Hybrid Plasmonic-dielectric Resonant Waveguide Grating for Diffraction with High Color Purity

B. Gallinet, G. Quaranta, O.J.F. Martin •

A hybrid dielectric-plasmonic waveguide grating enabling highly color-selective first order diffraction is reported. This work shows the promising use of hybrid structures for designing highly integrated optical devices such as spectrometers or optical security features.

Plasmonic waveguides and resonant waveguide gratings have been a subject of extensive research for a few decades. In particular, filtering has been achieved thanks to the extraordinary optical transmission effect, implemented for imaging and spectral imaging devices. In parallel, resonant waveguide gratings have been used for their filtering and coupling properties into thin film waveguides. The search for full control of polarization, amplitude and phase of the electromagnetic field from planar surfaces remains of high interest, especially for the development of highly integrated photonic systems. Here, we report on a hybrid dielectric-plasmonic resonant waveguide grating which enables highly color-selective first order diffraction in a multimode light guide.

The system investigated in this work is sketched in Figure 1a. A periodic sub-wavelength grating is patterned on a glass substrate and coated with a silver film and silica. The silver layer supports a surface plasmon mode, which is altered by the presence of the thin silica film into a hybrid dielectric waveguide-plasmon mode. At a given wavelength, the incident light is diffracted by the grating and coupled into the waveguide mode. It is released in the substrate by means of a Fano-like interference, as shown in the rigorous coupled wave analysis calculations in Figure 1b.

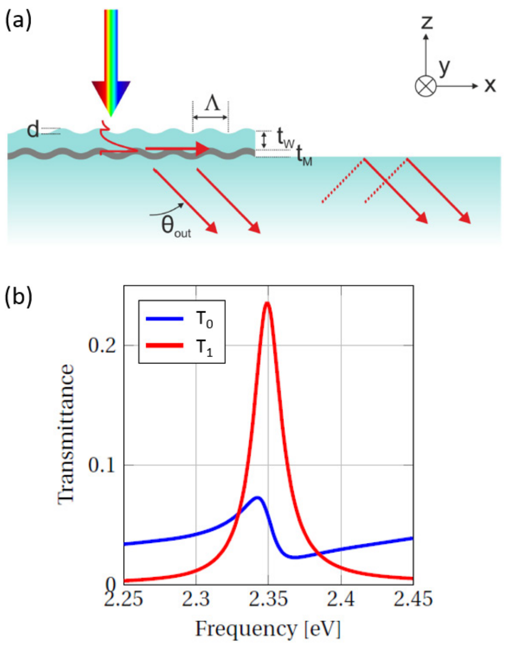

Figure 1: (a) Wavelength selective coupling in a highly multimode light guide using a hybrid plasmonic-dielectric resonant waveguide grating. The incident light is coupled by grating diffraction into a hybrid surface plasmon-dielectric waveguide mode and released into the substrate. (b) The interference between the direct diffracted light and the light coupled into a waveguide mode yields a Fano interference in the zeroth and first order of diffraction.

In the first transmitted order, an isolated peak at the resonance wavelength with a very weak amplitude at other wavelengths is observed, a signature of the resonance effect. In order to achieve high color purity, the coupling from free space to the waveguide should be small, which implies a low grating corrugation depth. The grating depth and silver coating thickness are chosen to achieve the critical coupling condition, thus optimizing the diffraction amplitude in the first order of diffraction while minimizing the contribution of the zeroth order, a potential source of noise.

The grating fabrication has been performed with electron beam lithography into a silicon wafer, which has been used as a replication template for UV-nanoimprinted lithography on glass. After silver and silica coating, the first order diffraction efficiency in the substrate has been measured as a function of the wavelength and the incidence angle (Figure 2). Figures 2b and 2c show the outcoupling angle and amplitude corresponding to the diffracted peak, respectively. As the incidence angle is varied, the resonance wavelength is shifted.

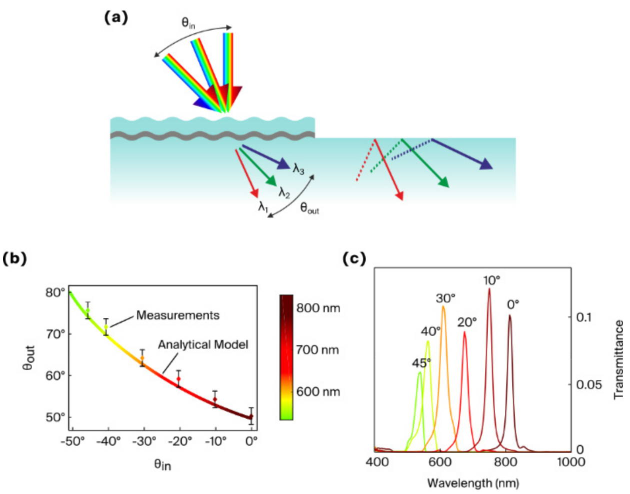

Figure 2: (a) Diffracted angle and wavelength related to the diffraction peak as a function of dielectric waveguide thickness and the period. (b-c) Separation of incident white light with a large range of incidence angles into a set of quasi-monochromatic diffracted beams, comparison between measurements and analytical model.

In particular, a white light beam with large angle divergence would be transformed into a set of angularly separated quasi-monochromatic light beams using this device (Figure 2a). In fact, both functionalities of angular and spectral filtering are performed using a single sub-micrometer interface. The diffracted light can be coupled into a light guide or directly harvested by a photodiode array. Applications in highly compact spectrometers or spectral imagers are foreseen. Alternatively, optical security features with original color effects could be designed using this approach.

• Ecole Polytechnique Fédérale de Lausanne