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Doubled Color Codes

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Combining protection from noise and computational universality is one of the biggest challenges in the fault-tolerant quantum computing. Topological stabilizer codes such as the 2D surface code can tolerate a high level of noise but implementing logical gates, especially non-Clifford ones, requires a prohibitively large overhead due to the need of state distillation. In this talk I will describe a new family of 2D quantum error correcting codes that enable a transversal implementation of all logical gates required for the universal quantum computing. Transversal logical gates (TLG) are encoded operations that can be realized by applying some single-qubit rotation to each physical qubit. TLG are highly desirable since they introduce no overhead and do not spread errors. It has been known before that a quantum code can have only a finite number of TLGs which rules out computational universality. Our scheme circumvents this no-go result by combining TLGs of two different quantum codes using the gauge-fixing method pioneered by Paetznick and Reichardt. The first code, closely related to the 2D color code, enables a transversal implementation of all single-qubit Clifford gates such as the Hadamard gate and the $\pi/2$ phase shift. The second code that we call a doubled color code provides a transversal T-gate, where T is the $\pi/4$ phase shift. The Clifford+T gate set is known to be computationally universal. The two codes can be laid out on the honeycomb lattice with two qubits per site such that the code conversion requires parity measurements for six-qubit Pauli operators supported on faces of the lattice. I will also describe numerical simulations of logical Clifford+T circuits encoded by the distance-3 doubled color code. Based on a joint work with Andrew Cross.