Sound mixing and nonlinearity in graphene-based thermoacoustic devices

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References

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Abstract

By periodically heating graphene, acoustic signals can be generated in the medium surrounding it. The high thermal conductivity and low thermal capacity make graphene the ideal material to observe such generation. Here, we show that control of the charge transport in a graphene-based field-effect transistor in air can influence the magnitude, phase and harmonic content of the sound produced [1]. The transistor gate voltage can be used to tune this output sound power by over an order of magnitude. This is demonstrated in both bottom- and top-gated devices for a wide range of device geometries and experimental conditions, Figure 1.

The Joule heating effect [2] at the root of the sound generation can be used to multiply source signals together. This heterodyning effect is shown to be highly efficient. Importantly for applications, the conduction in the graphene channel is linear, in stark contrast to traditional heterodyning systems that rely on nonlinear conduction.

Finally, we demonstrate that we can use the sound generated by graphene to probe its electrical conduction mechanisms. As a result, we show how thermoacoustics can be used as a sensitive tool to investigate both electrical and thermal properties of 2D materials.

Figures

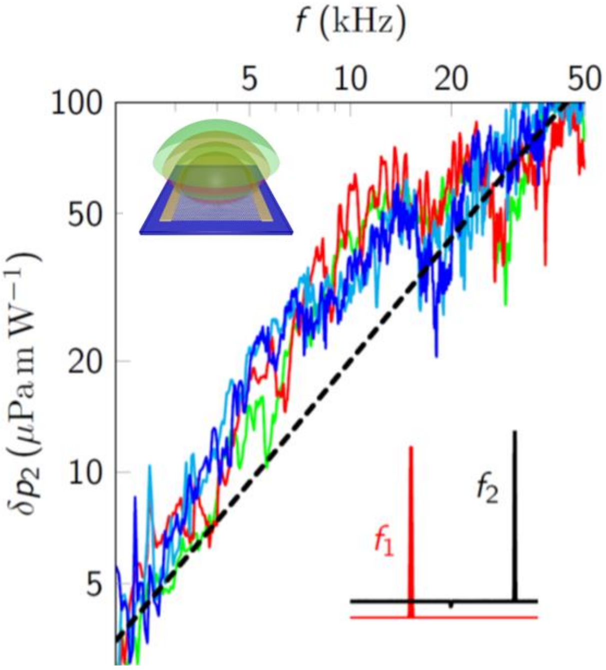

Figure 1: Sound pressure as a function of frequency for a range of top- and bottom-gated graphene-based field-effect transistors. (Pressure values have been normalised to those at 1m distance and 1W source power.) Top inset: Sketch of device (grey) on a silicon substrate (blue) generating sound waves (green). Bottom inset: Spectrum showing sound generated (black) at twice the frequency of the source (red). Heterodyning is seen when more than one source frequency is present in the transistor channel.