Assessing the impact of radiation on Si/SiGe quantum dot qubits

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Recently, it has been shown that gamma ray radiation impacts induce correlated errors in superconducting qubits fabricated on silicon substrates, a phenomenon that is particularly detrimental for error correcting codes. In this talk I will discuss recent experiments that imitate such radiation impacts in Si/SiGe quantum devices using fiber optic illumination on the back of the wafer to deposit energy and induce bursts of electron-hole pairs deep in the bulk of the wafer. We find that some of the generated charge – mostly electrons – migrates to the top region of the wafer and shifts the offset charge of quantum dot qubits. That is, it changes the qubit operating point. In some cases, these shifts are small enough that conventional, open-loop charge sensing can track the offset charge as a function of time, while in other cases we find it useful to use closed-loop feedback to track the offset charge. Using these methods, we identify abrupt jumps in the offset charge that appear to arise from trapping of individual electrons. Based on the magnitude of the jumps in the offset charge, the charge trapping occurs within a few hundred nanometers of the qubit. Importantly, the device can be very stable both before and right after the single-charge trapping, as we demonstrate by turning off the optical illumination as soon as a charge jump is observed. In addition to its implications for the migration of radiation-induced charges from the bulk through the SiGe relaxed buffer layer, we also find important lessons for qubit operation. We observe a significant reduction in the amount of time required for devices to stabilize after optical resets [1] if back-of-the-wafer illumination is used to accelerate the achievement of an electrostatically stable environment.

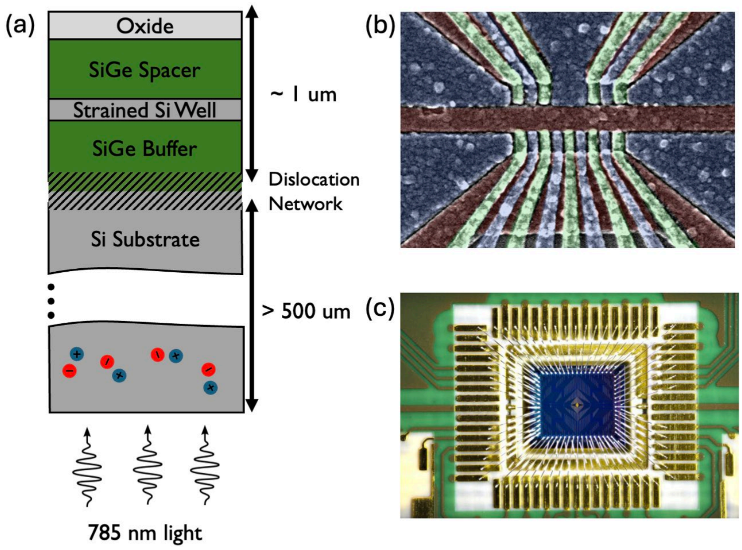

Figure 1 (a) A prototypical Si/SiGe qubit heterostructure showing (i) a buried defect layer formed during epitaxial growth aimed at producing (ii) relaxed SiGe, (iii) a tensile-strained Si quantum well, and (iv) a top barrier and oxide layer. Radiation impacts are far more likely to occur below the defect layer than above it. Experiments are performed using (b) overlapping gate devices fabricated at UW-Madison and (c) Tunnel Falls devices fabricated at Intel Corporation.

[1] M. A. Wolfe, Brighton X. Coe, et al., Control of threshold voltages in Si/SiGe quantum devices via optical illumination, arXiv:2312.14011