4. POST-MOORE'S LAW AND QUANTUM ELECTRONICS (PMQE) *Course Leader: Rao Tummala – Georgia Institute of Technology*

Course Objective:

Moore's law has been the driving engine for science, technology, manufacturing, hardware, software, systems, and applications, contributing to the prosperity of thousands of individuals, hundreds of corporations, and dozens of countries. As Moore's Law begins to come to an end, not only for fundamental reasons but also for computing performance, power, cost, and investments, it is becoming clear that a different vision for electronics systems must emerge. So, while transistor integration to a 20 billion-transistor-chip on individual ICs so far was the basis of Moore's Law for ICs, this can be extended in 2.5D and 3D by means of new paradigms in electronic and optoelectronic interconnections, in the short term. This is referred to as Moore's Law for Packaging or interconnections. Just like Moore's Law has both the doubling of transistors and simultaneous cost reduction from node to node, every 18-24 months, Moore's Law for Packaging can do the same.

Interconnections have been driven by computing systems and within computing systems, between logic and memory, consistent with Von Neumann's architecture. The new era of artificial intelligence mimicking the human brain, with several orders of magnitude of better computer performance than with the current electronics, is yet another reason for the end of Moore's Law. The human brain is the ultimate system packaging for the highest performance in the smallest size with the lowest power. A typical human brain has about 90 billion nerve cells interconnected by trillions of synapses providing trillions of pathways for the brain to process the information along with petabyte memory. Thus, the human brain is the new standard in packaging density and computing performance-power efficiency. This is more than the current 3D electronic architectures. There is no such electronics equivalent. Therefore, the new PMQE law must duplicate this architecture.

This tutorial describes a vision for post-Moore's Law and Quantum Electronics (PMQE) from current era of Moore's Law for ICs to the next era of electronic and photonic interconnections, and eventually to quantum electronics and computing. All large corporations such as Google, IBM, Microsoft, Intel and advanced countries such as the U.S., Europe, Japan, and China have targeted quantum electronics as the next Moore's Law. Quantum electronics consist of Quantum devices with superconducting interconnections that operate at absolute zero degrees Kelvin. Unlike current computing, which operates with binary 0 or 1, quantum operates with both simultaneously. This is referred to as Qubits. This leads to an exponential increase in computing power, as demonstrated by IBM and Google. Currently Qubits are only at about 50.

Post-Moore's Law electronics is highly interdisciplinary, requiring a team of scientists and engineers to work together from electrical, mechanical, thermal, optical, bio and nanomaterials, and chemical process disciplines. The PMQE provides a new opportunity for the electronics industry to continue, not on Moore's Law path, but on a computing roadmap.

Course Outline:

1. Current Approach to Devices and Systems
2. Moore's Law for ICs, Its Evolution and Its Future
3. Reasons for Moore's Law Coming to an End
4. What Will Replace Moore's Law?

5. Moore's Law for Electronic and Photonic Packaging as the 2nd Moore's Law

6. Quantum Electronics for the Next Computing Wave

Who Should Attend:

R&D executives as well as senior technical and marketing managers involved in all aspects of electronics R&D, supply-chain for ICs, packages and systems manufacturing, marketing, investments and users who deal with strategic directions for their company.

Bio:

Rao Tummala is the Joseph M. Pettit Chair Professor and Director in 3D Systems Research Center in the School of Electrical and Computer Engineering and Materials Science and Engineering at Georgia Tech. He is also the Founding Director of the first NSF ERC in the U.S. He is a world-renowned packaging expert and has developed several major technologies from concept to manufacturing including the industry's first 100-chip ceramic modules, first plasma display and thin film magnetic storage devices for which contributions he was named an IBM Fellow. Prior to joining Georgia Tech, he was Director of Packaging for IBM.