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Membrane Mirror Light shutters

Device Description

The Membrane-Mirror Light Shutter (MMLS), shown in Fig. 1, is an active diffraction-based light modulator that is used for either phase or intensity light modulation. A complete modulator system consists of: (1) the high-speed, electrically-addressed MMLS unit, (2) a high-voltage high-bandwidth (100 kHz) waveform amplifier, and (3) spatial filtering readout optics. The shutter can tolerate high optical power with active areas up to about 100 mm in diameter.

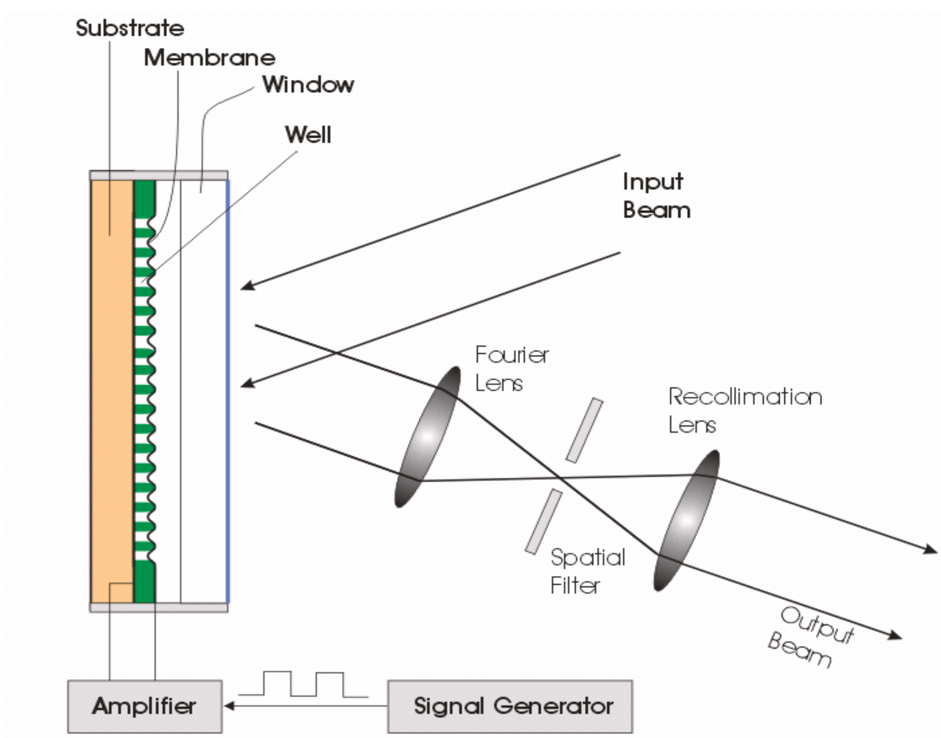

Fig. 1. Membrane-mirror light shutter system with zero-order-pass spatial filtering.

The MMLS consists of a substrate that supports a 2-D array of wells that are etched into an insulating layer atop the substrate. A thin metal-coated membrane-mirror bonded to the insulating layer covers the wells and serves as one of the electrodes. A second electrode located at the base of the wells allows voltages to be applied across the wells to electrostatically deform the membrane mirror into the wells. The assembly is sealed in an evacuated housing that is fitted with a readout window. The angle of incidence of the light on the mirror may vary from normal incidence to beyond 45^0.

Zero-Order-Pass Operation

In zero-order-pass operation, the light to be modulated or chopped (incoherent or coherent, polarized or unpolarized) is nominally collimated before it reaches the MMLS (see Fig. 1). Typically, up to 10^0 full cone angle of divergence can be tolerated. When there is no voltage across the wells, the membrane mirror is flat and the light reflecting off the shutter surface maintains its collimation. Thus, the lens focuses this light to a single zero-order spot which passes through the spatial filtering aperture and is recollimated by the second lens as shown. This corresponds to the *on* state of the shutter. In this case, essentially all the light reaching the modulator is recovered as *on*-state radiance. **The angle of incidence of the light on the mirror surface may be as large as 45^0**.

When a voltage waveform is applied to the shutter, the resulting electrostatic forces deform the membrane mirror into the underlying wells, and the membrane mirror becomes a diffraction grating. As the voltage across the wells increases, the deformation of the membrane-mirror increases, and more and more light is scattered out of the zero order into higher orders leading to lower and lower zero-order output intensity. Thus, gray-scale intensity modulation is achieved. At some specific applied voltage, V_{xt}, the zero-order light is extinguished and the *off* state is achieved. **Contrast ratios of 1000:1 are typical**. The modulator may be driven with a sine wave, square wave, triangular wave, pulses, or any arbitrary waveform. **Rise and fall times can be as short as 1 µs** depending on operating wavelength, device active area and well size.

Clearly, for high-contrast modulation, the zero-order diffraction spot must be spatially separated from the first-order spots, and the spatial filter aperture must be adjusted so that it is just large enough to pass only the zero-order spot. **When the light source is a small-diameter laser beam (2-5 mm), no lenses are necessary. The zero-order light will be separated from the higher orders and is easily filtered out**.

Zero-order-Block Operation

Zero-order block operation is achieved by placing a circular stop rather than a circular aperture in the center of the Fourier plane. In this case, since the stop blocks all the zero-order light, the optical output signal is *off* when there is no voltage on the modulator. The advantage of this mode is that extremely high contrast ratios (approaching that of mechanical choppers) if the device has no residual deformation in the absence of applied voltage. The disadvantage of this mode of operation is that the output light cannot be fully recollimated after going around the spatial filter.

Commercial Applications

General-purpose light shutter
Laser-pulse gating
Phase modulation
Printing and engraving
Broad-band image chopping
Laser beam switching
Dynamic focusing mirrror
High-speed photography
Variable beam splitting

Price List for Standard MMLS Systems

Model	Active Diam.	Grating Pitch	Package OD	Driver Amplifier	Price*
MMLS7R	7 mm	50 µm	TO-3	75V 100kHz (analog)	$995
MMLS7R	7 mm	50 µm	TO-3	125V 100kHz (pulse)	$995
MMLS12R	12 mm	50 µm	36 mm	75V 100kHz (analog)	$1,995
MMLS12R	12 mm	50 µm	36 mm	125V 100kHz (pulse)	$1,995
MMLS23R	23 mm	50 µm	47 mm	75V 100kHz (analog)	$2,995
MMLS23R	23 mm	50 µm	47 mm	125V 100kHz (pulse)	$2,995
MMLS36R	36 mm	50 µm	61 mm	75V 100kHz (analog)	$3,995
MMLS36R	36 mm	50 µm	61 mm	125V 100kHz (pulse)	$3,995
MMLS48R	48 mm	50 µm	74 mm	75V 100kHz (analog)	$4,995
MMLS48R	48 mm	50 µm	74 mm	125V 100kHz (pulse)	$4,995

*Price includes driver amplifier; Delivery: 30-45 days