![Optron Systems, Inc.]

VLSI Membrane Mirror Light Modulator for Multi-spectral Scene Projectors

Device Description

The **V**ery **L**arge **S**cale **I**ntegrated circuit **M**embrane-**M**irror **L**ight **M**odulator (VLSI-MMLM), shown in Figure 1, is an active diffraction-based spatial light modulator that forms the core of a multi-spectral scene projection system for testing infrared and visible sensors and imaging systems. A complete projector system consists of: (1) the high-speed electrically addressed VLSI-MMLM unit, (2) an electronic driver board to receive standard HDMI video signals, post-process the video data, and interface it to the modulator, and (3) spatial filtering readout optics.

Fig. 1: A bare VLSI-MMLM, mounted on interface card

As shown in Figs. 1 and 2, the VLSI-MMLM consists of a custom VLSI chip upon which a 2-D array of pixel wells is patterned in an insulating layer. A thin metal-coated membrane mirror bonded to the insulating layer covers the wells and serves as one of the electrodes. The 2-D array of electrodes on the chip then allows each pixel to be independently programmed with an analog voltage. The applied voltage between the pixel electrode and the membrane mirror causes electrostatic deformation of the membrane mirror into the wells. By varying the width and depth of the pixel wells, modulators optimized for mid-wave infrared (MWIR), long-wave infrared (LWIR) and visible light can be fabricated depending on the target waveband of interest.

System Operation

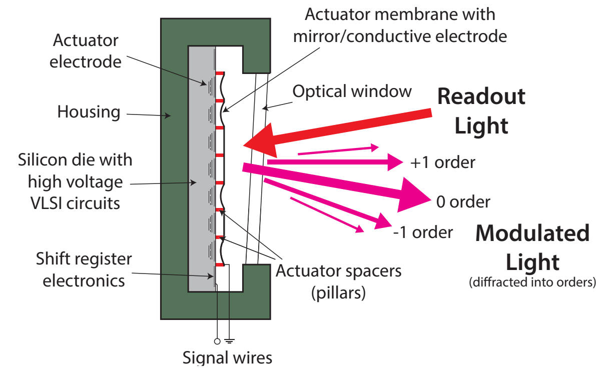
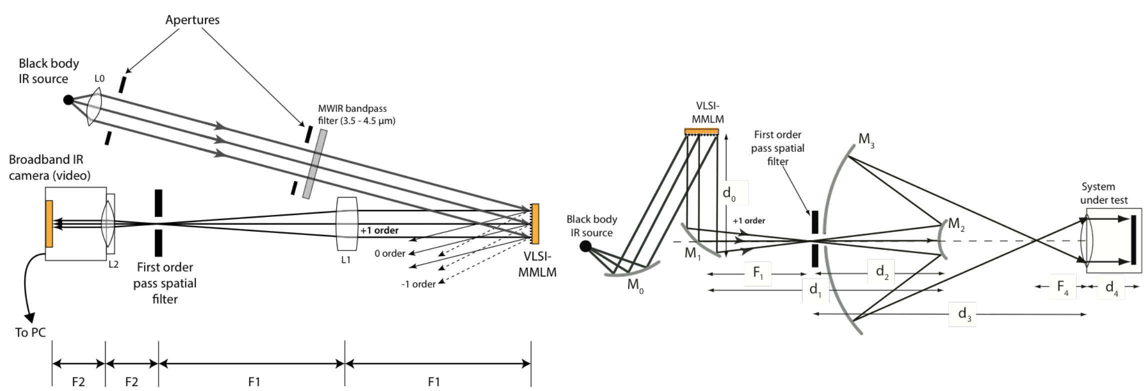


Figure 2: VLSI-MMLM schematic

In scene projector operation, the off-chip readout source is collimated before it reaches the VLSI-MMLM. The system may be operated in zero-order pass or zero-order stop modes. Figures 3(a) and (b) show projection systems employing refractive and reflective optics, respectively. Reflective readout optics are preferred for infrared operation. In most of our prototype development work we have used the simpler refractive system shown in Fig. 3(a) which blocks the zero order and passes the first-order light.

When there is no voltage across the pixel wells, the membrane mirror is flat, and the light reflecting off the surface maintains its collimation. Thus, lens L_1 in Fig. 3(a) (or mirror M_1 in Fig. 3(b)) focuses this light to a single diffraction-limited zero-order spot. In a zero-order stop system, for example, this spot is blocked by the spatial filter. Thus, in the zero-voltage state, essentially all of the light reflecting off the modulator is prevented from reaching the image plane.



