Spectrum splitting using multi-layer sub-wavelength high-index-contrast grating for solar energy harvesting efficiency improvement

Yuhan Yao, He Liu, Shujin Huang, Yifei Wang and Wei Wu*
Department of Electrical Engineering, University of Southern California, Los Angeles, CA 90089
* wu.w@usc.edu

There have been huge progresses in solar cell efficiency in recent years[1]. A principal reason for the limited efficiency is the broad solar spectrum. Parallel spectrum splitting to improve solar conversion efficiency has been reported[2], but issues including bulky setups and high costs greatly limit their industry utilization.

Here, we report our progress of developing a parallel spectrum splitting system (Figure 1A) for high-efficiency solar energy conversion, which is based on dispersive mirror composed of multi-layer sub-wavelength high-index-contrast gratings (HCG) (Figure 1B). Recently, the broadband reflection in HCG structures has been observed both theoretically and experimentally[3]. It has been incorporated in vertical-cavity surface-emitting lasers (VCSEL) as the reflective optics[4]. In addition, HCG's ability to control the phase of reflected light beam has led to other interesting applications[5]. However, most of the applications operate in limited range of wavelength. HCG-based structures capable of operating in the entire solar spectrum are needed.

By stacking multiple layers of two-dimensional HCGs with different pitches, our dispersive mirror can operate in much broader spectrum. Moreover, the mirror can reflectively direct light into different angles according to wavelengths, in a way of packaging all HCG layers subsequently in different tilting angles. Our numerical study results (Figure 2A) show that it can provide great reflectance over most solar spectrum.

Our design for the dispersive mirror can be fabricated using nanoimprint lithography (NIL)[6] in a large area and at a low cost (Figure 2B). Moreover, our proposed system features an easy integration with existing concentrator photovoltaic (CPV) setup[7], so it has the potential to be accepted widely by the industry to improve solar energy conversion efficiency. More fabrication details and optical characterizations will be presented in the conference.

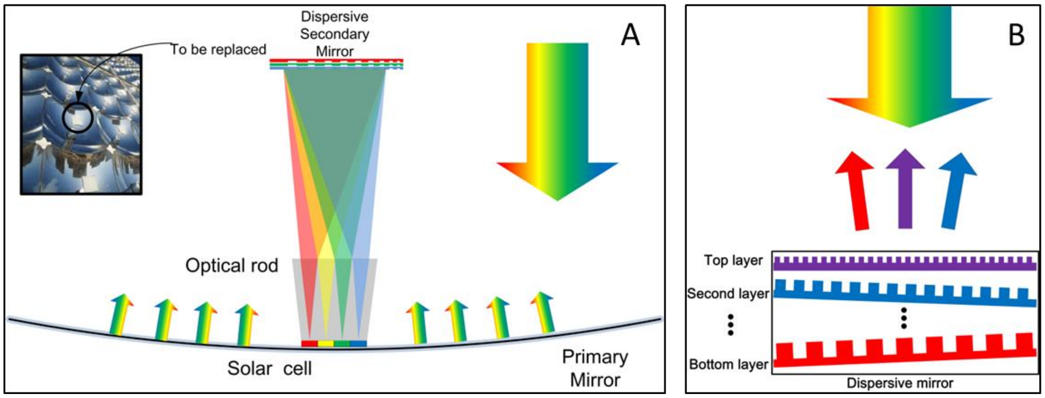

Figure 1: (A) Parallel spectrum splitting system compatible for CPV setup. (B) Schematic of our multi-layer HCG dispersive mirror.

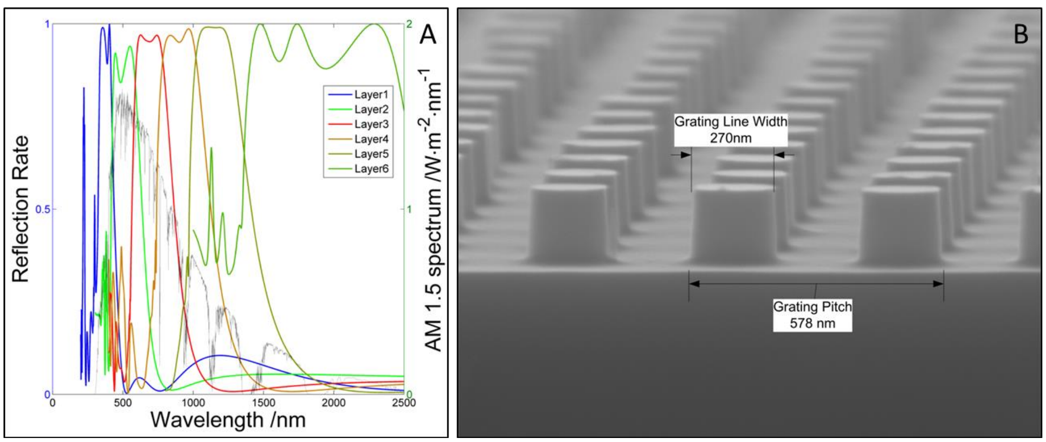

Figure 2: (A) Numerical result which shows the reflection curve of each HCG layer. (B) SEM photo of one of HCG layers with 578 nm pitch fabricated using NIL.

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