Theory-Guided Road Map for Electro-Optics and the Information Technology Revolution

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Chipscale integration of electronics and photonics is well recognized as a critical next step in the evolution of information technology (telecommunications, computing, sensing, metrology, imagining, and robotics). Electro-optics is central to such integration. We use multi-scale theoretical methods (quantum & statistical mechanics and beyond) to develop a road map for development of organic electro-optic materials and their integration into silicon photonic, plasmonic, photonic crystal, and metamaterial devices. This paradigm has already produced a factor of nearly 1000 improvement in electro-optic device performance yielding devices with drive voltage-length performance of 40 V-micrometers, single channel bandwidths of greater than 1 THz, energy efficiency for digital information processing of 1 femtojoule/bit, device footprints of 1 micrometer squared, and insertion loss of less than 2 dB. Such devices now permit gain to be realized in telecommunication systems and wireless signals to be converted directly to fiber optic transmission without the use of electronics. Extraordinary signal linearity has also been achieved. Theory has not only permitted the design of dramatically improved organic electro-optic materials but has also permitted simulation of the performance of materials in devices, elucidating the importance of interfacial interactions. Multi-scale theoretical simulations suggest that another factor of 500 improvement may be possible, permitting not only a revolution in electro-optic technology but also in photodetector technology through exploitation of optical rectification.