All-Optical Switching at the Fano Resonances of Plasmonic and Non-Plasmonic Gratings

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Abstract: We discuss all-optical switching at the Fano resonances of nonlinear, dielectric gratings with extremely narrow slits and ultra-thin, metallic (plasmonic) gratings embedded in a nonlinear material.
OCIS codes (050.6624) Subwavelength structures, (190.1450) Bistability, (240.6680) Surface Plasmons.

All-optical switching devices are based on the optical Kerr-effect in which the local refractive index of the material is linearly modified with the intensity of the field. Fano resonances [1] originate in any quantum or classical system that admits discrete states coupled with continuum states. In our case, Fano resonances can be simply obtained by using a subwavelength grating, as the ones shown in Fig.1. In Fig.1(a) is shown a nonlinear, dielectric grating made of a chalcogenide glass (As_2S_3) with extremely narrow slits, in Fig.1(b) is shown the same kind of grating whose slits are now filled with a host medium, and in Fig.1(c) is shown an ultrathin (~10nm), metallic, grating embedded in As_2S_3.

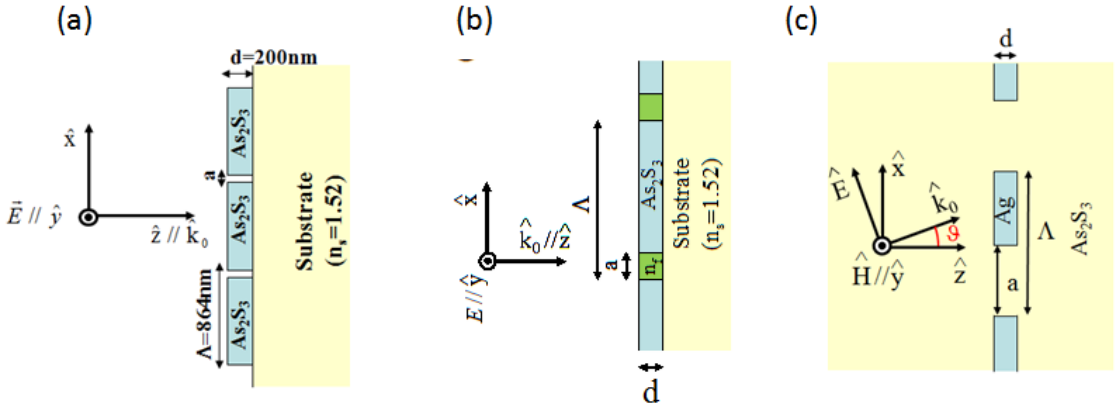

Figure 1: (a) As_2S_3 grating, thickness *d*=200nm, period Λ=864nm and slit aperture *a*, grown on a glass substrate with n_s=1.52. We consider an electromagnetic wave, TE-polarized at normal incidence. (b) Same as in (a) except that now the slits are filled with a generic material of refractive index n_f. (c) Ag grating having thickness *d=10nm*, period Λ and slit aperture *a*, embedded in As_2S_3. We consider an electromagnetic wave, TM-polarized incident on the grating at a generic angle ϑ.

For the case of Fig1(a) we find that when the grating possesses extremely narrow slits (channels ranging from a~10nm to a~40nm) the remarkable local field enhancement available in these situations [1] at the Fano resonances conspires to yield low-threshold switching intensities (~50MW/cm^2) at telecommunication wavelengths for extremely thin (d~200nm) gratings when a realistic value of the As_2S_3 cubic nonlinearity is used. The threshold intensities can be further lowered if, as in Fig.1(b), the slits are filled with a generic material whose refractive index is close to the refractive index of the nonlinear material so to generate the so-called "mode-matched Fano resonances" [2]. In Fig.1(c) it is instead analyzed a plasmonic metallic grating [3] where ultra-narrow, Fano-like resonances are generated by the coupling of long range surface plasmons with ultrathin (~10nm), metallic, sub-wavelength gratings embedded in a nonlinear, cubic material to obtain all-optical switching at telecommunication wavelengths for input intensities compatible with the photo-darkening threshold of the chalcogenide glass.

References

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