High Power MEMS Planar Light Valve

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Abstract: The PLV supports modulation of over 500W of laser power for materials processing. It provides a line beam with 1088 individually addressable pixels and 200kHz switching speed. A custom optical head complements the PLV.

1. Introduction

We present a high-power MEMS spatial light modulator called the Planar Light Valve (PLV). The PLV is geared towards high-power laser direct write applications such as additive manufacturing, laser marking and other materials processing. Contrary to the spot beam scan systems that dominate today's market [1,2], the PLV can simultaneously direct power into a line beam consisting of 1088 individually addressable spots with 10-bit analog modulation. Line modulation is compatible with systems where either the media or beam is scanned. The modulation principle is based on diffraction and is akin to the Grating Light Valve (GLV) which is a line beam modulator used in commercial printing systems [3]. Compared to the GLV, the larger area of the PLV accommodates more than an order of magnitude of incident optical power. Fig. 1(a) contrasts the large-area array of the PLV to the narrow "sweet spot" of the ribbons on the GLV. In addition, we have built a new optical illumination/projection system featuring anamorphic optics to complement the PLV. This pairing offers a turn-key solution for light processing in high-power laser applications.

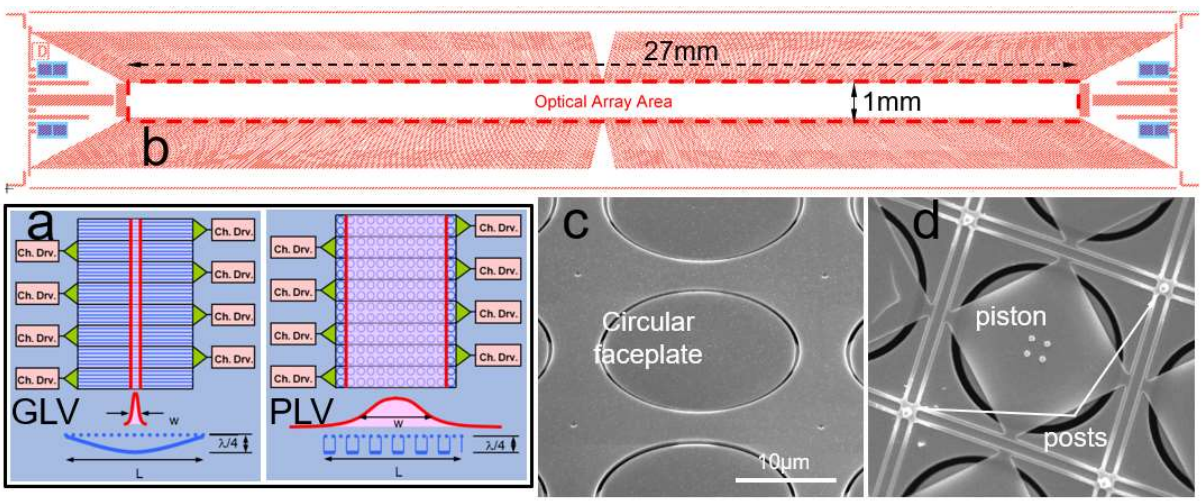

Fig. 1. (a) GLV vs PLV. (b) PLV device schematic. (c) Array surface (d) Underside of piston – tape lifted

2. Design and Fabrication

The PLV features a large 27mm by 1mm array consisting of 1088 pixels. Fig. 1(b) shows a schematic of the array. Each pixel incorporates 1 by 40 piston cells. These elongated pixels are imaged onto the work surface using anamorphic optics to resize the pixel dimensions. The piston cells feature a tri-layer suspended architecture based on electrostatic actuation. Fig. 1(c-d) display SEM images of the top and underside of the piston cells. The foundation of the tri-layer structure is an electrode layer. Suspended above the electrode is the actuating counter electrode called the piston. Above the piston is the faceplate which is partitioned into a circular dynamic surface and a static surface. Modulation is achieved by creating a step height between the dynamic and static surfaces. The PLV is fabricated using low temperature silicon germanium which is CMOS compatible. This allows for the integration of MEMS with CMOS in the future which can significantly reduce footprint and cost.

