Photon Management in Two-dimensional Disordered Media

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Given the ever-growing demand of green energy, many efforts of the industrialized societies are spent in the development of new technologies for renewable energy. In particular, the nanophotonic community has been producing a great deal of alternative strategies to improve the performance of various photovoltaic technologies. Thin-film solar cells are the current state-of-the-art in solar energy technologies, made out of different, sometimes very expensive, materials (e.g. CdTe, CIGS), for which nanophotonics is particularly suited for improving their performance. These so-called third-generation solar cells generally have high quantum efficiency, thereby yielding more electric current per absorbed photon. However, given the small thickness of the film (less than 1 $\mu$m), the probability for a photon to be absorbed is low, yielding a small net production of electric current, in spite of high quantum efficiencies. Nanophotonics aims to find reliable solutions to enhance the absorption of light in thin films. Engineering the absorbing material at the nanoscale indeed leads to interferences that can significantly increase light absorption [1,2].

In this talk, we will show how a novel photonic architecture based on engineered-disordered structures can be used to improve the absorption of a realistic thin-film solar cell. It has been theoretically shown that the introduction of a two-dimensional random structure yields to disordered modes which can be used to coherently ‘trap’ light in the film, increasing the probability of light to be absorbed in an extraordinary broad range of wavelengths [3]. Subsequently, experimental evidence of this broadband absorption enhancement as been reported [4]. Furthermore, the introduction of correlations in the random distribution of holes yields a strong reshaping of the absorption spectrum occurs, with an absorption enhancement comparable to its deterministic (periodic) counterpart. We will discuss the contribution of coherent light trapping to the absorption enhancement as the material absorptions is varied in a technologically relevant range. Also, we will show theoretical calculations of realistic solar cells based on thin technology employing different materials, showing that disordered structures obtain comparable, if not better, performances than the periodic equivalent.

This new nanophotonic architecture can be applied to many of the state-of-the-art third-generation photovoltaic technologies, since it is not affected by the kind of material employed. Given its random nature, the structure is inherently ‘optically robust’ and does not require a high degree of fabrication accuracy, crucial point for large scale production. In particular, the introduction of correlations in the disordered distribution of holes is extremely promising in terms of performances for future implementation in realist solar cells.

References
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