Light- Matter
The Quantum Science & technology of Semiconductor optoelectronics Devices From Deep UV- to THZ
Past, Present , and future Trend

Prof. Manijeh Razeghi

Center for Quantum Devices, Department of Electrical and Computer Engineering, Northwestern University, Evanston, Illinois 60208, USA.

Abstract:

Nature provides us with a vast assortment of atoms in the periodic table. When these atoms oscillate, they emit light at different energies, spanning the entire electromagnetic spectrum—from gamma rays and X-rays to ultraviolet (UV), visible light, infrared (IR), and terahertz (THz) radiation. However, human vision is limited to only a small portion of this spectrum—the colors of the rainbow.

To detect and generate light beyond visible wavelengths, scientists have developed artificial eyes, such as infrared cameras. Yet, there remain unexplored frontiers in the invisible spectrum that current technologies struggle to access. Advancing our ability to see and illuminate these spectral regions requires breakthroughs in quantum materials and device engineering.

Our research focuses on pushing these boundaries by developing III-V Sb-based quantum semiconductor technologies for light detection and emission across the deep UV to THz range. A significant milestone in this field was the invention of Sb-based superlattices by Nobel Laureate Leo Esaki. However, despite decades of research, no group in the world was able to fabricate focal plane arrays (FPAs) based on this material—until our group successfully demonstrated the world's first camera based on Sb-based superlattices. Moreover, we showed that these devices surpass the performance of the well-established mercury cadmium telluride (MCT) technology, which has long dominated infrared detection and imaging applications.

This talk will highlight our recent advancements in III-V Sb-based quantum sensors and imaging devices, which enable highly precise, accurate, and sensitive measurements across multiple applications. These technologies have the potential to enhance consumer devices and services in fields such as:

- **Medical diagnostics and imaging**
- **High-precision navigation**
- **Earth observation and environmental monitoring**

A key feature of Sb-based quantum imaging is the exploitation of light correlations, which improves imaging performance in terms of signal-to-noise ratio (SNR), 3D resolution, and robustness, while also enabling new imaging modalities, including single-photon detection from deep UV to THz.

From an industrial perspective, we have not only demonstrated superior technical performance but also validated the practical feasibility of these sensing solutions in real-world conditions. Our work addresses key challenges related to:

- **Miniaturization (size, weight, and power efficiency)**
- **Reliability in extreme environments (vibrations, noise, temperature variations, cosmic radiation)**
- **Integration into various platforms, including mobile and aerial systems**

For successful industrial applications, integrating quantum sensors into functional modules or systems requires a range of enabling technologies. Our work explores III-V Sb-based quantum sensors on Si, Al_2O_3, GaAs, and other substrates, ensuring versatility for different applications and platforms. By advancing these novel quantum imaging and sensing technologies, we aim to bridge the gap in our ability to see beyond the visible spectrum, unlocking new opportunities for scientific discovery and industrial innovation.

Manijeh Razeghi received the Doctorate d'état ES Sciences Physiques from the Université de Paris, France, in 1980.

Manijeh Razeghi was the Head of the Exploratory Materials Laboratory at Thomson-CSF (France) during the 80's where she developed and implemented modern metalorganic chemical vapor deposition (MOCVD) vapor phase epitaxy (VPE), molecular beam epitaxy (MBE), GasMBE, and MOMBE for entire compositional ranges of III-V compound semiconductors from deep UV to THZ. Developing these tools was fundamental in enabling her to achieve high purity semiconductor crystals with a consistency and reliability that was often unmatched, thereby leading to new physics phenomena in InP , GaAs, GaSb, and AlN based semiconductors and quantum structures. She realized the first InP Quantum wells and Superlattices and demonstrated the marvels of quantum mechanics in the low dimensional world.

She joined Northwestern University, Evanston, IL, as a Walter P. Murphy Professor and Director of the Center for Quantum Devices in Fall 1991, where she created the undergraduate and graduate program in solid-state engineering.

She has authored or co-authored more than 1000 papers, more than 35 book chapters, and 20 books, including the textbooks *Technology of Quantum Devices* (Springer Science Business Media, Inc., New York, NY U.S.A. 2010) and *Fundamentals of Solid State Engineering, 4th Edition* (Springer Science Business Media, Inc., New York, NY U.S.A. 2018). Two of her books, *MOCVD Challenge Vol. 1* (IOP Publishing Ltd., Bristol, U.K., 1989) and *MOCVD Challenge Vol. 2* (IOP Publishing Ltd., Bristol, U.K., 1995), discuss some of her pioneering work in InP-GaInAsP and GaAs-GaInAsP based systems. *The MOCVD Challenge*, 2nd Edition (Taylor & Francis/CRC Press, 2010) represents the combined updated version of Volumes 1 and 2. She holds many U.S. patents and has given more than 1000 invited and plenary talks. Her current research interest is in nanoscale optoelectronic quantum devices. From deep UV to Thz.

Dr. Razeghi is a Fellow of MRS, IOP, IEEE, APS, SPIE, OSA, Fellow and Life Member of Society of Women Engineers (SWE), and Fellow of the International Engineering Consortium (IEC). She received the IBM Europe Science and Technology Prize in 1987, the Achievement Award from the SWE in 1995, the R.F. Bun shah Award in 2004, IBM Faculty Award 2013, the Jan Czochralski Gold Medal in 2016, the 2018 Benjamin Franklin Medal in Electrical Engineering, LSA 10th Anniversary Outstanding Contribution Award, and many best paper awards. She is an elected life-Fellow of SWE, IEEE, and MRS. She is honored as a member of Academy of Europe 2021.