Slotted Ribbon Grating Light Valve for Compact Display

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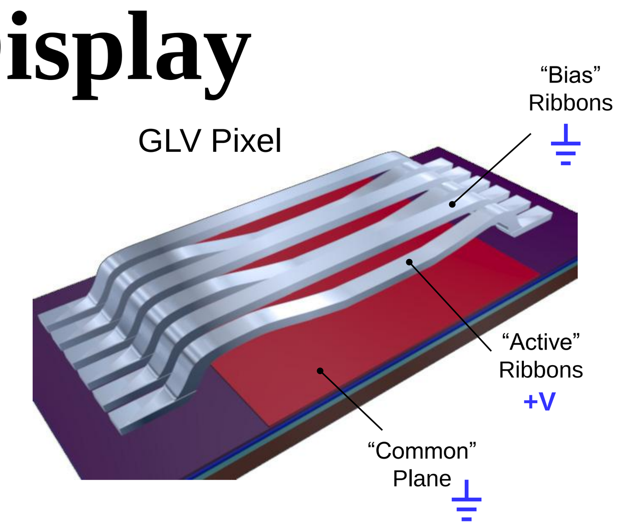
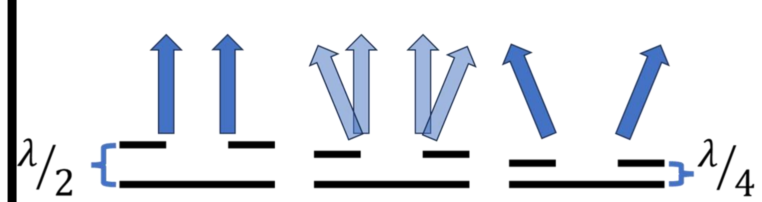
GLV for Display

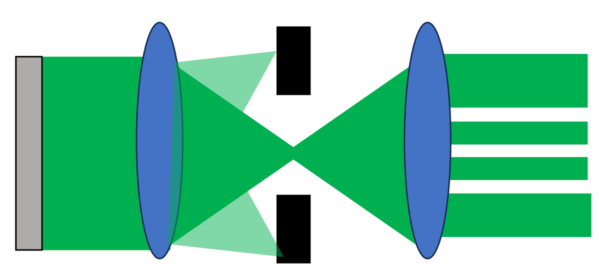
The Grating Light Valve (GLV®) is a 1D MEMS spatial light modulator comprising groups of electrostatically actuated ribbons and reflective reference surfaces, either the substrate or a bias ribbon [1, 2].

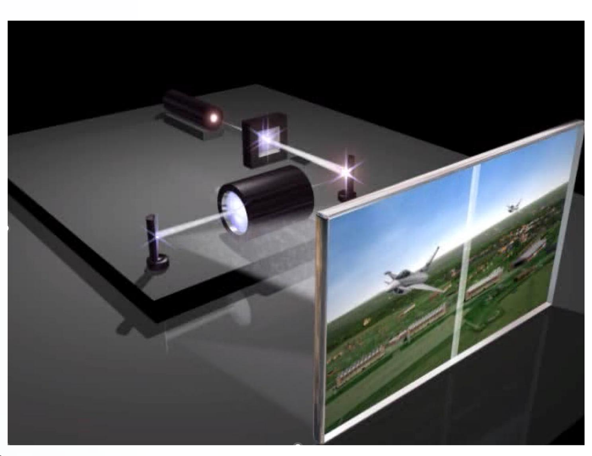




Deflecting ribbons cause a variable amount of light to be diverted from the 0th grating order to the 1st and higher orders. Typically, multiple line-pairs are used per pixel for high contrast amplitude modulation.

A Fourier filter with a 0th order or 1st order pass filter creates grayscale amplitude modulation in the conjugate plane.





