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National Tsing Hua University Scientists Reported the Smallest Semiconductor Laser *in Science*

Hsinchu, July 27, 2012. Two professors from National Tsing Hua University (NTHU,) Shangjr Gwo (果尚志) and Lih J. Chen (陳力俊), in collaboration with Professor Chih-Kang Shih (施至剛) and Professor Gennady Shvets of the University of Texas at Austin (UT-Austin,) led a team of collaborators, published a paper entitled “**Plasmonic Nanolaser Using Epitaxially Grown Silver Film**” in the July, 27, 2012 edition of *Science* magazine.

Gwo explains that “*up to now, significantly reducing the size of semiconductor lasers in all three dimensions is the ultimate*

challenge for the development of nanolasers, which is a key component for long-awaited on-chip optical communications and computing systems. However, the minimum size of conventional semiconductor lasers utilizing dielectric cavity resonators is governed by the optical diffraction limit.”

Recently, it was proposed that utilizing plasmonic cavities can break this limit. In such cavities, the coupling of photons and plasmons (collective oscillations of the free electron gas density) on noble metal surfaces at optical frequencies constitutes the necessary laser feedback mechanism.

But it remains whether one indeed can overcome the high losses in three-dimensional (3D)-confined, deep-subwavelength plasmonic cavities with the currently available metals and semiconductor gain materials.

In this paper, it is reported an important breakthrough in the growth of atomically smooth, epitaxial Ag films on Si substrates, which can be used as the platform material to fabricate low-loss plasmonic cavities due to their superior material properties. In particular, by using single, shape-controlled InGaN/GaN core-shell nanorods as the gain media with a large gain coefficient in the green spectral region, the authors were able to realize 3D diffraction-unlimited nanolasers that can be operated under continuous-wave (CW) conditions with an ultralow threshold power above liquid nitrogen temperature.

As predicted by Shvets and his students based on theoretical simulations using the known cavity dimensions and material parameters, a nearly 100% polarized lasing mode was experimentally confirmed. Moreover, the perfect crystalline quality of InGaN/GaN core-shell nanorod gain media was thoroughly confirmed by ultrahigh-resolution transmission electron microscopy in Chen's Laboratory.

In these nanolasers, record-small cavity and mode volumes are orders of magnitude smaller than the 3D diffraction limit and the feature sizes are comparable with that of the state-of-the-art metal-oxide-semiconductor (MOS) transistors used in nanoelectronics.

According to Shih, an NTHU alumnus who received his BS in Physics in 1977, “so far, most plasmonic devices are based on granular polycrystalline Ag films where surface roughness and grain boundaries lead to scattering losses of surface plasmons. This means that atomically smooth or single-crystalline plasmonic structures are highly desirable building blocks for low-loss plasmonic applications. Using polycrystalline metallic materials, the lasing threshold of plasmonic nanolaser remains impractically high and the CW operation of MOS-structured plasmonic laser has yet to be demonstrated.”

“Size mismatches between electronics and photonics have been a huge barrier to realize on-chip optical communications and computing systems. The recent surge of research interest in nanoplasmonics has been largely due to its capability to break the diffraction limit. However, the lossy nature of conventional plasmonic materials requires a remedy to overcome this difficulty. The epitaxial approach reported here opens a scalable platform for low-loss, active nanoplasmonics.” concluded Gwo.

About National Tsing Hua University (NTHU)

National Tsing Hua University is a research university with a long and proud tradition. Since the re-establishment in Hsinchu in 1956, the university has been known for her excellent academic programs as well as her spacious verdant campus. NTHU initially began in Taiwan with nuclear sciences studies, and gradually expanded to include general sciences and engineering; in the past twenty years, the social sciences and humanities, life sciences, information sciences, and management sciences were added. Over the last fifty-five years, NTHU has transformed herself into a comprehensive university and is recognized globally in many disciplines. There are thirteen Academia Sinica Academicians on the faculty, and sixteen professors awarded with various National Chair Professorships. Among the fifty thousand alumni, there is one Nobel

Laureate Yuan Tseh Lee and twelve Academicians. The university development, with active participation from all staff members, has been built on a transparent and progressive platform, and the campus life is visibly permeated with vitality and enthusiasm, with the eight colleges complementing each other in scholastic endeavors. The per-student funding from the Ministry of Education's "Toward World-Class Universities Project" surpasses all other universities in Taiwan.