Session 8

Posters:

Broadband Absorption Control of an Infrared Radiation using Subwavelength Metal Structures

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The use of absorbing films was found to be crucial for applications such as microbolometeric and pyroelectric cameras, or thermal detectors. Furthermore, a careful design of such films is important for solar cells or broadband absorbing filters. When referring to the designed absorbing material, several methods are considered. One method is termed the black metal absorber. This absorber uses a granular metal thin film with statistical distribution of grain diameters. The process of forming such an absorber is not repetitive. Another method is the thin metallic film in which the film is placed in a resonator configuration in order to achieve high absorption. The required thickness of such films is on the order of a few nano meters, thus, fabricating a uniform thin absorber is difficult, not repetitive and suffers from adhesion and oxidation problems.

In this work we propose using a two-dimensional subwavelength periodic structure embedded in a thin metal film, forming a metamaterial absorbing layer. By varying the structure parameters, e.g. period, fill factor, thickness or shape, we can control the optical properties, such as the refractive index, n and the absorption coefficient, k, and tailor a thicker absorbing layer with optimal properties for the required absorption. The optimal subwavelength structure upon a NiCr film (4 *micron* period, 30*nm* thickness and fill factor of 0.5) was realized and its optical properties were measured for the spectral range of 8-12*micron*. A resonator configuration, which was calculated using the measured subwavelength structure's properties, manifests a broadband and broad angle absorption. Such an absorber can be designed for any desired spectral range. Furthermore, space-variant manipulation of absorption can be applied using a single mask photolithography, simply by locally changing the grating structure.

Optical waveguide fabrication using Fast Sol-Gel method

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Abstract

In this work we present a method for fabrication of embedded waveguides using a class of Organically Modified Silicates (ORMOSILS) with low organic residuals and glass like properties. The manufacturing of the ORMOSILS was done by a fast sol-gel method. This method allows for preparation of materials with finely controlled optical and mechanical properties. Optical waveguides with widths and thickness ranges from a few micrometers up to hundreds of micrometers were fabricated. They were prepared using clad and core layers with tailored refractive indices over a wide range. The optical and mechanical performances of such waveguides are currently under investigation.

Manipulation of the Pancharatnam phase in vectorial vortices

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Singularities in scalar wave fields appear at points or along lines where the phase or the amplitude of the wave is either undefined or changes abruptly. An important type of singularity is the scalar vortex. A scalar vortex occurs where the phase of the scalar wave has a spiral structure around a singular point in the field. Until now, research had focused mainly on this type of singularity. However, if we allow the polarization to be space varying, vectorial vortices can be generated. A vectorial vortex occurs around a point where a scalar vortex is centered in at least one of the scalar components of the vectorial wave field. Vectorial vortices can be found at the center of vectorial Bessel beams as well as at the center of a recently proposed phenomenon – rotating vectorial vortices. It is expected that vectorial vortices will find application in advanced optical schemes such as phase mask coronagraphy, particle acceleration, and the tight focusing of light beams.

We present experimental study and analysis of linearly polarized vectorial vortices by use of geometric phase elements. It is argued that the Pancharatnam phase is a prominent structural feature of these fields, where the Pancharatnam phase is the argument of the inner product of distinctly polarized waves. We show that linearly polarized vectorial vortices that have no Pancharatnam phase are stable upon propagation and have no angular momentum. However, if a Pancharatnam phase is present, then the linearly polarized vectorial vortices have orbital angular momentum and collapse upon propagation. The vectorial vortices are achieved by use of discretely oriented space-variant subwavelength gratings. These devices employ a geometric Pancharatnam phase that results from space-variant polarization state manipulation. The structure and properties of linearly polarized vectorial vortices as well as their design and fabrication are reviewed. The gratings were realized on GaAs wafers and illuminated by CO_2 laser radiation of 10.6 micron wavelength. The experimental demonstration verifies the theoretical analysis of the vectorial vortices generated by these space-variant subwavelength gratings. This verification is achieved by measuring the full polarization state at the immediate outlet of the devices, and at their Fraunhofer diffraction.

SIMULATION OF THE ETCHING PROCESS AND THE BI-CONTINUITY CHECK IN THE FABRICATION OF PHOTONIC CRYSTALS

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Using the fast marching method, we make computer simulations of the etching process. Such simulations are especially important for the successful fabrication of microstructures, in particular photonic crystals, from photosensitive materials without a well-defined threshold. Furthermore, we develop a technique for the computer check of the bi-continuity of photonic crystals made by holographic lithography. The disconnected regions are subsequently removed from the calculations of the optical properties.

