Optical Limiting and Transient Grating in VO_2 Thin Multilayers

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Lasers find important applications in a variety of fields, ranging from spectroscopy to manufacturing. However, exposure to high-intensity radiation can be harmful to human eyes and sensitive detectors [1]. Attenuators and filters that are usually employed for safety applications have a flat response with increasing intensity. Hence, low-intensity, non-harmful sources are completely obscured, hampering procedures such as laser alignment. A possible solution is provided by dynamic devices whose optical transmittivity depends on the intensity of the impinging radiation [2]. In this regard, phase change materials (PCMs) allow high transmittance at low intensities and optical limiting at high incident intensities [3]. In particular, Vanadium Dioxide (VO_2) exhibits a dielectric-to-metal phase transition at around 70°C, which can be triggered thermally, electrically, or optically [4].

Here we propose a self-activating multilayer structure featuring VO_2 for the optical limiting of near-infrared radiation and study its response by employing opto-thermal numerical simulations. By employing transient finite elements simulations of the dynamical process [5], we demonstrate the device switching and the recovery to its initial state. Furthermore, we study the excitation of a flat device with a transient grating pump, inducing a volatile phase transition in some regions of the VO_2 film, with a periodic profile. This introduces a transient subwavelength periodic pattern, switching on the transient light diffusion through the first diffraction order. Our theoretical predictions are confirmed by experimental findings. The proposed flat multilayer design features easier fabrication compared to nanostructured metasurfaces, and fast switching response with a switch-off time of 10 ps and recovery time of 5 ns.

[1] Yaniv Barkana and Michael Belkin, *Laser Eye Injuries*, Survey of Ophthalmology **44**, 6 (2000)

[2] L. Carletti et al., *Reconfigurable Nonlinear Response of Dielectric and Semiconductor Metasurfaces*, De Gruyter Nanophotonics (2021)

[3] C. Wan et al., *Limiting Optical Diodes Enabled by the Phase Transition of Vanadium Dioxide*, ACS Photon. **5**, 7 (2018)

[4] C. Wan et al., *On the Optical Properties of Thin-Film Vanadium Dioxide from the Visible to the Far Infrared*, Annalen Der Physik, 1900188 (2019)

[5] M. Gandolfi et al., *Ultrafast Photoacoustic Nanometrology of InAs Nanowires Mechanical Properties*, Jour. of Phys Chem. C, **126**, 636 (2022)