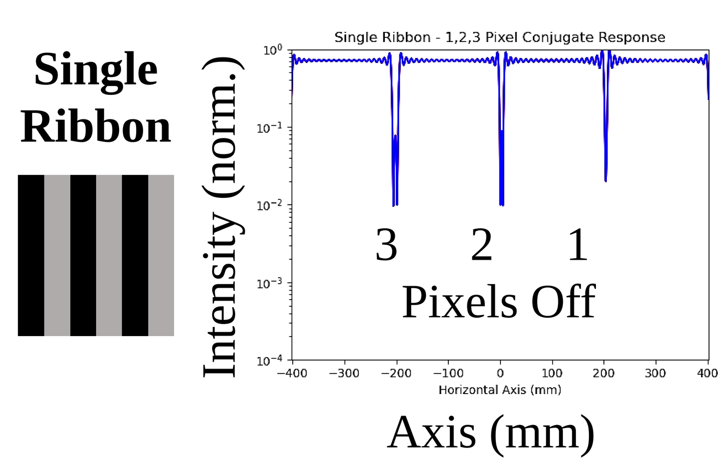
The 1D device creates instantaneous grayscale, borderless patterns with very high column rates, up to 500 kHz, making the GLV suitable for scanned projector systems in display and industrial applications [3].

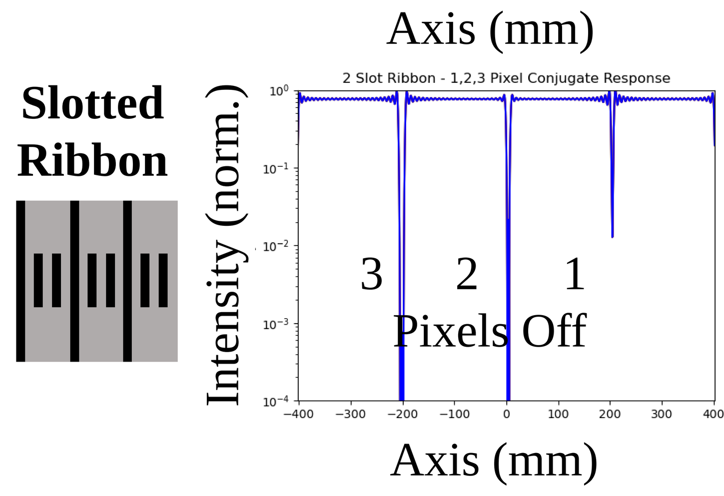
Slotted GLV Concept

Grating light valve ribbons constructed of Aluminum and Silicon-Germanium have been demonstrated down to 2μm, or 4μm effective pixel pitch. However, ganging multiple pixels is needed to achieve a good contrast in zero order.

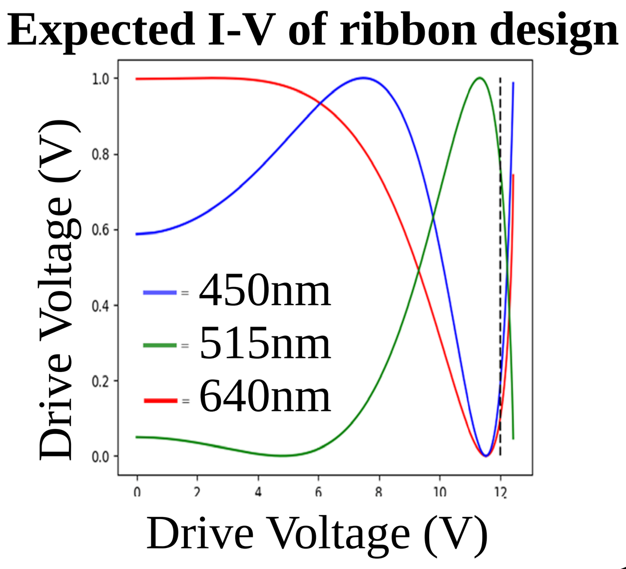
Adding slots in the ribbon allows for an active area with multiple line-pairs while retaining the better speed (damping) and voltage characteristics of the wider ribbon.