SEARCHING FOR THE LARGEST PHOTONIC CRYSTAL BAND-GAP STRUCTURE MADE BY THE 4-LASER-BEAM LITHOGRAPHY TECHNIQUE.

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We are using a genetic algorithm to systematically search for the three-dimensional photonic crystals structures exhibiting the largest available band-gap. The optimization procedure searches for the most accurate set of intensity parameters of four laser beams required in the fabrication of three-dimensional photonic crystals obtained through holographic lithography. In this approach, we perform the Fourier transform of the local inverse dielectric susceptibility on the crystal lattice. This allows us to express the Maxwell's equations in the reciprocal space making the calculation of the band-gap fast enough to perform the optimization. Starting from an arbitrary ensemble of generated photonic crystals with negligible or inexistent band-gaps, our optimization method succeeds to exhibit a complete photonic band gap with a better gap/midgap ratio than some actually designed structures.

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OPTICAL PROPERTIES OF POLARIZATION DEPENDENT GEOMETRIC LENS WITH PARTIALLY POLARIZED LIGHT

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The behavior of geometrical phase elements illuminated with partially polarized monochromatic beams is being theoretically as well as experimentally investigated [1,2]. The element discussed in this paper is composed of wave plates with π-retardation and space-variant orientation angle [3,4]. We found that a beam emerging from such an element comprises two polarization orders of right and left-handed circularly polarized states with conjugate geometrical phase modification. This phase equals twice the orientation angle of the space-variant wave plate comprising the element [1]. Apart from the two polarization orders, the emerging beam coherence polarization matrix comprises a matrix termed as the vectorial interference matrix. This matrix contains the information concerning the correlation between the two orthogonal circularly polarized portions of the incident beam. We measure this correlation by a simple interference experiment. Furthermore, we found that the equivalent mutual intensity of the emerging beam is being modulated according to the geometrical phase induced by the element. Other interesting phenomena along propagation will be discussed theoretically and experimentally demonstrated. We demonstrate experimentally our analysis by using a spherical geometrical phase element, which is realized by use of space-variant subwavelength grating and illuminated with a CO_2 laser radiation of 10.6μm wavelength.

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NANOTECHNOLOGY BASED OPTICAL POWER CONTROL DEVICES

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Optical technology plays an increasingly important role in numerous applications areas like communications, information processing, and data storage as well as digital photography and much more. The need of optical power controlling and regulating implies not only to sophisticate communication systems but also to everyday cameras and even to a common car rearview mirror. Regulating optical power levels within various systems requires today an electronic feedback control or after data processing, which introduce complex and expensive systems. We explore the unique capabilities and advantages of nanotechnology in developing next generation non-linear components and devices to control and regulate optical power in a passive way.

We report on passive optical power control devices based on a range of photonic nanostructures, including mainly nanostructures for spatial field localization to enhance optical nonlinearities. These nonlinearities facilitate the invention of the optical fuse, optical limiter and wideband protection filter as well as on-chip system integration through compatible nanostructure materials and fabrication processes. We present our main controlling mechanism of blocking and limiting and their nanotechnologies origin. We introduce several generic optical power control devices such as optical fuse, optical limiter and wideband protection filter. Finally, further applications such as optical power regulating for cameras, car rearview mirror and house windows are discussed.

DESIGN, FABRICATION AND CHARACTERIZATION OF THERMALLY EVAPORATED PHOTONIC CRYSTAL MIRRORS

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We have designed and fabricated omnidirectional mirrors based on 1D photonic crystals made of chalcogenide and cryolite using thermal evaporation. A two-dimensional mapping that provides a direct, visual signature of the mirrors is proposed. Experimental signatures for different multilayer structures are presented. Finally a mirror with an omnidirectional reflectivity of more than 94% for a general polarization, a TE omnidirectional reflectivity of more than 99%, and a TE reflectivity of more than 99.99% for high incident angles is shown. The surface roughness of the mirrors is less than 5nm.

