Role of frustrated modes in the performance of near-field radiation mediated thermophotovoltaic devices

E. Blandre[1], M.P. Bernardi[2], O. Dupré[1], M. Francoeur[2], P-O. Chapuis[1], R. Vaillon[1,2]

1 CETHIL, UMR5008, INSA-Lyon, Villeurbanne, France
2 RETL, University of Utah, Salt Lake City, UT 84112, USA

Near-field Radiation mediated Thermophotovoltaic (NFR-TPV) systems are energy converters where the radiator and the photovoltaic (PV) cell are separated by a distance smaller than the thermal wavelength. At these distances, the system can benefit from the enhancement of the radiative energy emitted by the radiator due to near-field effects: in addition to the far-field propagative waves, the contribution of evanescent waves has to be accounted for in the vacuum gap between the radiator and the cell. There are two types of evanescent waves: surface modes, that are evanescent in the radiator and the vacuum gap, and frustrated modes, that are propagative in the radiator and become evanescent by total internal reflection at the radiator-vacuum interface.

Numerical simulations of the radiative, electrical and thermal behavior of NFR-TPV systems allow comparing the enhancement of the electrical power output originating respectively from the propagative, the frustrated and the surface modes[1]. The surface modes can generate lower electrical power enhancement than the frustrated modes, even for the smallest separation gaps, even though they are supposed to contribute the most. An analysis of the different losses shows that a limiting factor for the conversion of radiative power from the surface waves into electrical power is due to surface recombination at the illuminated surface of the cell. As a result, frustrated modes may appear currently as having a better potential for NFR-TPV applications since they become propagative in the cell, and thus lead to photogeneration of EHP farther from the illuminated surface than surface modes do.

To better analyze their potential, near-field radiative heat transfer in a configuration similar to a NFR-TPV system was studied: a semi-infinite medium emitting toward a flat film[2]. It is shown that frustrated modes, propagative inside the film, can interfere. This opens a way for spectral selection by designing appropriate thickness for the film (PV cell) so as to reduce the losses.

Another possible advantage of frustrated modes over surface modes could be the avoidance of too-large local generation rates of EHPs, which can cause a damageable increase of Auger recombination and resistance losses. Recent results obtained by solving the drift–diffusion equations for electrical charge carriers and Poisson’s equation for the electrostatic potential enable the estimation of such effects.

[1] M. P Bernardi *et al.*, *Impacts of propagating, frustrated and surface modes on radiative, electrical and thermal losses in nanoscale-gap thermophotovoltaic power generators*, Scientific Reports 5, 11626, 2015

[2] E Blandre *et al.*, *Spatial and spectral distributions of thermal radiation emitted by a semi-infinite body and absorbed by a flat film* ,AIP Advances 5, 057106, 2015