Banff International Research Station (BIRS)

for Mathematical Innovation and Discovery

Workshop on Quantum Control

April 4–8, 2010

Workshop Program

General Information

Meals

Breakfast (Buffet): 7:00–9:30 am, Sally Borden Building, Monday–Friday*

Lunch (Buffet): 11:30 am–1:30 pm, Sally Borden Building, Monday–Friday*

Dinner (Buffet): 5:30–7:30 pm, Sally Borden Building, Sunday–Thursday*

Coffee Breaks: As per daily schedule, 2nd floor lounge, Corbett Hall

***Please remember to scan your meal card at the host/hostess station in the dining room for each meal.**

Meeting Rooms

All lectures will be held in Max Bell 159 (Max Bell Building accessible by walkway on 2nd floor of Corbett Hall).

LCD projector, overhead projectors and blackboards are available for presentations.

Note that the meeting space designated for BIRS is the lower level of Max Bell, Rooms 155–159. Please respect that all other space has been contracted to other Banff Centre guests, including any Food and Beverage in those areas.

Schedule

Sunday, April 3

16:00 **Check-in** begins
(Front Desk - Professional Development Centre - open 24 hours)
Lecture rooms available after 16:00 (if desired)

17:30–19:30 Buffet Dinner, Sally Borden Building

20:00– Informal gathering in 2nd floor lounge, Corbett Hall
Beverages and a small assortment of snacks are available on a cash honor system.

Monday, April 4

7:00–8:45	Breakfast
8:45–9:00	Introduction and Welcome by BIRS Station Manager, Max Bell 159
9:00–9:30	**Welcome and Introduction by Organizers**
9:30–10:30	**Survey Talk I** **David Tannor**, Weizmann Institute .... 17 *Overview of the control of physical quantum systems*
10:30–10:45	Coffee Break, 2nd floor lounge, Corbett Hall
10:45–11:30	**Discussion** on Survey Talk I
11:30–13:30	Lunch
13:30–14:00	Group Photo; meet on the front steps of Corbett Hall
14:00–15:00	**Survey Talk II** **Jean-Michel Coron**, Laboratoire Jacques-Louis Lions .... 12 *Feedback laws: results and methods, with applications to quantum control systems*
15:00–15:30	Coffee Break, 2nd floor lounge, Corbett Hall
15:30–16:00	**Discussion** on Survey Talk II
16:00–16:10	Short break
16:10–17:30	**Recent Research Results I** **Kirsten Morris**, University of Waterloo .... 16 *Controller design for infinite-dimensional systems* **Andreea Grigoriu Lachapelle**, Princeton University .... 13 *Laser-Driven Quantum Control of Nuclear Excitations* **Mazyar Mirrahimi**, INRIA Paris-Rocquencourt .... 15 *Approximate stabilization of an infinite dimensional quantum stochastic system* **Robert Kosut**, SC Solutions .... 13 *Adaptive/Learning Quantum Control via Extremum Seeking Feedback*
17:30–19:30	Dinner

Tuesday, April 5

7:00–8:45 Breakfast

8:45–9:45 **Survey Talk III**
Re-Bing Wu, Tsinghua University 18
Quantum Control Landscapes

9:45–10:15 **Discussion** on Survey Talk III

10:15–10:30 Coffee Break, 2nd floor lounge, Corbett Hall

10:30–11:30 **Recent Research Results II**
Sophie Schirmer, University of Cambridge 17
Optimal control algorithms and landscape issues
Constantin Brif, Princeton University 10
Robustness of quantum information processing to the control noise
Katharine Moore, Princeton University 16
Are landscape traps lurking to impede quantum control?

11:30–13:30 Lunch

13:30–14:30 **Survey Talk IV**
Enrique Zuazua, Basque Center of Applied Mathematics 18
Control and Numerics: Continuous versus discrete approaches

14:30–15:00 **Discussion** on Survey Talk IV

15:00–15:20 Coffee Break, 2nd floor lounge, Corbett Hall

15:20–16:20 **Survey Talk V**
André Bandrauk, Université de Sherbrooke 10
FAZSST-Femto-Atto-Zepto-Second Simulations-Theory
(Science and Technology)

16:20–16:50 **Discussion** on Survey Talk V

16:50–17:30 **Recent Research Results III**
Aurora Marica, BCAM 14
On the quadratic finite element approximation of 1-D waves:
propagation, observation, control and numerical implementation
Quan-Fang Wang, The Chinese University of Hong Kong 18
Numerical Quantum Control