DIFFRACTION FROM PHOTONIC NANO-STRUCTURES: REFLECTION, POLARIZATION AND INTENSITY MANIPULATION

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Abstract

Among functional devices to control light, optical gratings have played a crucial role until recently. There exists a plethora of grating derived phenomena which strikingly show up on nanometer scale, e.g. enhanced spectral reflection and transmission caused by grating-waveguide and cavity-mode resonance, respectively, antireflection and total absorption that still waits for device applications. We will present overview of an in-house state-of-art toolbox [1] for simulating general grating multilayer. Far-field and near-field characteristics of the nanometer scale structures are calculated and analyzed. The spectral behavior of these characteristics, which displays the above-noted phenomena, will be demonstrated on examples of selected structures. In addition, we will demonstrate that some multilayer-grating structures, when diffracting incident coherent light, may produce giant changes of polarization ellipse, and transform input information on the polarization phase of into a peculiar output diffracted-intensity distribution.

References

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VECTORIAL VORTEX MODE TRANSFORMATION FOR A HOLLOW FIBER USING SUBWAVELENGTH STRUCTURES

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Electromagnetic vectorial modes are characteristic of a specific medium such as hollow fibers, which are tubes with highly reflective inner surfaces. The hollow fiber's air core enables broadband as well as high power transmission. These capabilities make hollow fibers an important tool in mid-infrared (IR) technology, where optical materials are scarce. Today, the structure of the hollow fiber's vectorial modes is well understood. For circular hollow fibers, the low-loss modes are vectorial vortices whose exact structure depends on the reflecting surface's optical properties. The main drawback of hollow fibers is that their low-loss modes are optical vortices having dark central cores. Therefore, coupling linearly or any other uniformly polarized light to the low-loss modes of a hollow fiber requires spatial polarization manipulation. Another drawback is the low focusability that results when the low-loss modes of circular hollow fibers are used. Therefore, the next evolution in hollow fiber technology will require the ability to transform the free-space scalar modes to the vectorial modes of hollow fiber, and vice-versa. Recently, we have demonstrated spatial polarization manipulation by space-variant subwavelength gratings. The optical properties of these devices stem from the geometric Pancharatnam-Berry phase. Thus, they are called Pancharatnam-Berry phase optical elements (PBOEs). PBOEs are compact optical devices with high power durability.[1] We present the transformation of a free space linearly polarized beam to the hollow fiber's azimuthally polarized vectorial mode, and its inverse transformation, by use of GaAs PBOEs.[2] Experimental demonstration is obtained by coupling a linearly polarized 10.6μm wavelength CO_2 laser radiation to a single vectorial mode of a 300μm-diameter hollow metallic fiber. The transformation and excitation of a single vectorial mode is confirmed by full polarization measurement. We also demonstrate that single mode operation and inverse mode transformation produces a linearly polarized bright spot with a high central lobe.

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Electrooptic Dielectric Gratings

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A method for implementing an electrically controlled Bragg grating (ECBG) by the introduction of periodic spatial variations of the composition in paraelectric Perovskites is presented. This method opens the way for a family of electroholographic devices that can be operated at short wavelengths without inflecting optical damage, and can be stored at very high temperatures.

Electroholography (EH) is an optical switching method based on electrical control of the reconstruction process of volume holograms. EH has hitherto been implemented by the voltage controlled photorefractive effect. As such the EH devices were sensitive to two erasure mechanisms: optical erasure during readout and thermal erasure.

We present a new mechanism for constructing ECBGs: The dielectric electrooptic mechanism. Dielectric electrooptic ECBGs are implemented by creating periodic striations produced during the crystal growth process. In these gratings the two erasure mechanisms are obviated. The periodic striations were produced by introducing a periodic modulation to the seed temperature. During operation of the grating the periodic striations induce a spatial modulation of the low frequency dielectric constant by locally modulating the phase transition temperature of the crystal. The application of a uniform electric field produces an induced polarization grating. The latter, through the quadratic electrooptic effect, induces an electrically controlled birefringence grating.

Experimental evidence substantiating the validity of the dielectric electrooptic mechanism including direct imaging of the grating, and measurements of the diffraction efficiency vs. the applied electric field will be presented.

DIFFRACTIVE PLANAR OPTICAL INTERCONNECTS: TEMPERATURE COMPENSATION

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Planar diffractive optical interconnects have many advantages, however, their inherent chromaticity leads to temperature instability due to the wavelength shift of laser diodes' radiation. This shift can be compensated if the optical interconnect is bended in an appropriate direction with curvature proportional to the relative wavelength shift. The bending can be performed by attaching an additional plate to the element with a different thermal expansion coefficient. Theoretical analysis and ray tracing are reported.

