Patch Antenna Microcavities for THz lasers

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1. Introduction

The Terahertz (THz) frequency range refers to electromagnetic radiation from 100 GHz to 10 THz. The unique characteristics of THz waves have allowed the development of wide-ranging applications such as molecular spectroscopy, medical imaging, security scanning, non-destructive testing, information technology among many others [1]. The ability to realize efficient and compact THz devices will benefit the further development of THz technology both for basic research and applications.

In the optical regime it has been demonstrated that strong subwavelength confinement of light is an effective strategy for obtaining highly efficient optoelectronic devices, for example with optical microcavities [2]. This concept can be translated to the THz regime by using double metal (DM) microcavity structures. High performance Mid-IR and THz detectors have been fabricated based on hybrid DM antenna -coupled microcavities [3,4]. Following this strategy to achieve THz emitters has proved challenging, as the subwavelength confinement of the THz field results in low photon out-coupling efficiencies and extreme divergence of the far field radiation. Recently we have studied numerically the possibility to use arrays of patch antenna microcavities (PAMs) to overcome those limitations [5]. Here we present a study on the emission properties of arrays of PAMs based on quantum cascade (QC) active regions. We demonstrate enhanced emission compared to standard THz DM ridge waveguide QCLs owing to the engineered losses provided by the array geometry, and quasi collimation of the THz beam produced by far-field constructive interferences.

2. Results

We studied emission from arrays of DM PAMs containing GaAs/AlGaAs QC active regions based on a hybrid bound-to-continuum – LO phonon extraction design [6]. We compared the performance of these structures with a reference sample processed in a conventional DM ridge waveguide. Optical and electrical characterization of the fabricated devices (Fig. 1) demonstrate enhanced performance of the PAM array over the ridge waveguides, namely a 40-fold enhancement of the emission efficiency, lower lasing threshold current and improved slope efficiency. Also, quasi collimation of the THz beam was observed. A far-field pattern with gaussian profile and beam divergence as low as 2° x 2° was measured. The significant enhancement of the emission properties is a signature of an improved extraction efficiency from PAMs and a better beam profile than the ridge structure attained by constructive interferences from single resonators in the far field.

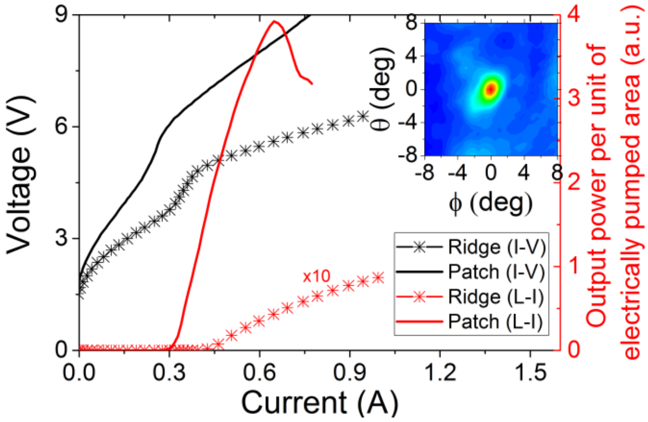

Figure 1. L-I-V characteristics of a DM ridge waveguide compared with the PAM array. Inset: measured far-field pattern of the PAM array. A beam divergence with FWHM= 2°x2° was measured.

3. Conclusions

Arrays of PAMs allow a precise tuning of the losses, leading to high extraction efficiencies and shaping of the beam. We believe that our design can become an important platform to exploit the benefits of microcavities to achieve efficient and compact THz sources as well as to study novel regimes such as THz optical nonlinearities and amplification, which would be beneficial for many imaging and spectroscopy applications.

Acknowledgements

This work was supported by JSPS Kakenhi grant number JP17K14126.

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