PROGRAMMABLE MICRO-OPTICS COMPONENTS

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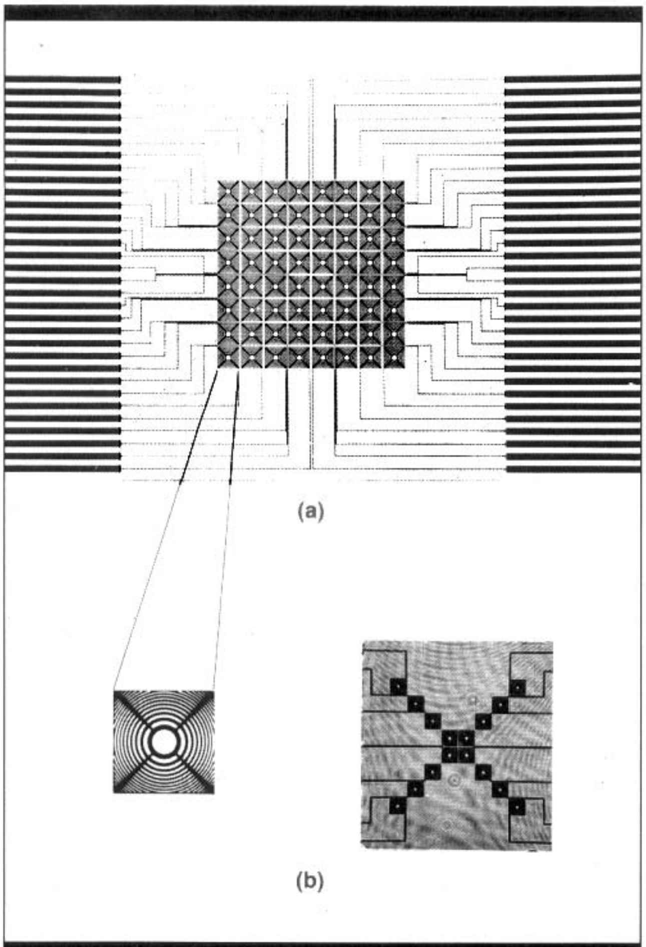
Micro-lenses and micro-gratings are now routinely fabricated on a variety of substrates such as glass and semiconductors using well-established photolithographic techniques. These optical components are so small that they can be arranged in large two-dimensional arrays for use in a variety of applications in image processing and parallel interconnections.[1] Our aim is to make these micro-optic components programmable. For this purpose, we have suggested and demonstrated the use of addressable two-dimensional spatial light modulators (SLMs).[2]

Although the concepts described here can be generalized to different types of SLMs, our work has concentrated on liquid crystal technology. The devices that we have fabricated and characterized are programmable arrays generated either by combining micro-lenses etched on glass with liquid crystal optical gates in a hybrid fashion, or by directly writing the Fresnel zone plates on optically- or electrically-addressed modulators.



(a) Electrode mask used with liquid crystal devices fabricated at Bellcore. (b) Illustration of the programmability afforded with such a modulator.

A binary Fresnel lens has multiple focal planes. The primary one is of most interest because the largest intensity is focused there. The location of the primary plane (or focal length f) is determined by the optical wavelength and the radius of the zones. The position of this focal plane can be changed by varying this radius, which could be done easily with an addressable two-dimensional SLM. The multiple foci are generally detrimental to the performance of an optical system and are usually unwanted. Thus, it is desirable to focus most of the light into the primary focal plane. The intensity of higher diffracted orders decreases if graded (as opposed to binary) modulation is used with analog spatial light modulators. In fact, the closer one gets to a sinusoidal modulation, the more light is diffracted in the primary plane to the detriment of the other planes. Recently, a total conversion efficiency of 91% of the light into the primary focus was achieved with an eight-level array of phase lenses, close to theoretical predictions.[3] Theoretically, the diffraction efficiency in the primary plane is 10% for a binary amplitude Fresnel zone plate and 41% for a binary phase plate. The latter limit has also been approached recently using two etching techniques.[4]

One alternative design for the programmable array of micro-lenses that we investigated is the use of a custom liquid crystal device with its electrodes patterned as Fresnel zone plates. This design allows for individual addressing of the elements in the array. The cell consists of a thin layer of nematic liquid crystal confined between two parallel glass plates. In this geometry, the device acts as an electrically-controlled phase plate. The optical path length is changed by reorienting the molecules with an applied electric field, thus causing the effective index to change since the two indices parallel and perpendicular to the long axis of the molecules are different. This device could be fabricated to optimize either phase (cell with liquid crystal molecules parallel to each other) or amplitude (twisted cell) modulation.