17:30–19:30 Dinner

Wednesday, April 6

7:00–8:45 Breakfast

8:45–9:45 **Survey Talk VI**
Raj Chakrabarti, Purdue University 11
Engineering Control: Concepts and their links/opportunities offered to Quantum Control

9:45–10:15 **Discussion** on Survey Talk VI

10:15–10:30 Coffee Break, 2nd floor lounge, Corbett Hall

10:30–11:30 **Recent Research Results IV**
Gabriel Turinici, Université Paris Dauphine 17
Multi-polarization quantum control of rotational motion through dipole coupling
Shuang Cong, University of Science and Technology of China 12
Resent Researches on Quantum Systems Controls based on Lypunov methods in USTC
Matthew D. Grace, Sandia National Laboratories 12
Protecting Quantum Information with Optimal Control

11:30–13:30 Lunch

13:30–14:30 **Survey Talk VII**
Alberto Castro, University of Zaragoza 11
Time-dependent Density Functional Theory and its rôle in quantum control

14:30–15:00 **Discussion** on Survey Talk VII

15:00–15:20 Coffee Break, 2nd floor lounge, Corbett Hall

15:20–16:20 **Survey Talk VIII**
Thomas Chambrion, Nancy University 11
Finite dimensional techniques for control of bilinear Schrdinger equations

16:20–16:50 **Discussion** on Survey Talk VIII

16:50–17:30 **Recent Research Results V**
Vahagn Nersesyan, Versailles 16
Controllability for Schrödinger equations and applications
Alex Brown, University of Alberta 10
Optimal control of quantum dynamics in polyatomic molecules

17:30–19:30 Dinner

Thursday, April 6

7:00–8:30 Breakfast

8:30–10:10 **Recent Research Results VI**

Roderick Melnik, Wilfrid Laurier University 14
Gate Control of Single Electron Spins in Quantum Dots via the Application of the Geometric Phase

Francesca Chittaro, L2S-Supléc 12
Quantum Control via adiabatic Theory

Yannick Privat, Ecole Normale Suprieure de Cachan 17
Modelling and control of a loop shaped nanowire

Andreas Jacob, MPI Dresden 13
Rotational effects on enantioseparation

Chitra Rangan, University of Windsor 17
Role of complex control matrices in the adiabatic control of sequentially connected quantum states

10:10–10:30 Coffee Break, 2nd floor lounge, Corbett Hall

10:30–11:30 **Recent Research Results VII**

Robert Kosut, SC Solutions 13
Quantum Process Tomography via Compressive Sensing

Cristian Cazacu, BCAM 11
Controllability of the wave and the Schrödinger equations with inverse square potentials in a new functional framework

Kevin Young, Sandia National Labatories 18
Quantum control for noise spectroscopy

11:30–13:30 Lunch

14:00–17:30 Free Afternoon

17:30–19:30 Dinner

Friday, April 8

7:00–9:00 Breakfast

9:00–11:30 **Draft workshop report**

10:00–10:30 Coffee Break, 2nd floor lounge, Corbett Hall

11:30–13:30 Lunch

End of workshop. Checkout by 12 noon*

*5-day workshops are welcome to use BIRS facilities (2nd Floor Lounge, Max Bell Meeting Rooms, Reading Room) until 3 pm on Friday, although participants are still required to checkout of the guest rooms by 12 noon.

List of Participants

List of Abstracts

Bandrauk, André, Université de Sherbrooke

FAZSST-Femto-Atto-Zepto-Second Simulations-Theory (Science and Technology)

Abstract: Advances in modern laser technology allow for the generation of phase controlled intense ultrashort (few cycles) ($> 10^{14}$ W/cm^2) pulses with which one can explore light-matter interactions in the nonlinear nonperturbative regime. One important "spin-off" of this research has been the theoretical prediction and finally the experimental implementation of MHOHG, Molecular High Order Harmonic Generation [1], the main source of current attosecond (asec = 10^{-18} s) pulses and asec physics [2]. Since the electron orbit period in the H atom is 152 asecs, such pulses will become the preferred future tools for "imaging, visualizing and finally controlling" electron motion in matter on its own time scale. Nuclear motion, such as proton motion, the fastest atom in chemistry, biology, etc., whose own time scale is ~ 10 femtoseconds (fs = 10^{-15} s) adds another time scale to the complete control of matter at the atomic and molecular level. Numerical solutions of multidimentional molecular time-dependent Schrödinger equations, TDSEs, and/or Dirac equations, TDDEs for relativistic effects coupled to the photon Maxwell equations on multiprocessor parallel supercomputers are the essential tools for modelling and simulating the generation of asec pulses. Simple classical models based on laser induced recollision, LIER [3], surprisingly add simple interpretations of nonlinear nonperturbative phenomena such as MHOHG. The asec pulses are becoming the essential tools for creating Coherent Electron WavePackets, CEWPs [2,4]. The generation of these wave packets, intrinsic properties, their coherence and decoherence from asec to fs timescales due to coupling with nuclear motion are the subject of a new science-Attosecond Science; i.e., the ultimate control of electrons in matter [5-6].

