Opportunities in microstructured photonics

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Summary

The progress in novel light sources, detectors, materials and technology enable new opportunities and challenges for diffractive optics and nanoscale photonics. Important are also analysis tools, such as near-field imaging (SNOM). Only structures that can be characterized can be fabricated.

Opportunities

Diffractive optical elements are components relying on the physical phenomena of diffraction and interference to control the propagation of light. Such elements are usually macroscopically planar microstructures, consisting of features with dimensions from a couple of wavelengths to a few tens of microns and being designed by advanced numerical algorithms based on rigorous diffraction theory. The progress in diffractive optics is closely related to the progress in microfabrication technology. As a result, researchers working in diffractive optics are now exploring structures with features below the wavelength such as resonant grating filters, photonic crystals, plasmonic structures and microcavities [1].

Not only micromachining, but also devices and applications are important factors for the development of new domains. Quantum cascade lasers, for example, are compact light sources working in the mid-infrared (mid-IR) [2]. They are ideal light sources for sensor applications, because most of optical absorption spectral lines associated to the vibrational frequencies of gas molecules take place in the mid-IR domain of the optical spectrum. Mid-IR lasers offer also opportunities for diffractive optics, because the longer wavelength (compared to the visible spectrum) facilitates the fabrication of diffractive structures. Highly efficient binary sub-wavelength structures become attractive and feasible [3].

Characterization with nanometer resolution

In order to understand the fundamental behavior of photonic devices, and to optimize their structure, it is important to measure not only the reflection and transmission properties but also the electromagnetic (EM) field distribution inside the structure, with nanoscale resolution. This information is invisible using conventional optics for observation. Subwavelength-scale variations in the structure of the device and evanescent waves can be observed by scanning near-field microscopy (SNOM) [4]. Of particular interest is the simultaneous amplitude, phase and polarization measurement using heterodyne techniques in order to get full information of the light distribution. Another interesting technique is high-resolution interference microscopy (HRIM), a technique that allows the characterization of the EM-field in the far-field with a spatial accuracy that corresponds to a few nanometers in the object plane [5].

Important is the precise determination of phase singularities in the wave field, which are spatial points within the electromagnetic wave at which the amplitude is zero.

Application to characterize surface waves

Surface electromagnetic waves (SEWs) can be generated and guided by optical microstructures. They are interesting for the realization of integrated systems and for sensor applications. SEWs are waves confined at the interface between two media. The most common SEWs are the surface plasmon polaritons that appear at the interface between a dielectric medium and a metal. SEWs can also be created at the interface of a dielectric multilayer, which has to advantage of quasi-lossless propagation.

An example of such a structure is presented in [6]. The multilayer is in silicon nitride, where varying the nitrogen concentration yields to variations in the refractive index. In addition, a shallow subwavelength polymeric grating is deposited on the top flat interface of the multilayer [4].

A multi-heterodyne scanning near-field microscope (SNOM) is used to perform a detailed analysis of the modes propagating within these two structures (multilayer with and without polymer grating). Using this technique, the amplitudes and phases of the modes excited by two orthogonally polarized input beams can be simultaneously resolved. The flat and corrugated multilayers are illuminated in total internal reflection. The results are shown in Fig. 1.

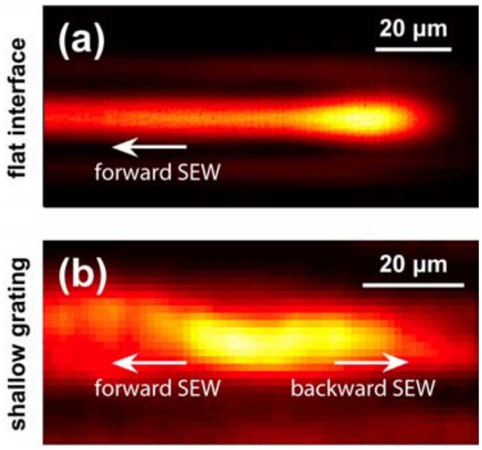

Fig 1 TE-polarized near-field intensity map of surface electromagnetic waves: (a) at the flat interface of a multilayer, (b) at the surface of the some multilayer covered with a subwavelength dielectric grating. In (b), the field is acquired at a band edge.

References

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