A Fresnel phase lens is created by inducing a π phase difference between two adjacent zones in a parallel cell. The zones are directly etched on the transparent electrodes, allowing for an electrical control of the focusing capability of the cell. The figure shows the mask used to pattern the indium tin oxide transparent electrode. The applied voltage reaches all the dark zones in each lens because they are interconnected by lines extending diagonally from the central zone to the edge of the lens pattern.

The lenses are placed 1.2 mm center-to-center and have 15 bright zones.

The figure also illustrates the device programming capability. A voltage is applied to the pixels along the diagonals of an 8 × 8 array while the others are grounded. In this experiment a phase device was used, which explains the bright background. An average efficiency of 26% was achieved with the 514 nm line of an argon laser. Amplitude programmable arrays of microlenses have also been fabricated with an average conversion efficiency of about 8%.

As illustrative examples of the applications envisaged with these micro-optic components, we have demonstrated the generation of programmable coherent beam arrays with a two-dimensional arrangement of binary Fresnel micro-lenses.[5] We have also shown their use in an optical cross connect with broadcast capability that can be remotely controlled.

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FEMTOSECOND TECHNOLOGY

SURFACE DYNAMICS ON THE FEMTOSECOND TIME SCALE: A REAL-TIME STUDY OF DESORPTION

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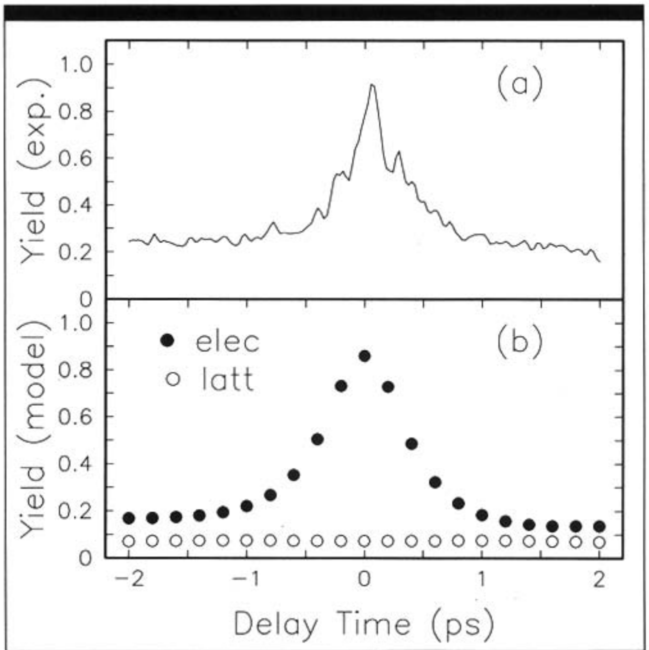
Energy flow between a molecule and a surface is critical in determining the evolution of surface processes such as absorption, desorption, and fragmentation. Energy transfer between an adsorbate and the substrate occurs on a very short time scale, typically in the range of 10^{-15} - 10^{-10} s. Information on these rapid processes has generally been inferred from spectroscopic data. Recently, however, significant progress has been made in probing surface dynamics directly in the time domain. Elegant linear and nonlinear optical techniques have been applied to determine lifetimes[1] and dephasing rates[2] of vibrational excitation in adsorbates.

The nature of energy flow between the substrate and a molecule in the process of leaving the surface—a prototypic surface reaction—has been the object of study by our group.[3,4] Real-time measurements with subpicosecond laser pulses have permitted desorption to be examined on a time scale approaching that of a single molecule-surface vibration.[4] This was accomplished by means of a correlation scheme in which the total desorption yield is determined as a function of the separation between two subpicosecond excitation pulses. Part (a) of the figure displays results for the model system of nitric oxide (NO) molecules adsorbed on a Pd(111) surface.



TWO-PULSE CORRELATION TRACES. THE DESORPTION YIELD IS PLOTTED AS A FUNCTION OF THE TEMPORAL SEPARATION OF THE PULSES. (a) EXPERIMENTAL DATA FOR NO DESORBED FROM PD(111) BY 400 FS PULSES OF 620 NM RADIATION. (b) MODEL CALCULATION ASSUMING FULL EQUILIBRIUM WITH THE SUBSTRATE ELECTRONIC TEMPERATURE (FILLED SYMBOLS) AND THE LATTICE TEMPERATURE (OPEN SYMBOLS). (AFTER REF. 4).

The width of the correlation trace indicates that the desorption process occurs within 1 ps. This extremely short time scale has important implications for one of the long standing issues concerning molecule-surface interactions: the relative importance of electronic and lattice