[1] A D Bandrauk et al, in "Progress in Ultrafast Intense Laser Science", edit K Yamanouchi et al. (Springer,NY,2007),chapt 9
[2] F Krausz,M Y Ivanov, Rev Mod Phys 81,163(2009)
[3] P B Corkum, Phys Today,March 2011,p 36
[4] A D Bandauk,N H Shon, Intnl J Quant Chem,100,834(2004)
[5] "The Economist", nov 2010, p 161
[6] "La Recherche",#448, jan 2011

Brif, Constantin, Princeton University

Robustness of quantum information processing to the control noise

Authors: Constantin Brif, Katharine W. Moore, David Hocker, Matthew D. Grace, Tak-San Ho, and Herschel Rabitz

Abstract: External controls are necessary to enact quantum logic operations, and the inevitable control noise will result in gate errors in a realistic quantum computer. We investigate the robustness of unitary quantum gates to the noise in an optimal control field, by utilizing properties of the quantum control landscape that relates the physical objective (in the present case, the quantum gate fidelity) to the applied controls. We also explore possibilities of identifying controls with improved robustness by using the analysis of landscape characteristics in the vicinity of the optimal control manifold.

Brown, Alex, University of Alberta

Optimal control of quantum dynamics in polyatomic molecules

Abstract: In this talk, I will highlight briefly our recent work combining optimal control

theory with the multi-configuration time-dependent Hartree approach for examining the quantum dynamics (OCT-MCTDH). I will illustrate the method using results from control of quantum dynamics in ammonia (NH3) with six vibrational degrees of freedom. I will introduce some of the challenges and potential problems that can be tackled with this approach.

Castro, Alberto, University of Zaragoza
Time-dependent Density Functional Theory and its rôle in quantum control
Abstract: TBA

Cazacu, Cristian, Basque Center for Applied Mathematics
Controllability of the wave and the Schrödinger equations with inverse square potentials in a new functional framework
Abstract: In [1] the authors have shown the null-controllability of the wave and the Schrödinger equations with singular potentials, in terms of the Hardy inequality and its corresponding Hardy functional introduced in [3]. Here, we reformulate the controllability problem discussed in [1] by means of a new Hardy norm. This is necessary due to the oscillations near origin produced by the standard Hardy functional as emphasized by [2]. The goal of the talk is to show briefly that the multipliers identity, which is the main tool to prove control properties in our situations, holds true in the new functional setting.

[1] J. Vancostenoble and E. Zuazua, *Hardy inequalities, observability, and control for the wave and Schrödinger equations with singular potentials*, SIAM J. Math. Anal. 41 (2009), no. 4, 1508-1532.

[2] J. L. Vázquez and N. B. Zographopoulos, *Functional aspects of the Hardy inequality. Appearance of a hidden energy*, http://arxiv.org/abs/1102.5661.

[3] J. L. Vázquez and E. Zuazua, *The Hardy inequality and the asymptotic behaviour of the heat equation with an inverse-square potential*, J. Funct. Anal. 173 (2000), no. 1, 103-153.

Chakrabarti, Raj, Purdue University
Engineering Control: Concepts and their links/opportunities offered to Quantum Control
Abstract: TBA

Chambrion, Thomas, Nancy University
Finite dimensional techniques for control of bilinear Schrödinger equations
Abstract: Controllability issues for finite dimensional bilinear systems are now pretty well understood. The situation is much more complicated for infinite dimensional bilinear systems. In the recent few years, some substantial advances have been made on the control of the infinite dimensional bilinear Schrödinger equation when the free Hamiltonian has discrete spectrum. The aim of this talk is to present a survey of these results and to demonstrate on an example the strengths and the limits of geometric control theory for bilinear quantum control.

Chittaro, Francesca , L2S-Supléc
Quantum Control via adiabatic Theory
Autors: Francesca Chittaro, Ugo Boscain, Paolo Mason and Mario Sigalotti
Abstract: The abstract is the following "In this talk we present a constructive method to control the bilinear Schrodinger equation via two controls. The methods is based on adiabatic techniques and works is the spectrum of the Hamiltonian admits conical eigenvalues intersection.

