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Quantum Control Engineering with Trapped Ions

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Technologies fundamentally enabled by quantum mechanics are poised to transform a broad range of applications from computation to precision metrology over the coming decades. This talk will introduce a new field of research which is seeing concepts from control engineering translated to the domain of quantum mechanics in an effort to realize the full potential of engineered quantum technologies. We focus on understanding the physics underlying controlled quantum dynamics in the presence of rapidly fluctuating time-dependent Hamiltonians, leveraging the unique capabilities provided by trapped ions as a model quantum system. Our results introduce and experimentally validate generalized filter-transfer functions which cast arbitrary quantum control operations on qubits as noise spectral filters. We demonstrate the utility of these constructs for directly predicting the evolution of a quantum state in a realistic noisy environment, for developing novel robust control and sensing protocols, and for improving the stability of atomic clocks. This work demonstrates how quantum control can be leveraged to overcome some of the most challenging problems in quantum engineering, and even provide totally new functionality to quantum systems.