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Single-Setting Quantum State Characterization

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A cornerstone of all quantum technology is the reliable characterization of the underlying building blocks, in particular the prepared quantum states. The standard approach for this task is to perform local Pauli measurements and from that estimate the quantities of interest. As the system size grows, however, the number of measurement bases to consider grows exponentially. We show that this challenge can be overcome by implementing symmetric informationally complete (SIC) POVMs on a trapped-ion quantum processor. While SIC POVMs are non-projective and cannot be implemented in a qubit, we make use of additional states within each ion to locally extend the Hilbert space from two to four dimensions, where SIC POVMs can be measured directly. This approach thus enables full quantum state characterization with a single, fixed measurement setting independent of the system size and with negligible experimental overhead. Combining the SIC POVM measurements with classical shadows enables the efficient estimation of arbitrary linear and nonlinear properties of quantum states orders of magnitude faster than standard methods. We demonstrate this potential by performing online tomography of an eight-qubit state in real time.

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