Cong, Shuang, University of Science and Technology of China
Resent Researches on Quantum Systems Controls based on Lypunov methods in USTC
Abstract: In this presentation, I will give some introduction on our resent research results on quantum systems controls. In the closed quantum system control, our main achievements are in the preparation and transfer methods design of the different kinds of states, such as eigenstate transfer, superposition states preparation, pure state control, mixed state transfer, purification of mixed state, and transfer from arbitrary pure state to target mixed state. In the open quantum system control, we published papers have: design of control sequence of pulses for the population transfer of high dimensional spin 1/2 quantum systems, purity and coherence compensation by using interactions, purity preservation of quantum systems by resonant field, phase decoherence suppression in arbitrary n-level atom in Ξ-configuration with Bang-Bang controls, preparation of entanglement states in a two-spin system by Lyapunov-based method. I also present some work on cooperation with the Hefei National Laboratory for Physical Sciences at the Microscale in real quantum device implementation.

Coron, Jean-Michel, Laboratoire Jacques-Louis Lions
Feedback laws: results and methods, with applications to quantum control systems
Abstract: TBA

Grace, Matthew D., Sandia National Laboratories
Protecting Quantum Information with Optimal Control
Authors: Matthew D. Grace, Paul Boggs, Constantin Brif, Malcolm Carroll, Jason Dominy, Robert Kosut, Daniel Lidar, Herschel Rabitz, Wayne Witzel
Abstract: Methods of optimal control (OC) are applied to elements of a spin-based quantum information processor (QIP), providing solutions for the generation of logical operations and the suppression of decoherence. The results illustrate how practical quantum computing can be greatly facilitated by OC and reveal interesting physical insights through the discovery of effective control mechanisms. Optimization algorithms are developed which generate controls that protect the QIP from the effects of the environment, and simultaneously achieve a target objective, e.g., a state-to-state transition or unitary quantum operation. For unitary control, we developed a measure that evaluates the distance between unitary time-evolution operations of a composite quantum system consisting of a QIP and environment, where only the effect on the QIP is relevant. Results from optimal robust control and hybrid quantum control protocols integrating dynamical decoupling and optimal control will be presented.

Grigoriu Lachapelle, Andreea, Princeton University
Laser-Driven Quantum Control of Nuclear Excitations
Abstract: The possibility of controlled direct laser-nuclear excitations is considered from a quantum control perspective. In particular, the controllability of laser-driven electric and magnetic dipole transitions is analyzed amongst pure nuclear states. Within a set of realistic and general conditions, atomic nuclei are demonstrated to possess full state controllability.

Jacob, Andreas, MPI Dresden
Rotational effects on enantioseparation
Abstract: Recently, several ideas to separate enantiomers have been proposed, i.e. to split molecules in a left handed configuration from their right handed mirror state [1,2]. They are based on the dynamics described by the equations of motion in an adiabatic basis produced by laser induced gauge potentials. Since the effect of molecular rotation has been neglected in these studies, we want to study the influence of the orientation state on the enantioseparation by numerical integration of the full molecular rotation state.
[1] Li, Bruder and Sun, Physical Review Letters 99, 130403 (2007)
[2] Li and Shapiro, The Journal of Chemical Physics 132, 194315 (2010)

Kosut, Robert, SC Solutions
Adaptive/Learning Quantum Control via Extremum Seeking Feedback
Abstract: In this talk I will report on very recent work, essentially preliminary efforts, to find open loop control of a quantum system using the control update algorithm referred to as "extremum seeking feedback" [*]. The goal of quantum control is oftentimes either to increase the population of a designated quantum state or to make the dynamic behavior attain as close as possible to a desired unitary. In the former we are trying to maximize a probability function associated with the desired state. In the latter we are trying to maximize the fidelity between the actual process and the desired unitary. In either case the problem is one of seeking to maximize a function of the control, i.e., seeking the extremum of some unknown function of the control. This is the scenario envisioned for the work described in [*]. It is in effect an automated feedback system whose goal is to find the unknown extremum using data from the actual system. It relies on very comprehensible filters and associated parameters which can be selected by the user. I will briefly describe how I see its use in the two quantum control scenarios mentioned previously. Whether or not it is competitive or compatible with current validated approaches (e.g., [**]) remains to be seen.
[*] Kartik Ariyur and Miroslav Krstic. "Real-Time Optimization by Extremum Seeking Feedback," Wiley (2003).
[**] H. Rabitz, M. Hsieh, and C. Rosenthal, "Quantum Optimally Controlled Transition Landscapes," Science, 303, 998 (2004).

