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Outline of dissertation

The dissertation consists of 5 chapters. The content of each chapter is as follows:

Chapter 1 Introduction

General information and previous publications of energy consumption, thermophotovoltaic (TPV) system, near-field radiation, near-field thermophotovoltaic (NTPV) system and hyperbolic metamaterials (HMMs) are provided. Subsequently, motivation and objectives are presented followed by the scope of work.

Motivation of this study is as follows:

- The current TPV system still has room regarding improvement of TPV performance.

- There is lack of experimental studies regarding NTPV system due to difficulties in setting up the system, i.e. surface curvature, particles and thermal management.

Objectives of this study are as follows:

- Improve the TPV performance by introducing near-field radiation (i.e. NTPV system).

- Further improve the NTPV performance by proposing hyperbolic modes.

- Study feasibility of practical NTPV system

Chapter 2 Numerical study of near-field thermophotovoltaic (NTPV) system

Performance of NTPV system is analyzed numerically after a HMM emitter (i.e. a pillar-array structured emitter) is applied. A schematic diagram is presented first. Subsequently, methodology including near-field calculation, anisotropic calculation and evaluation of NTPV performance is explained. Next, numerical results including total radiative flux, maximum power output and conversion efficiency are shown. An HMM region plot, spectral radiative flux and energy density plots are provided for discussion in order to confirm occurrence and effect of hyperbolic modes. Spatial distribution and radiative losses are provided for discussion to explain two different trends of conversion efficiency.

Conclusion is as follows:

- The occurrence of hyperbolic modes is confirmed.

- The effect of hyperbolic modes is elucidated and quantified. Substantial improvement of NTPV performance is observed.

Chapter 3 Comparison of numerical methods between Finite Difference Time Domain (FDTD) and Effective Medium Theory (EMT)

Two numerical calculations, i.e. the FDTD and the EMT implemented in chapter 2 are discussed in this chapter. Their advantages and disadvantages are listed. Numerical accuracy is compared. Appropriate circumstances for each method to be used are explained.

Chapter 4 Electricity generation using near-field thermophotovoltaic (NTPV) system

Performance of NTPV system is analyzed experimentally through an electricity generation experiment. An experimental setup is firstly explained. Subsequently, manufacturing processes of TPV cells (i.e. p-n junction semiconductors and schottky diodes) and pillar-array structured emitter are described. Next, experimental procedure is explained followed by a calculation of current generation in the schottky diode that is different from p-n junction semiconductor provided in chapter 2. The next section is results and discussion. Experimental results obtained from two different TPV cells (i.e. p-n junction semiconductors and schottky diodes) and two different emitters (i.e. a flat emitter and a pillar-array structured emitter) are shown. All experimental results are compared with numerical results to observe both trend and discrepancy. Discussion regarding factors influencing the discrepancy, i.e. experimental environment and quality of TPV cell, is provided.

Conclusion is as follows:

- Trend of experimental results arguably agree well with trend of numerical results especially in case of the flat emitter. Inversely proportional trend is observed when the results are in a region where evanescent mode is dominant. Undulant trend is observed when the results are in a region where propagating mode is comparable to the evanescent mode or is dominant. The undulation is a result of constructive and destructive wave interferences.

- The effect of hyperbolic modes is detected as shown in enhancement of power output.

- Evanescent wave effect is detected. The experimental results show arguably good agreement with the numerical results.

Chapter 5 General conclusions

General conclusions obtained from the previous chapters are drawn. Suggestions for future research in numerical and experimental aspects are provided lastly.

General conclusions are as follows:

- The evanescent wave effect is detected in both numerical simulation and electricity generation experiment.

- The occurrence and effect of hyperbolic modes are confirmed and explained via the numerical simulation. In case of the experiment, the effect of hyperbolic modes is also detected as well since the power output is shown to improve compared to the case when a flat emitter is applied in the majority of all experimental cases.

- The NTPV system is feasible according to the good agreement between numerical and experimental trends indicating that a nano-scale gap can be achieved. In addition, the thermal management issue can be overcome as temperature of TPV cell is kept at 10-16 ^{o}C throughout the experiment while temperature of emitter is 500 ^{o}C and higher.