(a) **(b)**

Figure 3: (a) Lens-based first-order pass readout projector; (b) proposed all-reflective mirror-based readout projector

When a voltage is applied to a particular electrode or a group of electrodes, the resulting electrostatic force deforms the membrane mirror into the corresponding pixel wells, and the portion of the membrane mirror above those wells becomes a diffraction center. In this state, light is scattered out of the zero order into higher diffractive orders, and passed by the zero-order-block spatial filter such that the surface of the modulator is reimaged by lenses L_2 and L_3 (or mirrors M_2 and M_3) into the system under test. As the voltage between the electrodes and the membrane increases, the deformation of the membrane mirror increases, with correspondingly more light passing the spatial filter, leading to increasing projector output intensity. Thus, true gray-scale intensity modulation is achieved.

By successively programming each pixel of the VLSI chip with an analog voltage, a 2-D gray-scale image is created at the image plane. An on-chip pixel capacitor, as well as the intrinsic capacitance between the pixel electrode and the membrane mirror, stores the charge between pixel raster updates and thereby flickerless image operation is achieved.

System Specifications and Performance

The current generation VLSI chip (~25 mm square) uses a raster-scanning addressing scheme which offers update rates potentially in excess of 500 frames per second. Our current prototype mid-wave infrared (2-5 µm) projector supports a resolution of 320 x 320 pixels on a 60 µm pitch. Sample test output of an earlier 200 x 200 pixel prototype operating in the MWIR is shown in Figure 4.

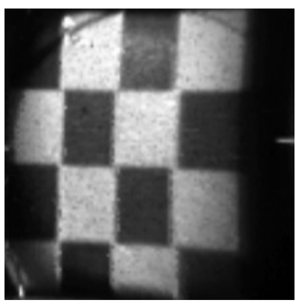


Fig. 4: MWIR output of early low-resolution prototype VLSI-MMLM

This current VLSI-MMLM chip is capable of supporting resolutions up to 1000 x 1000 pixels on a 20 µm pitch. These finer resolutions are best suited for visible and UV use, as longer IR wavelengths require greater mirror deflection (achieved using larger pixels) to attain comparable contrast at maximum chip drive voltage.

Currently under development for the MWIR is a larger-format VLSI-MMLM scene projector based on a new 50-mm square chip with 768 x 768 pixels on a 60 µm pitch. This chip has the potential to scale to higher resolutions in the future.

Because the projector light source is off-chip, the VLSI-MMLM is a low-power device and is thus well suited for use in chilled chambers when cold background temperatures are required. Prototype VLSI-MMLM scene projectors have been demonstrated at -32° C in the mid-wave infrared.

Multiple VLSI-MMLMs operating in parallel may be optically combined and registered to project red, green, and blue (RGB) full-color images where each modulator projects a separate color. RGB systems may also be integrated with one or more UV or IR channels to provide fully multispectral scene generation. In applications where flicker is not a concern, sequential color video for RGB/IR is also an option, requiring just a single VLSI-MMLM.

Background of Infrared Scene Projection

Infrared scene projectors are used to test infrared focal plane detector arrays and advanced IR imaging systems. There are three basic approaches to infrared scene projection: thermal emissive systems, solid-state emitter (LED/VCSEL) arrays, and spatial light modulator systems. Each of these projector technologies offers its unique advantages and disadvantages, but none meet all of the performance goals that test facility users now require. In particular, the conventional emissive array technology in widespread use today suffers from poor spatial uniformity, limited apparent temperature dynamic range, high cost, and the inability to produce visible images.

Among the more significant applications are preflight testing and verification of missile-seeker infrared sensor hardware and software. Today's requirements call for scene projectors that are capable of simultaneously producing dynamic, flickerless images of point sources, extended objects and backgrounds with large gray-scale dynamic range from UV to LWIR. In particular, such testing of imaging sensors requires the ability to project virtual reality scenes that include simultaneous infrared, visible, and ultraviolet images of objects that are registered and synchronized.

Background of Optron Systems

Founded in 1982, Optron Systems has significant experience in the development of micro-electromechanical systems (MEMS)-based spatial light modulators for adaptive optics, and visible and infrared scene projection. The company has commercialized this technology into a line of optical shutters. Previously, the company has developed VLSI-chip liquid-crystal micro-displays, and spun off Radiant Images, Inc. in 2002 to commercialize that technology. Since that time, the company has focused on developing the VLSI-MMLM technology, specifically targeting the infrared and multi-spectral scene projection markets for both military and commercial applications, while exploring additional applications of its key innovative technologies.

Contact Us

Address: 235 Bear Hill Rd Ste 200, Waltham MA 02451
Email: *info@optronsystems.com*
Phone: *+1-781-890-3600*
Fax: *+1-781-275-3106*