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Hot electron emission processes in waveguide integrated graphene

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Photoemission plays a central role in a wide range of areas, from electronic structure measurements to free electron laser sources. In metallic emitters, photons with energy lower than the material workfunction can only drive photoemission through the multi-photon, or strong-field processes, both of which require large optical power densities, limiting the integration and deployment of these photoemitters despite their favorable properties. Here, we demonstrate a graphene emitter that is excited via a waveguide with 3.06 eV photons from a continuous wave (CW) laser exhibits two hot-electron processes that drive photoemission at peak powers orders of magnitude lower than previously reported multi-photon and strong-field metallic photoemitters. We use optical power dependent experiments combined with modeling to suggest that the observed behavior can be explained by considering two hot-electron emission processes: (i) non-equilibrium electron heating, and (ii) direct emission of excited electrons. These processes are dramatically enhanced in graphene due to the relatively weak electron-phonon coupling and the single layer structure.

By observing the optical power dependence as a function of electric field, we show that there is a crossover from non-linear at low electric fields to linear at high electric fields. This crossover in optical power dependence is also reproduced in our model only when we consider both electron heating and direct emission of excited electrons. When LaB6 nanoparticles are used, the power dependence is linear regardless of the electric field, due to the low workfunction of the LaB6. Additionally, the integrated photonics approach demonstrates an efficiency three orders of magnitude greater than free space excitation. These results suggest the approach of integrated photonics combined with materials exhibiting low electron-phonon coupling and thin structures, such as 2-D materials or quantum dots, could provide a rich new area for electron emitters and integrated photonic devices.

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