ETCHING OF PHOTOSENSITIVE CHALCOGENIDE GLASSES: EXPERIMENTS AND SIMULATIONS

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Arsenic-based chalcogenide glasses are known for their photostructural transformation properties, together with their high refractive index and very low absorption in the infrared. These properties make them very attractive for the creation of micro and nano optical elements for the infra-red, including two and three-dimensional photonic crystals. However a critical element in the fabrication of such devices is the understanding of the etching process of the chalcogenide glasses. We have developed a simulation that mimics the etching behavior of different compositions chalcogenide glasses and compared the simulation results with actual experiments. By analyzing the simple structure of a grating written by interference of two laser beams we characterize the suitability of the chalcogenide glasses as a photosensitive layer for complex structures. Experimental results and the appropriate simulations are presented.

Evanescent Wave Phenomena in TiO_2 Nanoparticles Based Dye Sensitized Solar Cell, as a Promising Way Towards Extremely Efficient Energy Conversion

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Dye sensitized solar cell is a photoelectrochemical cell based on high surface area nanocrystalline TiO_2 film that allows adsorption of dye molecules. Such nanocrystalline film mediated by a redox couple to a counter electrode can show solar conversion efficiency of ~ 11% in the laboratory conditions. These kinds of solar cells are very much attractive due to their simple and low cost preparation compared to the conventional silicon solar cells. However, there are some losses due to a limited life time of free electrons before they are recombined. Regarding to the specific absorption pattern, the most dominant losses are obtain in the red part of the visible spectrum due to low absorption coefficient of the N_3 dye molecule. The red photons are being absorbed far from the current collector so they have less chances to collect and much more chances to recombine.

Using a wave guide solar cell that is based on the evanescent wave phenomena, we are demonstrating the obtained enhanced photocurrent in dye sensitized solar cell. In this approach, we are benefiting from both efficient photon collections throughout the solar spectrum, as well as high electron transport efficiency due to the short distance that the electron has to travel towards the current collector.

OPTICAL THIN FILM ANALYSIS INSTRUMENTATION

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Instrumentation for Optical Thin Film Analysis has included reflectometers, spectrophotometers & ellipsometers, all instruments developed for other fields. Now, a new instrument & methodology, designed from the start for Optical Thin Film Analysis, offers new strengths while it avoids old weaknesses. For example, samples with transparent substrates do not require blackening or roughening to eliminate reflections. The introduction of two broad-band detectors allows measurement of both transmission & reflection spectra in the same place, at the same time. This enables, in turn, an absolute measure of absorption, the ability to determine n (refractive index) without knowing or assuming d (thickness), and the ability to determine d (thickness) without knowing or assuming n (refractive index). The unique ability to determine n, k & d from a single measurement gives the instrument its name: The Aquila nkd.

NEW MICRO-OPTICAL DEVICES BASED ON CHALCOGENIDE PHOTORESISTS

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Micro-lenses and micro-lens arrays can be found in an increasing number of optoelectronic applications. Micro-lens arrays have been fabricated by a variety of techniques, having certain advantages and disadvantages. At the previous Conference we reported our development of a new simple technology for fabrication of spherical and cylindrical micro-lens arrays for the I.R. This technology was based on the use of chalcogenide glassy films, which are simultaneously effective photoresists and very good I.R. optical materials. Mainly binary As_2S_3 and As_2Se_3 chalcogenide photoresists were used in these early experiments. In the present paper a review is presented of our recent achievements in the development of improved micro-lens arrays and also other micro-optical devices. These results were obtained with new three-component As-S-Se chalcogenide photoresists and new efficient amine-based selective developers, which together allowed the realization of soft contrast characteristics when used with a Xe-light source. A grey scale photolithographic process was developed with these new photoresists. The micro-lenses in this case could have essentially increased focal length. Among newly developed micro-optical devices, micro-mirror and micro-prism arrays and Fresnel lenses with a wide variation of parameters.

In this paper, a new approach towards electro-optics technology has been used - adaptive micro-optical devices, particularly, adaptive micro-lens arrays for the infrared range. Recently an adaptive liquid crystal micro-lens array design for the infrared range has been developed and experimental samples have been fabricated and characterized. These new adaptive micro-optical devices are based on a chalcogenide photoresist micro-lens immersed in a nematic liquid crystal to form an electrically controllable focal length.

All fabricated micro-devices were measured using a "Zygo Corporation" micro-interferometer (USA). Parameters and characteristics of several new micro-optical devices are discussed.

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