Structural topological optimization of a 3-D nano-aperture based on the phase field method

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Abstract

Nano-apertures are used in many fields in which high optical resolution is required, such as lithography, optical data storage, and the Vertical-Cavity Surface Emitting Laser (VCSEL). However, as a result of the diffraction limit of the opening of the nanoscale incidence's wavelength, the output becomes extremely weak. This problem can be solved by using the surface plasmon effect occurring under a particular resonance condition. In this study, a 3-D nano-aperture topology optimization design, made of a metal material and in a wavelength region equal to or shorter than infrared, was carried out. The optimal material distribution within the domain of this fixed design was deduced through wave propagation analysis, taking into account the surface plasmon effect. Additionally, to achieve a simple shape within nanostructure production characteristics, double well potential was combined with the reaction diffusion update scheme used in existing phase field methodology. This combined update scheme is not only able to control the complexity of the shape via the diffusion coefficient, but also effectively reduces the commonly occurring problem of grayscale. Thus, this study proposes the new, optimized 3-D nano-aperture design due to its enhanced transmission efficiency when compared to designs suggested in previous research.

Keywords: Topology optimization, Electromagnetic field, Phase field method, Finite element analysis, Nano-aperture.

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