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Information Processing Devices Beyond CMOS – A Physics Perspective

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Conventional computing technology has been dominated by aggressively scaled CMOS gates (utilizing electrons as information bearing particles), and single core microprocessor architecture for more than 20 years. Continued CMOS scaling to and beyond the 90 nm technology node has greatly increased static power dissipation, caused by increased leakage currents, and by dynamic power dissipation, caused by increased clock rates. Responding to these challenges, the semiconductor and related research communities are pursuing many new device concepts to further scale information processing into the sub-nanometer domain. Low dimensional approaches such as nanotubes, nanowires, molecules, SETs, etc, have been proposed for charge based logic devices. Further, a variety of spin-based (electron or nuclei) devices have been proposed for new spin-based logic or information processing. These spin-based systems require high magnetic fields for reliable spin manipulation. Therefore, breakthroughs in the physics of spin manipulation are needed, e.g., is it possible to obtain suitable materials that exhibit a high g-factor to enable controllable devices that operate at ambient temperatures with reasonable energies and magnetic fields? Similarly, some new optical approaches may be candidates for photon-based logic. While many of these alternatives are appealing, their functionality and density appear to be limited by fundamental physics, such that they will be comparable to or not as attractive as charge-based devices. This assessment is based on their potential device or functional density and their power dissipation. This presentation will discuss the similarity of these different approaches to binary logic based upon a logical state distinguishability model that requires an energy barrier to separate the two states and minimize error in a binary logic system. We will also discuss the feasibility devices having critical dimensions less than one nanometer which may require an information bearing particle much more massive than the electron. Finally, the presentation will conclude with a brief discussion of how possibly unique analog properties of new nanoelectronic devices might be used to extend a CMOS platform technology to new domains of application.