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New Developments in Quantum Control: Phase Space Learning Algorithms and Uncontrollable Quantum Systems[1]

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This talk has two parts. The first deals with a new representation of shaped ultrafast laser pulses based on a von Neumann time-frequency lattice. We show that a pulse defined in terms of an amplitude and a phase at N frequency points can be represented on the von Neumann lattice using $\sqrt{N}$ points in frequency and $\sqrt{N}$ in time without loss of information. The transformation from the frequency (or time) representation to the von Neumann representation is one-to-one and therefore invertible. We discuss three possible applications of the von Neumann representation of pulses: 1) for cleaning and interpreting complex pulses; 2) for performing systematic scans of the effect of timing and frequency on molecular control; 3) as genes to be used in mutations and crossover in evolutionary algorithms. The second part of the talk deals with the classification of uncontrollable quantum systems. It is well-known that for a quantum system to be controllable the Lie algebra spanned by iterated commutators of H_0 and H_1 must span the full space of the dynamical algebra. We pose the following questions: When a system is **not** completely controllable, can we classify different families of uncontrollable systems? If so, can we associate these different types of mathematical structures with different underlying physics (for example, dark states or generalized entangled states)? We show that uncontrollable quantum systems fall into two categories: reducible and irreducible. The former is associated with dark states and the latter with generalized entangled states. Based on Lie subalgebras we give a complete characterization of irreducible uncontrollable systems for systems up to 9 levels. Finally, we show that an earlier intuitive concept of connectivity only incompletely captures this Lie algebraic structure of uncontrollable systems.

[1]The first part of this work was done in collaboration with Susanne Fechner, Frank Dimler, Tobias Brixner, and Gustav Gerber, University of Wuerzburg. The second part was done in collaboration with Thomas Polack and Haim Suchowski, Weizmann Institute.