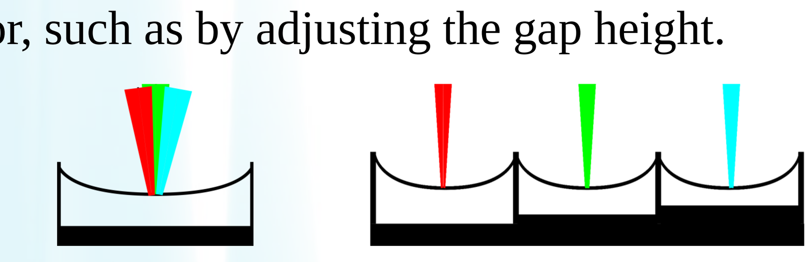
The slotted ribbon micro display concept will first be demonstrated using a passive prototype with a single ribbon for RGB. This passive prototype utilizes already existing GLV module drivers. Later, an integrated device may have separate RGB channels to optimize performance for each color, such as by adjusting the gap height.





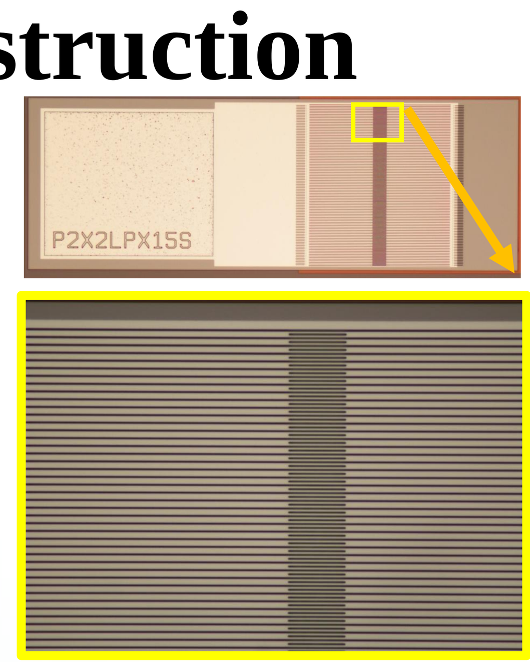
Expected I-V of ribbon design

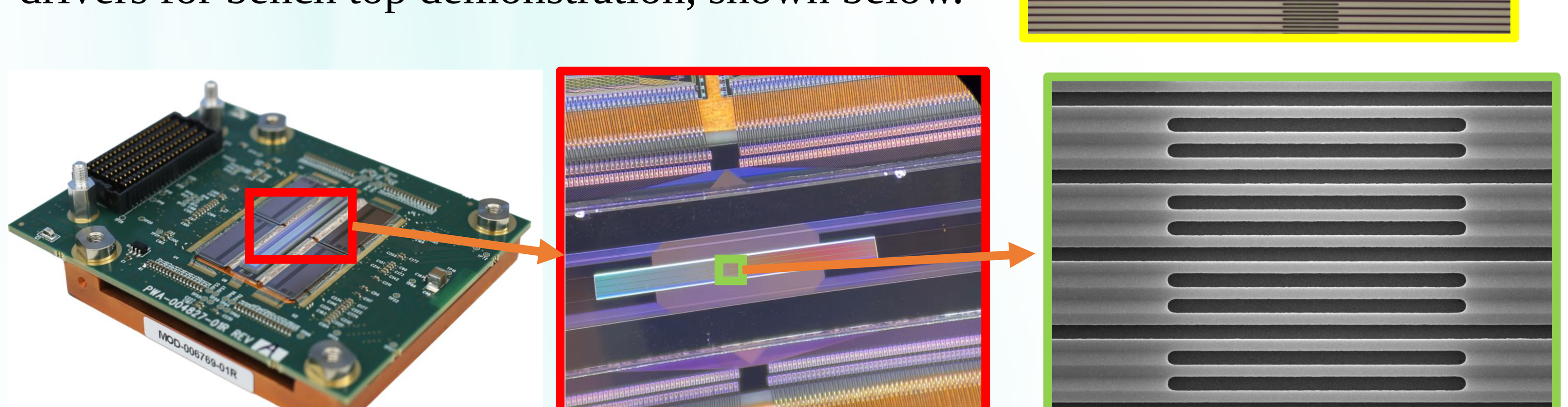




Slotted GLV Construction

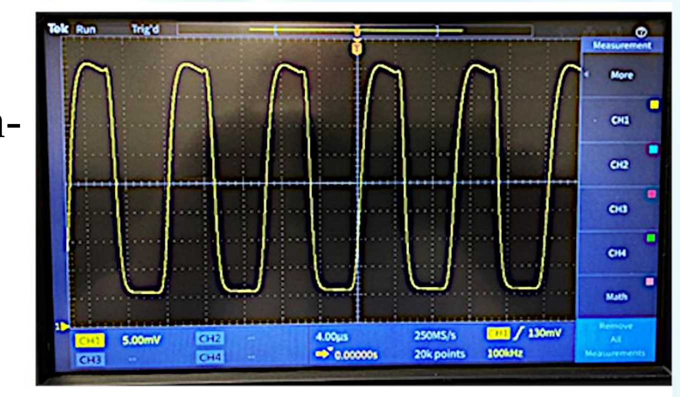
Slotted ribbons were successfully constructed down to 2μm pixel pitch on electronically ganged, actuatable short loops. A 15μm single slot design at 2μm pixel pitch is shown right.
