A modal approach to optimize light trapping in ultrathin solar cells

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Ultrathin light absorbers hold many promises for photovoltaics, especially high-efficiency concepts like hot-carrier solar cells. However, they require the implementation of light trapping schemes to maintain high broadband absorption[1]. To do so, we can introduce a diffraction grating that couples incident light with resonant modes in the absorber. This grating must be optimized to maximize absorption, which typically involves extensive electromagnetic simulations. This approach has led to significant results[2,3], albeit with several limitations. Beyond being time-consuming, it only explores a tiny subset of all possible gratings, and it does not explain why a given design is better than another.

To address these issues, we have developed a modal approach in which we consider the resonant modes in a device as the building blocks of broadband absorption. We propose a simple analytical method to calculate approximately the frequency and absorption losses of these resonant modes. Then, we introduce a diffraction grating as a perturbation, which scatters the incident light without influencing the properties of the modes. With this method, we can accurately predict, in low-absorption materials, several characteristics of a multi-resonant absorption spectrum, including the frequency and width of the absorption peaks as well as the electromagnetic field at these peak frequencies (Figure 1). We also highlight the need to break some of the grating symmetries to increase the number of modes. Finally, we explain how this method could be applied to fast and comprehensive optimization of grating designs for ultrathin solar cells.

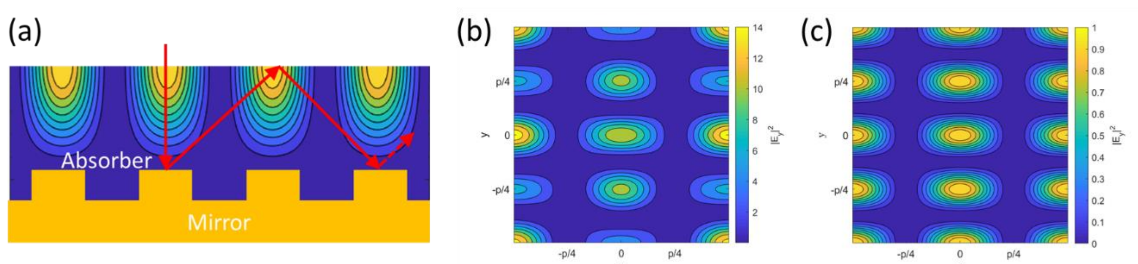

Figure 1: (a) We consider an ultrathin light absorber (100 nm) on top of a perfect mirror patterned with a 2D periodic grating. The grating can diffract incident light so that it can couple with resonant modes in the absorber. (b) Top view of the electric field intensity map obtained from a RCWA simulation at an absorption peak. (c) The same map as expected from our analytical model for the corresponding resonant mode. The shapes of (b) and (c) are in perfect agreement.

References:

1 Giteau, M. *et al. EPJ Photovolt.* 10, 1 (2019)
2 Massiot, I. *et al. ACS Photonics* 1, 878–884 (2014)
3 Chen, H.-L. *et al. Nature Energy* 4, 761–767 (2019)