Seminar announcement

Tuesday, September 19, 2023
2 pm
WSI, Seminar room S 101

"Broadband terahertz metasurface quantum-cascade lasers for heterodyne and mode-locking applications"

In this talk, I will summarize our recent progress in developing terahertz quantum-cascade (QC) lasers based upon metasurfaces, and their suitability as sources for spectroscopy at frequencies above 1.5 THz. This approach is a hybrid of electronic and photonic techniques: the gain originates from quantum-cascade (QC) gain material which produces gain via intersubband electronic transitions within heterostructure GaAs/AlGaAs quantum wells, but uses sub-wavelength sized waveguides and antennas that have a strong resemblance to microstrip patch antennas. The enabling component is a 2-dimensional reflectarray metasurface based upon a sub-wavelength arrays of such antennas loaded with QC-gain material that reflects and amplifies incident THz waves. These metasurfaces are then used to realize QC vertical-external-cavity surface-emitting lasers (QC-VECSELs), by using the metasurface is used as one reflector in an external cavity, which supports a well-shaped circulating THz beam. The QC-VECSEL architecture offers a solution to many problems that have plagued THz QC-lasers – namely their low emission powers and efficiencies (especially above 77 K), their limited beam quality (especially at high powers), and their limited range of continuous single-mode tunability.

I will present advances in two areas. First, QC-VECSELs are strong candidates for single-frequency continuous-wave sources that can act as local oscillators for heterodyne receivers. Our lab has currently demonstrated QC VECSELs operating at various frequencies between 1.9 THz and 4.6 THz, with a goal of operating up to 6 THz. By scaling the active area of the metasurface, the output power can be scaled while maintaining a favorable thermal geometry. In this way record-high powers of 20 mW continuous-wave and > 1 W pulsed have been demonstrated at 77 K heat sink temperature at 3.4 THz. Such high powers are suitable for pumping large format arrays of HEB mixers for next generation heterodyne instruments. Additionally, since the laser gain is localized in the metasurface itself, and not in a bulk gain medium, the length of the external cavity can be made extremely short to lase on low-order Fabry-Perot modes. By using tuning the cavity length using piezoelectric control, highly frequency tunable QC-VECSELs have been realized – up to 19% fractional tuning bandwidth – that would be suitable for frequency agile-local oscillators. Finally, we have shown that the emission can be stabilized either via phase locking to a microwave reference, or direct injection locking from an electronic source.

Second, I will present our recent demonstration of multi-mode QC-VECSEL sources using active RF injection locking. Although QC-VECSELs exhibit a large gain bandwidth, ordinarily they prefer to oscillate in one mode only. We have shown that multi-mode oscillation can be induced over a few hundred GHz spectral width by driving the QC-material with an RF signal at the cavity round trip rate (about 5 GHz). Signatures of injection locking of the round trip are observed for low-power injection (< -10 dBm) and induced multimoding and spectral broadening is observed for high power injection (> 0 dBm). These results show a path towards QC-VECSEL frequency-comb sources with high power and adjustable repetition rates, and potentially actively mode-locked pulsed THz sources.

Speaker´s Biography: Benjamin Williams is a Professor in the Department of Electrical and Computer Engineering at University of California Los Angeles. He received his B.S. in Physics from Haverford College in 1996, and his M.S. in 1998 and Ph.D. in 2003 both from the Massachusetts Institute of Technology in Electrical Engineering. He is currently Associate Editor for IEEE Transactions in Terahertz Science and Technology. He has received the APS Apker Award (1996), the DARPA Young Faculty Award (2008), the NSF CAREER Award (2012), and the Presidential Early Career Award for Scientists and Engineers (PECASE) (2016). His research interests lie in photonic materials, devices, and applications for the terahertz and mid-infrared frequency ranges, including low-dimensional semiconductors, quantum-cascade lasers, and plasmonics and metamaterials.

Prof. Benjamin S. Williams
Department of Electrical and Computer Engineering
University of California Los Angeles
USA