IOP Publishing Journal of Optics
J. Opt. 18 (2016) 125008 (9pp) doi:10.1088/2040-8978/18/12/125008

Anomalous retroreflection from nanoporous materials as backscattering by 'dark' and 'bright' modes

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Received 10 July 2016, revised 11 October 2016
Accepted for publication 12 October 2016
Published 22 November 2016

Abstract

In this paper the mechanisms of previously experimentally observed anomalous retroreflection in a strongly absorbing nanostructured medium are explained by using 'dark' and 'bright' modes. The observed regularities are analyzed for both s-polarized and p-polarized incident radiation with respect to the contribution from 'dark' and 'bright' modes and the influence of the absorption on the scattering indicatrix. The theoretical consideration provides explanation not only for the retroreflection itself but explains also correlations with absorption and differences for retroreflection efficiency for s- and p-polarized radiation. The possibilities of using 'dark modes' for processing and transmission of energy are discussed.

Keywords: nanostructured medium, retroreflection, electromagnetic field, scattering indicatrix, longitudinal mode, transverse mode, backscattering

(Some figures may appear in colour only in the online journal)

1. Introduction

Over the last two decades, porosity opened new perspectives to modify physical properties of semiconductor compounds in a controlled fashion. In particular, persistent photoconductivity [1], optical phonon engineering [2, 3], optical anisotropy [4] and enhanced terahertz emission [5, 6] have been reported for porous III–V compounds. Besides, ordered arrays of metal nanotubes embedded in porous semiconductor matrices have been developed for electronic and photonic applications [7, 8].

Anomalous retroreflection apparent by the naked eye with daylight illumination has been recently observed from a fishnet nanoporous strongly absorbing semiconductor material [9]. The retroreflection features a half-cone about 0.35 rad along with diffusive specular reflection for all angles of incidence and it measures 12% in the backward direction with respect to a white scattering etalon. It was suggested that the observed phenomenon can be classified neither as coherent backscattering nor as Anderson localization of light, since strong absorption inhibits multiple reflection, the necessary prerequisite for coherent backscattering and Anderson localization. Pronounced correlation of the phenomenon with strong absorption has been further established experimentally [10].

In this paper, we propose an explanation of the mechanism of anomalous retroreflection observed in [9, 10] on the basis of formation of both 'dark' and 'bright' modes in a nanoporous strongly absorbing semiconductor material. The proposed model explains also the observed peculiarities of the anomalous retroreflection, namely correlation with strong absoprtion and differences for s- and p-polarizations of incident radiation.