After testing for dynamic response, a 3.9μm 2-slot design is chosen to construct a 1088 channel passive device. This passive chip is mounted in a pre-existing PCB module and wire-bonded to external drivers for bench top demonstration, shown below.



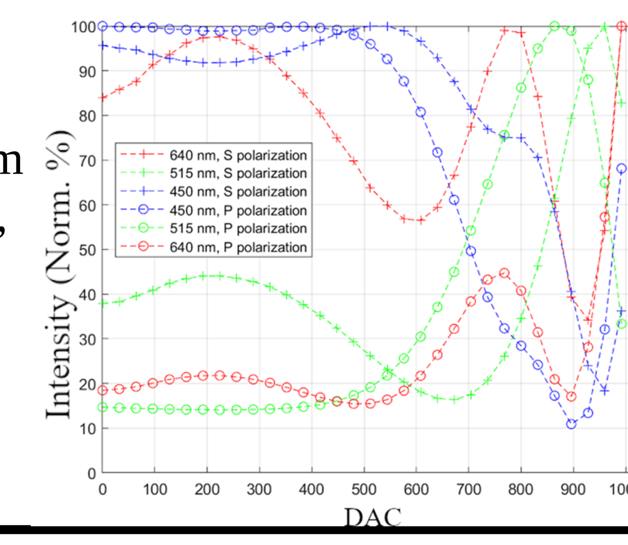


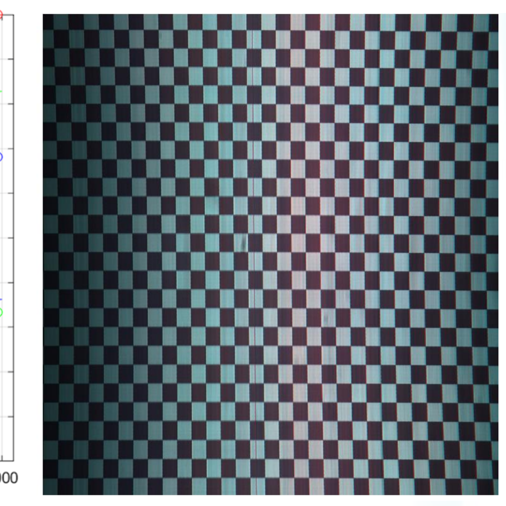
Passive Prototype Testing

Optical testing at Meta Reality Labs demonstrated critical damping for 200khz operation. The oscilloscope reading of an on-off strobe onto a photodiode is shown right. However, the IV response, below, has a polarization dependence, unusually shaped curves, and worse contrast than expected.



Contrast ranged from 6:1 to 12:1, >100:1 is desired for display.