3. Device Characterization

We characterized the optical intensity response as a function of actuation voltage. A spot beam is used to interrogate the pixels as they are actuated. A Fourier filter is used to select the *0th* order component. Fig. 2(a) plots the intensity of the *0th* order beam as a function of voltage. Each color represents a different measurement location on the array. We can see that the behavior of the pistons across the array is very consistent. Additionally, to quantify the array uniformity, we plot the reflectivity (Fig. 2(b)) along the length of the array at both the bright and dark states. Fig. 2(c) shows the step response of the PLV evaluated with a 405nm laser. Under normal use conditions at 1064nm, we operate the device with switching speeds of up to 200kHz.

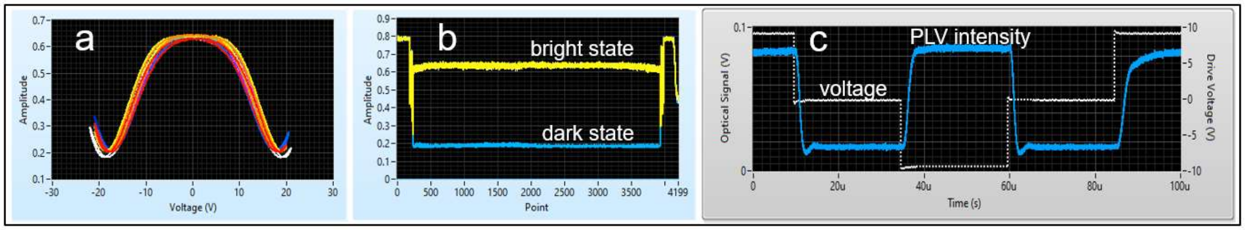

Fig. 2. (a) Measured intensity as a function of voltage. (b) Measured array uniformity. (c) Step response.

4. Optical Head

In conjunction with the PLV, we have designed and built an optical illumination/projection system called the optical head. Fig. 3 shows a picture of the optical head and modulated output line beam. The illumination system transforms the light from the laser into a line with a "top-hat" profile to uniformly fill the array. The projection system comprises a conjugate set of lenses with apertures in the Fourier plane between the lenses, used to select the imaging order. For additive manufacturing or laser marking applications, the output beam can easily be conveyed across the part bed either by scanning with a single axis galvo or translating the work surface under the stationary modulated line beam.

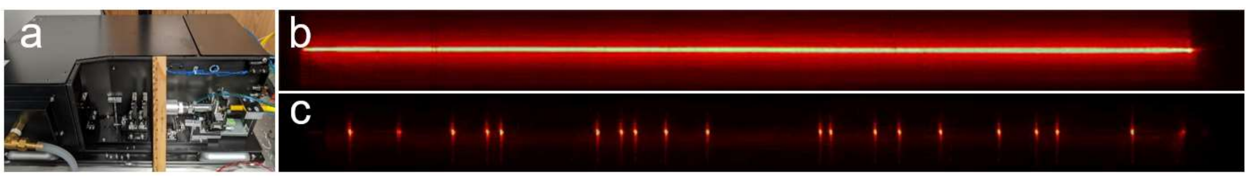

Fig. 3. (a) Image of optical head. (b) Output beam with all pixels turned on. (c) Output beam with a random pattern.

5. High Power Performance

The PLV has demonstrated over 100 hours of continuous operation at 520W of incident power with no degradation. At 520W of incident power, we measure 360W at the output of the optical head when all pixels are full brightness. The loss is mainly due to the diffraction efficiency of the PLV (75%) and the projector efficiency (93%). We are currently developing a second generation of PLV with significantly improved thermal management. Our preliminary results show that the spot beam laser induced damage threshold is 2.8 times higher than the current devices. From our experience, the operational full power handling of the device scales with the laser induced damage threshold. This suggests that the new devices are capable of modulating over 1.4kW of laser power. Furthermore, we are implementing additional measures for modulating over 2kW of incident power in the near future.

6. Conclusion

We have developed a new high-power PLV MEMS spatial light modulator capable of continuous modulation of over 500W of laser power. We believe the PLV provides the highest power handling and switching speed of any currently available MEMS spatial light modulator. This along with its individually addressable pixels supporting gray scale modulation provide a highly desirable solution for high-power applications such as additive manufacturing and laser marking. The PLV with the optical head is ready for deployment. This is a new generation of high-power laser modulators currently capable of 500W and with path to >2kW.

7. References

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