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Electrical Sciences and Computer Engineering (ESCE) Seminar

Terahertz Laser Frequency Combs

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The development of optical frequency combs has had a revolutionary impact on high-precision metrology and spectroscopy, and the development was recognized with a Nobel Prize in 2005. At visible and near-infrared frequencies, the combs are often formed based on mode-locked lasers whose periodic pulse trains in the time-domain naturally lead to frequency combs from the duality relation in Fourier transform. More recently, a new type of frequency comb was developed using nonlinear optical sideband generation based on four-wave mixing (FWM). In these devices, a coherent *cw* laser source is used to pump a microresonator with high quality factor and equally spaced cavity modes. When the pump lasing frequency coincides with a cavity mode, the cavity-enhanced FWM generates multiple sidebands in a bifurcate fashion at other cavity modes.

In 2012, a mid-infrared frequency comb was developed based on FWM in a quantum cascade structure. A straightforward implementation of this scheme will be difficult at THz frequencies because of the much stronger group-velocity dispersion (GVD) due to the proximity to the *Reststrahlen* band. By using a carefully designed and fabricated integrated dispersion compensator, we were able to develop laser frequency combs at THz. This breakthrough will enable the creation of compact terahertz spectrometers that replace the bulky systems currently in use. With comb-based spectrometers, we can achieve the high resolution (~kHz) and S/N ratios of laser spectroscopy, the broadband capabilities of FTIR (>1 THz), all with no mechanical moving parts. This development will enable a wide range of applications not currently possible.

Qing Hu received his B.A. from Lanzhow University in 1982 and his Ph.D. in physics from Harvard University in 1987. From 1987 to 1989, he was a postdoctoral associate at University of California, Berkeley. He joined the MIT faculty in 1990, where he is now a Distinguished Professor in the Electrical Engineering and Computer Science Department.

Professor Hu has made significant contributions to physics and device applications over a broad electromagnetic spectrum from millimeter wave, THz, to infrared frequencies. Among those contributions, the most distinctive is his development of high-performance terahertz (THz) quantum cascade lasers (QCLs). Now this breakthrough has already found applications in heterodyne receiver technology and real-time THz imaging, which was also pioneered by his group. He is a Fellow of the Optical Society of America (OSA), a Fellow of the American Physical Society (APS), a Fellow of the Institute of Electrical and Electronics Engineers (IEEE), and a Fellow of the American Association for the Advancement of Science (AAAS). He is the recipient of 2012 IEEE Photonics Society William Streifer Scientific Achievement Award, and 2015 Nick Holonyak Jr. Award from OSA. He has been an Associate Editor of Applied Physics Letters during 2006-2014 and a Deputy Editor since 2015.

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