Grating Light Valve^{TM} Technology: Update and Novel Applications*, Society for Information Display Symposium, Anaheim, CA, May 1998.
3. US Patent No.6,611,382 B2
4. US Patent No.4,617,578, US Patent No.4810,068
5. R. W. Corrigan, *Scanned linear architecture improves laser projectors*, Laser Focus World, January 1999, 169-174