A Light-Eye Technology (LeyeT) for Biomedical Applications

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1. Abstract

Though the biomedical technologies for diagnostic and treatment have been rapidly developed, the early detection and treatment of life-threatening major diseases remained crucial and required further researches and investigations, especially for cancer diseases. Cancer diseases, the leading causes of human deaths worldwide, are mostly diagnosed in the middle or late stages. Therefore, many nanotechnologies have been studied for early detection and diagnosis of cancer diseases in the fields of biotechnology and bioengineering. In this paper, a novel Light-Eye Technology (LeyeT) is developed to deliver a generalized light source for biomedical applications such as early inspections of single molecule or cell of cancer diseases. Multiple high-directionality single-Watt light-emitting diodes (LED) in the colors of red, green, blue, royal blue, cyan, warm white and cold white are packed together and integrated to deliver a wide-bandwidth white light source. The working currents and voltages are optimized to maximize the uniformity of the mixed light source. The light spectrums of the LED are measured experimentally using an integrated sphere with a spectrometer meter. The light mixing is first simulated numerically using Monte Carlo ray tracing and compared with experiment results. The errors between the numerical and experimental results are less than 10%. Furthermore, the joule heat distribution of the integrated light system is simulated numerically using the commercial software of finite element analyses (FEA). The heat spreader and fins are designed to provide forced cooling of the integrated system to avoid the effects of optical decay.

The integration of LED optical design, light spectrum, heat conduction and convection is a complex multidisciplinary design optimization (MDO) problem. Though each component, such as single LED channel in the integrated light source, is designed and built independently, the local performances are mutually coupled with each other. The system is, therefore, decomposed into several subsystems. Two different formulations of objective functions are investigated: weighted-sum objective functions and disciplinary objective functions. The weighted-sum objective functions are defined to maximize the uniformity of LED color mixing, the intensity of the mixed light source and system reliability simultaneously. On the other hand, three distinct objective functions are assigned to different disciplines. The subsystems of optical design and light mixing maximize the uniformity and intensity of the integrated light source, while the ones of heat transfer maximize the system reliability. In both formulations, the dependency of the design variables and the local constraint functions is investigated using the Gradient-based Transformation Method (GTM). The local optimums of the objective variables are efficiently found due to the monotonic characteristics in GTM while the feasibilities of the non-objective variables are evaluated to meet the subsystem requirements. The GTM is integrated with the aforementioned simulations and experiments to find the optimal designs of the generalized light sources in LeyeT. Both objective formulations deliver applicable solutions. Weighted-sum formulations are more flexible but may deliver too conservative or aggressive results. In the end, LeyeT is expected to deliver a complete platform for early detection and diagnosis of cancer diseases in biomedical and bioengineering applications.

[496 words]

2. Keywords: Light-Eye Technology (LeyeT); LED light mixing; Monte Carlo ray tracing; multidisciplinary design optimization; Gradient-based Transformation Method (GTM).