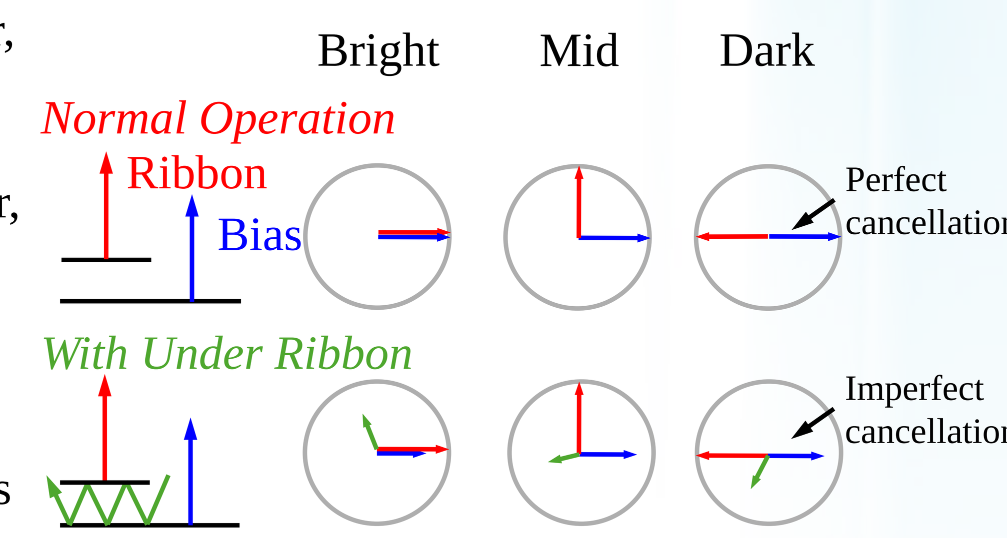


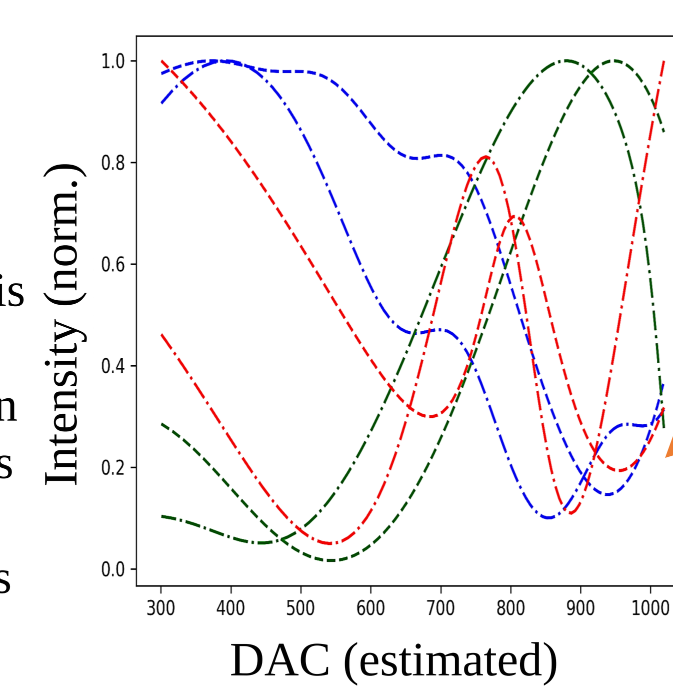


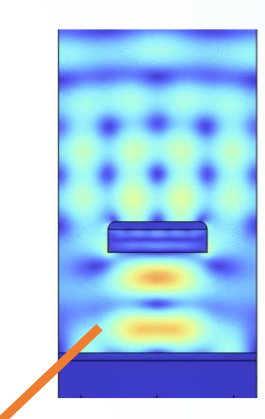
Benchtop demonstration of a direct view display checkerboard pattern

Analysis

A two-phasor model can be used to explain typical GLV behavior, with the real part of the phasor addition being the resulting grayscale modulation. However, as the feature size becomes smaller: A) light is diffracted at greater angles under the ribbon, and B) more aluminum is sputtered under the ribbon. This diffracted light is therefore reflected as a third phasor, disrupting the two-phasor dark state.
COMSOL Wave Optics simulations of the SEM measured structure confirms this under-ribbon effect, in addition to coupling into the SiGe ribbon that may cause additional losses at specific wavelengths. The simulated I-V response matches the measured well, including polarization dependence and contrast degradation.



