Hot Electrons and Integrated Photonics for Electron Emitters

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In this talk, we will discuss some of our recent work on how hot electrons and integrated photonics can be used to fabricate electron emitters with properties.

First, we show how hot-electron processes can dramatically reduce the optical power densities required for photoemission. In metallic emitters, single-photon, multi-photon, or strong-field emission processes are the three mechanisms via which photoemission takes place. 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 powers, limiting the integration of photoemitters with photonic integrated circuits. Here, we show that a waveguide integrated graphene electron emitter excited with 3.06 eV photons from a continuous wave (CW) laser exhibits two hot-electron processes that drive photoemission at peak powers >5 orders of magnitude lower than previously reported multi-photon and strong-field metallic photoemitters. Optical power dependent studies combined with modeling illustrate that the observed behavior can be explained by considering 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. These results show that hot electron devices still offer a rich area of exploration.

In the second part of the talk, we discuss how integrated photonic can be utilized to create photocathodes exhibiting simultaneous high quantum efficiency, low mean transverse energy, and fast temporal response are critical for next generation electron sources. Currently, caesiated negative electron affinity GaAs photocathodes have demonstrated good overall results.1,2 However, due to the nature of the photoemission process and the details of the Cs surface structure, a tradeoff exists. A low mean transverse energy of ~25 meV can be obtained by using photons with near bandgap energy, at the cost of an unacceptably high response time, or higher energy photons can be used with mean transverse energy of ~60 meV with acceptable response times of 2-5 ps.3-5 Here, it is shown through a calibrated simulation that a thin layer of ceasiated GaAs on a waveguide can potentially exhibit photoemission with MTEs ~30 meV, ultrafast response times of ~0.2-1 ps, and QE of 1-10%, breaking the traditional tradeoffs associated with bulk negative electron affinity photoemitters.

Professor Kapadia joined the faculty of the University of Southern California in the Ming Hsieh Department of Electrical and Computer Engineering in July 2014 and holds the Colleen and Roberto Padovani Early Career Chair. He received his bachelors in electrical engineering from the University of Texas at Austin in 2008, and his Ph.D. in electrical engineering from the University of California, Berkeley in 2013. During his time at Berkeley, he was a National Science Foundation Graduate Research Fellow and winner of the David J. Sakrison Memorial Prize for outstanding research. At USC he has been the recipient of an Air Force Young Investigator Award, an Office of Naval Research Young Investigator Award, and the AVS Peter Mark Memorial Award. His interests lie at the intersection of material science and electrical engineering, with a focus on developing next-generation electronic and photonic devices. Additionally, he is the co-director of a recently created Center for Integrated Electronics and Biological Organisms (CIEBOrg) at USC.