Design Optimization of Bowtie Nanoantenna for High-Efficiency Thermophotovoltaics

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The field enhancement and a novel matching technique at the terminals of a bowtie nanoantenna are utilized for developing compact, highly efficient, and flexible thermophotovoltaic (TPV) cells. The bowtie antenna is designed for maximum power transfer to an infra-red band (1μm to 2.2μm) of a TPV cell using Indium Gallium Arsenide Antimonide (InGaAsSb). A nano-meter size block of InGaAsSb with a low bandgap energy of ~0.5eV is mounted at the terminal of the antenna. Such load presents a frequency dependent impedance with high resistance and capacitance at the desired frequency (180THz). For maximum power transform a high impedance bowtie antenna operating at the anti-resonance mode in conjunction with an inductive stub is designed. The inductive stub which is implemented by open-ended transmission line with a length of 140nm is used to compensate the high capacitance of the load. The plasmonic behavior of the metal that tends to reduce the antenna size is to some extent compensated with the extra length needed to achieve anti-resonance condition. The proposed nanoantenna loaded with InGaAsSb block shows a field enhancement of order of ~23.5 at its terminal making this design also suitable for development of very sensitive IR detectors.

A novel array configuration of the bowtie nanoantennas is presented that allows for collection of DC currents through an almost arbitrary parallel or series configuration of TPV or IR cells without adversely affecting the IR performance of the individual antennas. In this scheme elements can be arranged to be polarization dependent or independent. It is shown that the performance such thin flexible array can supersede the performance TPV cells of thick bulk InGaAsSb having same area.