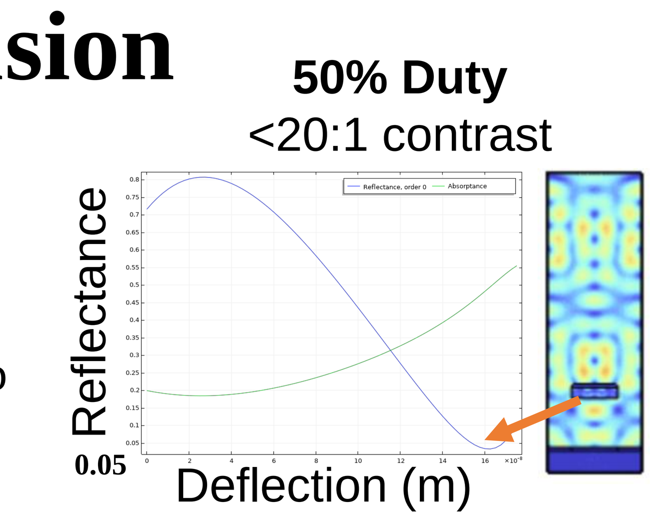


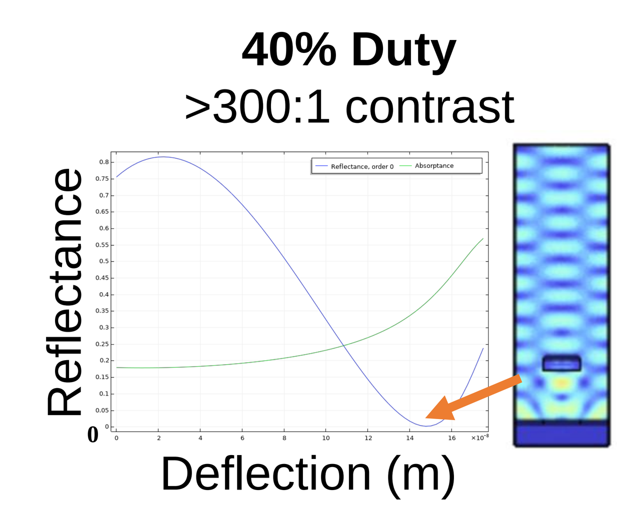


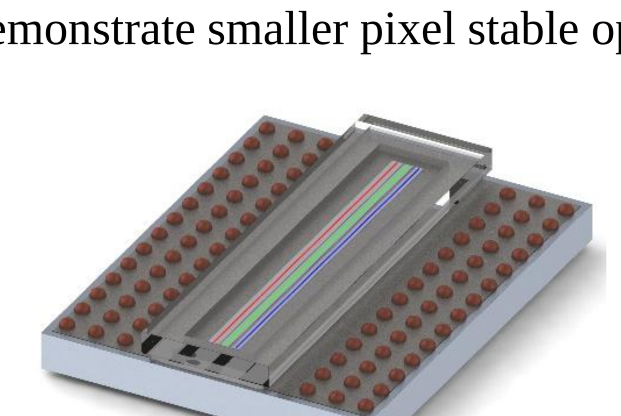
Strong presence of under-ribbon light corresponds to worse contrast, as seen in the measured results.

Conclusion

The three-phasor model suggests that simply changing the duty cycle so that the phasors once again cancel completely will regain contrast. Wave Optics simulation confirms this approach, with a 40% ribbon to 60% gap increasing contrast by over 15x. Adjusting the slot shape along with careful ribbon design accounting for under ribbon and absorption effects may also allow for more optimal IV curves with faster voltage swings while maintaining contrast.
Additional short loop work is required to confirm the contrast model and fix, and to demonstrate smaller pixel stable operation.







Once an optimal design has been found, these MEMS pixels may be monolithically integrated over new CMOS ASIC drivers for an ultra-compact device for near eye and pico-projector display.

References

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[2] D. Amm and R. Corrigan "Optical performance of the Grating Light Valve technology," Projection Displays V, (1999)
[3] J. Trisnadi, C. Carlisle and R. Monteverde, "Overview and applications of Grating-Light-Valve-based optical write engines for high-speed digital imaging," MOEMS Display and Imaging Systems II, (2004)