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Design of a far-infrared lens based on topology optimization

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Abstract

In recent years, the use of far-infrared cameras for night-time security applications and in automotive pedestrian detection systems has been extensively promoted [1]. Conventional pedestrian detection sensors typically use near-infrared cameras or laser radar, but far-infrared cameras offer several advantages, such as the ability to directly detect heat radiated by the human body without the need for a separate infrared source, and the possibility of developing simpler systems. Moreover, far-infrared systems are not affected by fog or rain. A far-infrared camera is composed of a lens and a sensor, but basic performances such as the angle of view, resolution, and so on, are determined by the design of the lens. Despite the use of various aids when designing lenses, trial and error approaches and dependence on the experience and intuition of skilled designers are still factors, hence the desirability of a systematic method for lens design. In such case, topology optimization is useful. Since 1988, when the concept of topology optimization was first proposed by Bendsøe and Kikuchi [2], a broad spectrum of topology optimization studies have been carried out, mainly for structural design problems such as maximum stiffness problems and compliant mechanism design problems. More recently, topology optimization techniques have been extended to electromagnetic wave propagation problems. Chung et al. [3] carried out studies on the design of microlenses, using topology optimization based on a density method, in which lenses were optimized for relatively near focal points lying in the fixed design domain. However, their method can only be applied to problems with focal points in the design domain, and does not take viewing angles or resolutions into account.

In this study, we propose a new far-infrared lens design method using topology optimization in which the directivity in the far-field is optimized by using the electric field distribution in the near-field, which enables the optimal design of lenses given only a desired directivity pattern. Here, we optimized a light collimator, to verify the effectiveness of the proposed method. Finally, numerical examples of an optimally designed far-infrared lens structure are presented.

References

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