06/9501 Microstructured Radiators

Type of activity: Medium Study (2 months, 15 KEUR)

Background and Motivation

Periodic microstructures on a polar material (ex: SiC) act as an IR antenna whose emission spectrum depends not only on the wavelength, but also on the observation direction: the emission exhibits narrow angular lobes similar to the ones of an antenna (these properties manifests itself only in p-polarization). Furthermore, the authors of [1] point out that “the emissivity of the source is enhanced by a factor of 20 compared to the emissivity of a flat surface.”

The physical origin of this coherent thermal emission are the coherent properties of surface waves, in this particular case surface-phonon polaritons, which are phonons in a polar material. They are mechanical modes of the system, so they can be resonantly excited, and charge-density waves, i.e. they generate electromagnetic fields. Because these excitations are delocalized, so are the corresponding electromagnetic fields; moreover these modes are evanescent, so their effect is not seen in the far-field. By ruling a grating on the interface, they are coupled to the propagating modes, leading to a focused thermal emission in the far-field.

There exist other possibilities of realizing a coherent thermal emission source; e.g. different kinds of microstructures (reverse-pyramids cavities [2] etc.), a multilayer structure mode of a polar material or a 1D photonic crystal [3] have been investigated.

The potential applications in space concern surfaces from about one cm^2 up to several m^2: small radiators with an improved emissivity for nanosatellites, radiator designs e.g. for RTGs that would allow much closer fin packing by changing the thermal emission direction, or radiators with directive emissivity that would offer new structural possibilities by modifying the radiative heat load going to and coming from external spacecraft surfaces (solar arrays, antennas, instruments…)

Research and Study Objectives

- Analysis and overview of the different ways of realizing a coherent thermal source.
- Analysis of the scalability of such systems (ranging from cm^2 to m^2.)
- Assessment of the dependence of the emission angle on the temperature of the surface and the frequency of the emitted radiation (e.g. important for applications that need a fixed emission angle and undergo thermal cycling in orbit)
- Investigation of the robustness of the device as a whole, in particular the influence of charging and cosmic radiation.
- As a function of the emission angle, assessment of the maximal and the total emissivity and radiated power of a microstructured surface and their comparison to a (traditional) flat one.

References

[1] *Coherent emission of light by thermal sources*, J.-J. Greffet, R. Carminati, K. Joulain, J.-P. Mulet, S. Mainguy & Y. Chen, Nature, Vol 416, 61-64, 2002 (France)

[2] *Spectral control of thermal emission by periodic microstructured surfaces in the near-infrared region*, H. Sai, H. Yugami, Y. Akiyama, Y. Kanamori, and K. Hane, J. Opt. Soc. Am. A, Vol. 18, No. 7, 1471-1476, 2001 (Japan)

[3] *Coherent thermal emission from one-dimensional photonic crystals*, B. J. Lee, C. J. Fu, and Z. M. Zhanga, Appl. Phys. Lett., 87, 071904, 2005 (USA)

Additional literature:

Planar heterogeneous structures for coherent emission of radiation, C. J. Fu, Z. M. Zhang, G. W. Woodruff and D. B. Tanner, Optics Letters, Vol. 30, No. 14, 1873-1875, 2005 (USA)

Near-Field Effects in Spatial Coherence of Thermal Sources, R. Carminati and J.-J. Greffet, Phys.Rev.Lett., 82, 1660-1663, 1999;

Surface Electromagnetic Waves Thermally Excited: Radiative Heat Transfer, Coherence Properties and Casimir Forces Revisited in the Near Field, K. Joulin, J.-P. Mulet, F. Marquier, R. Carminati and J.-J. Greffet, to appear in Surface Science Reports, eprint physics/0504068, 2004