Mathematical Characterization of Improved Efficiency of Solar Energy Collection Based on Quantum Biology

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Recent advances in the field of quantum biology have revealed that quantum phenomena may play a significant role in several biological processes, including photosynthesis. Recent research suggests that quantum interference of excitons within photosynthetic pigments allows for a near 100% rate of excitation transfer to the reaction center of pigment molecules. This phenomenon has the potential to revolutionize the solar industry if it can be harnessed within synthetic photovoltaic (PV) cells. The objective of this research is to determine the maximum theoretical efficiency of a PV cell designed to harness light energy using pigment-like structures to generate excitations while avoiding recombination of electrons and holes. Modelling our calculation strategy on the 1961 Shockley-Queisser Limit, we used the solar irradiance spectrum and the bacteriochlorophyll A absorption spectrum to calculate the ultimate efficiency factor, as well as the fill factor, of the nature-based PV cell. Ultimately, we determined that both the efficiency considering spectral losses alone, and maximum theoretical efficiency taking impedance matching into account, were significantly higher than the corresponding values for standard PV cells. The use of quantum interference within nature-based photovoltaics almost doubles the overall theoretical efficiency of the cell. Implementation of this technology could drive energy costs down while augmenting power output from solar cells, significantly increasing global reliance on the burning of fossil fuels.