Thermal emission control with surface waves

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Abstract: Cheap and practical infra red (IR) sources are incandescent sources such as globar or hot membranes. These sources are broadband, omnidirectional, have a low efficiency and cannot be modulated faster than 100 Hz. In this paper, we show how it is possible to overcome all these limitations by taking advantage of surface waves.
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1. Introduction

IR sources are required for spectroscopic applications and gas sensing for instance. Several IR lasers are aailable. Yet, there is no equivalent of a LED in the IR part of the spectrum. Hence, incandescent emitters such as globars or hot membranes are still the most common source despite many drawbacks including a low efficiency, a low directivity and the impossibility of fast modulaton. In this paper, we will introduce different strategies to overcome these limitations by taking advantage of surface waves.

2. Controlling the spectrum and the directivity

There have been several demonstrations on how to control the directivity and spectrum of thermal sources [1,2]. Owing to Kirchhoff's law, this amounts to control the directional and spectral absorptivity. Hence, one can take advantage of absorption due to resonant excitation of surface waves. In other words, designing a directional and spectrally selective emitter amounts to design an absorber. While several structures have been published demonstrating either directional or spectral control of the emission, controlling both simultaneously is more challenging. In this section, we will report recent progress along this line by using a periodic array of metal-insulator-metal square on a metal substrate.

3. Improving the efficiency

One of the major drawbacks of incandescent sources is their efficiency. A typical light bulb has a wall-plug efficiency of 3% in terms of useful radiation emitted in the visible. When using a globar for gas sensing, the spectralk range of interest is very narrow thereby reducing the efficiency. Here, we report a hot membrane design allowing to improve significantly the efficiency for gas sensing applications [3]. We first discuss the different energy leakage mechanisms and show how to deal with them. Our design is based on a hot membrane encapsulated in vacuum to suppress convective losses. The membrane has a frequency selective coating in order to reduce unwanted radiative losses. Finally, we reduce significantly the conduction losses by heating only the central part of the membrane.

4. Introducing fast modulation for incandescent sources.

As explained above, the key to a simple model of the control of radiation is the concept of emissivity. As the emitted flux is proportional to the product of emissivity and specific intensity of a black body, it is possible to modulate the flux by modulating the emissivity instead of modulating the temperature. In other words, the idea is to have a source that can oscillate between a "mirror" state and "blackbody" state depending on an applied voltage. Here, we will report the first proof of principle of this idea. The device uses the recently introduced concept of modulation based on the epsilon near zero (ENZ) mode [4].

4. References

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