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VLSI Membrane Mirror Light Modulator for Multi-spectral Scene Projectors

Device Description

The Very Large Scale Integrated circuit Membrane-Mirror Light Modulator (VLSI-MMLM), shown in Figure 1, is an active diffraction-based light modulator that forms the core of a multi-spectral scene projection system for testing infrared and visible seekers and sensors. A complete projector system consists of: (1) the high-speed, electrically addressed VLSI-MMLM unit, (2) an electronic driver board to interface the standard VGA video output of a PC to the modulator, and (3) spatial filtering readout optics.

The VLSI-MMLM consists of a custom VLSI chip upon which a 2-D array of wells is etched into an insulating layer. A thin metal-coated membrane-mirror bonded to the insulating layer covers the wells and serves as one of the electrodes. A 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 the membrane mirror to electrostatically deform into the wells. By varying the width and depth of the pixel wells, modulators for mid-wave infrared (MWIR), long-wave infrared (LWIR) and visible light can be fabricated depending on the target waveband of interest.

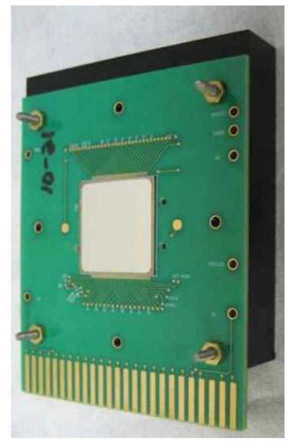

Figure 1: VLSI-MMLM.

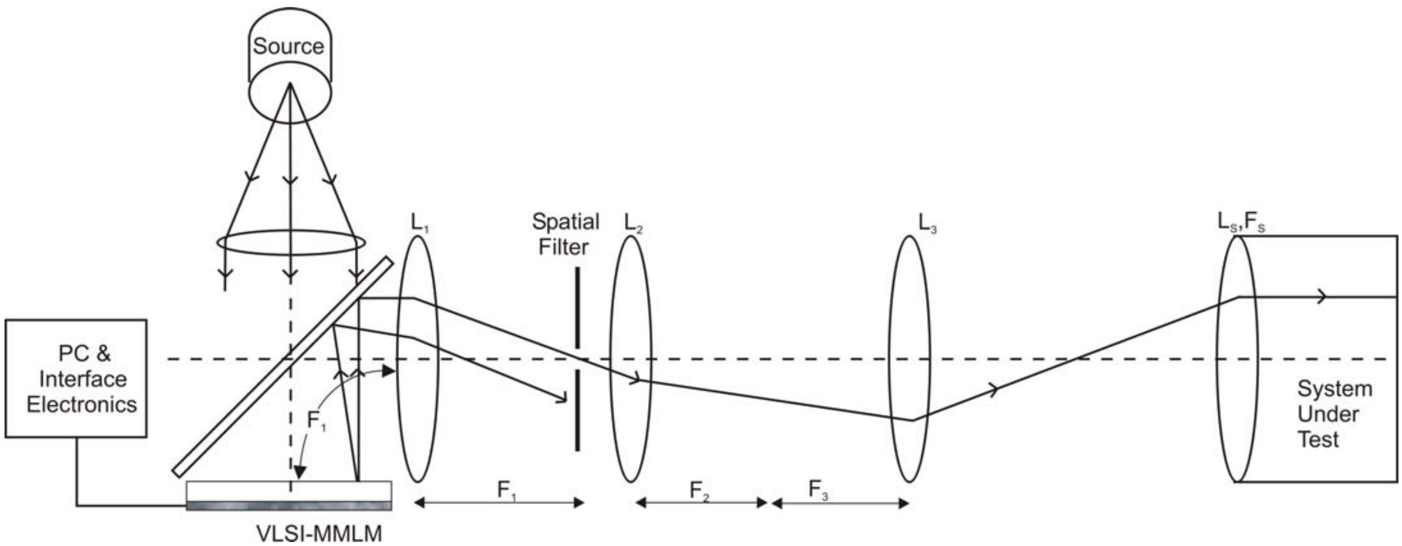

Fig. 2: Optical path of one channel of the multi-spectral scene projector with the output coupled to a system under test

System Operation

In zero-order pass operation, the infrared light (generated off-chip) is collimated before it reaches the VLSI-MMLM. When there is no voltage across the wells, the membrane mirror is flat, and the light reflecting off the surface maintains its collimation. Thus, lens L_1 focuses this light to a single zero-order spot, which passes through the spatial filtering aperture so that the surface of the modulator is reimaged by lenses L_2 and L_3 into the system under test as shown in Figure 2. In this state, essentially all of the light reaching the modulator is transmitted to the image plane.

When a voltage is applied to a particular electrode or a group of electrodes that drive a single pixel, the resulting electrostatic force deforms the membrane mirror into the corresponding pixel well, and the portion of the membrane mirror above that well becomes a diffraction center. As the voltage between the electrode and the membrane increases, the deformation of the membrane-mirror increases and more and more light is scattered out of the zero order and blocked by the spatial filter. This leads to lower and lower output intensity. Thus, 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. The intrinsic capacitance between the pixel electrode and the membrane mirror, as well as an on-chip pixel capacitor, stores the charge between successive frames and thereby flickerless image operation is achieved.

System Specifications and Performance

The VLSI chip uses a raster-scanning addressing scheme, which offers update rates in excess of 500 frames per second. Typical resolution for an infrared scene projector based on the VLSI-MMLM operating in the mid-wave infrared (2-5 μm) is 200 x 200 pixels with the potential to scale to higher resolutions in the future. Because the source of light is off-chip, the VLSI-MMLM is low power and is thus well suited for use in chilled chambers where cold background temperatures are required. Figure 3 shows the output of the VLSI-MMLM operating at -32° C as captured by a mid-wave infrared camera.

When operating in the visible wavebands, the VLSI-MMLM supports a resolution of 1000 x 1000. Multiple VLSI-MMLMs can also be combined to project red, green and blue (RGB) full-color images where each modulator projects a separate color. A checkerboard pattern is shown in Figure 4 where a HeNe laser is used as the light source and the image is projected onto a screen.

Figure 3: MWIR output of the VLSI-MMLM at -32° C

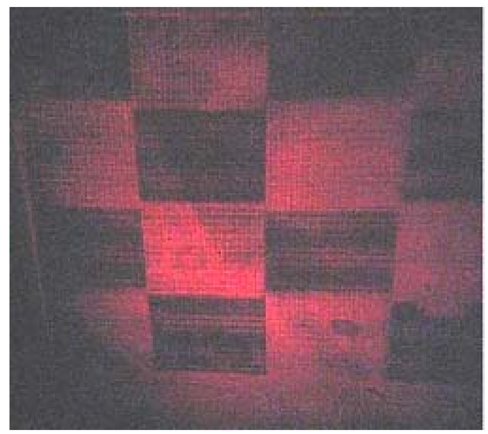

Figure 4: Visible output of the VLSI-MMLM.

Background of Infrared Scene Projection

Infrared scene projectors are used to test infrared focal plane detector arrays and advanced infrared (IR) imaging systems. There are three basic approaches to infrared scene projection: thermal emissive systems, spatial light modulator systems, and optical scanning 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 of this technology 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 ultraviolet (UV) to the 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 electro-mechanical 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 in 2002, Radiant Images, Inc. was spun-off to commercialize this 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.