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A LOW-COST HIGH-FLUX SOLAR SIMULATOR BASED ON XENON SEARCHLIGHT TECHNOLOGY

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ABSTRACT

Solar simulators are essential tools for the development and characterization of solar energy conversion devices including photovoltaics cells and solar thermal collectors. Solar simulators may be broadly categorized according to the achievable irradiance, with low-flux simulators (LFSS) achieving irradiance levels in range of one to several “suns” (1 sun = l kW/m^2), and high-flux solar simulators (HFSS) which may achieve peak irradiance levels up to several tens of thousands of suns. In this work, we present the design, implementation, and characterization of an adaptable low-cost solar simulator which can achieve both low-flux and high-flux configurations. The simulator is based on a commercial xenon searchlight lamphouse which comprises a 1 kW short-arc xenon lamp with an integrated parabolic back reflector. In its basic form, the lamphouse outputs a nominally 250-mm-diameter collimated beam with an average irradiance of approximately 1 sun. Placing a Fresnel lens in front of the lamphouse as a condensing optic transforms the setup into a high-flux configuration, achieving peak fluxes exceeding 2000 suns. The irradiance can be further fine tuned by electronic control of the lamp’s power level in addition to precise adjustment of the lamp-to-device distance via motorized position control. A novel irradiance self-calibrating mapping system based on a pyranometer, Lambertian target, and grayscale camera was implemented to characterize key performance metrics including average irradiance, peak irradiance, radiant power output, and efficiency. In LFSS mode, the simulator achieves an average irradiance of 1.1 suns and 2.8 suns, for low and high lamp power setting respectively, over a 300-mm-diameter spot area. In HFSS mode, the simulator achieves a peak irradiance of 2348 suns, with an average irradiance >1000 suns over a 1-cm-diameter spot area. The overall electricity to radiant power conversion efficiency of the system ranges from 13% to 22% depending on the configuration and lamp power level. This study offers a promising approach to develop high-performance solar simulators from commercially available components, thus enabling cost-effective advanced solar research tools.