Kosut, Robert, SC Solutions
Quantum Process Tomography via Compressive Sensing
Abstract: In this talk I will summarize our recent work reported in [*] on the theory and supporting experiment showing the efficacy of using a "compressive sensing" approach to

quantum process tomography. As stated in the abstract for [*], the resources required to characterize the dynamics of engineered quantum systems—such as quantum computers and quantum sensors—grow exponentially with system size. Consequently, only small two- and three-qubit entangling logic-gates have been fully characterized. Here we adapt techniques from compressive sensing to exponentially reduce the experimental configurations required for quantum process tomography. Our method is applicable to dynamical processes that are known to be nearly-sparse in a certain basis and which can be implemented using only single-body preparations and measurements. We perform efficient, high-fidelity estimation of process matrices on an experiment attempting to implement a photonic two-qubit logic-gate. The data base is obtained using two- and four- photons, under various decoherence strengths. We find that our technique is both accurate and noise robust, thus removing a key roadblock to the development and scaling of quantum technologies.
[*] "Efficient Measurement of Quantum Dynamics via Compressive Sensing", by Alireza Shabani, Robert Kosut, Masoud Mohseni, Hersch Rabitz, Matthew Broome, Marcelo de Almeida, Alessandro Fedrizzi, and Andrew White. Physical Review Letters (March 2011).

Marica, Aurora, Basque Center of Applied Mathematics
On the quadratic finite element approximation of 1-D waves: propagation, observation, control and numerical implementation
Authors: Aurora Marica and Enrique Zuazua
Abstract: We will present the propagation, observation and control properties of the 1-d wave equation on a bounded interval discretized in space using the quadratic classical finite element approximation. A careful Fourier analysis of the discrete wave dynamics reveals two modes: the acoustic one, of physical nature, and the optic one, related to the perturbations that this second-order finite element approximation introduces with respect to the linear one. On both modes high frequencies have vanishing group velocity as the mesh size tends to zero. Therefore, one can construct numerical solutions for which the energy is concentrated in the interior of the domain, without propagating, making the discrete observability constant to blow-up. This shows that the classical property of continuous waves of being observable from the boundary fails to be uniform for this discretization scheme. As a consequence of this, we also show that the controls of minimal norm for the discrete waves may blow-up as the mesh size tends to zero. To remedy these high frequency pathologies, we design filtering mechanisms based on a bi-grid algorithm for which one can recover the uniformity of the observability constant in a finite time and, consequently, the possibility to control with uniformly bounded L^2-controls appropriate projections of the solutions. We will also present implementation details of these filtering mechanisms and some numerical results.

Melnik, Roderick, Wilfrid Laurier University
Gate Control of Single Electron Spins in Quantum Dots via the Application of the Geometric Phase
Authors: Sanjay Prabhakar and Roderick Melnik
Abstract: Coherent states of single electron spins in quantum dots can be topologically protected by moving the dots adiabatically in a closed loop in the plane of two-dimensional electron gas (2DEG) with the application of magnetic fields, as well as electric fields. We

study the non-Abelian unitary operator of single electron spin states during the adiabatic motion of (GaAs) quantum dots in two dimensions. In one complete adiabatic rotation of such a dot, in addition to the dynamical phase factor, the system acquires an additional phase factor. This additional phase is referred to as the geometric phase or Berry phase. The non-Abelian nature of spin states in the geometric phase stems from the Rashba and Dresselhaus spin-orbit coupling of an electron in two dimensions. The Rashba spin-orbit coupling arises due to the structural inversion symmetry along the z-direction, while the bulk inversion symmetry gives rise to the Dresselhaus spin-orbit coupling. The evolution operator, which is responsible for the Berry phase, is not easy to evaluate since it contains non-commuting spin operators.

In recent work [1], we have found an exact analytical expression for the transition probability of electron spins in quantum dots for the equal strength of Rashba and Dresselhaus spin-orbit couplings. We have estimated the spin diffusion length and found the conditions under which the complete spin flip occurs. Similar to quantum wells [2], the corresponding phenomenon associated with these findings is termed as the persistent spin helix in quantum dots.

In this talk, we extend the results obtained in [1] and present an exact analytical expression for the non-Abelean unitary operator (the transformation matrix) for electron spin states in quantum dots influenced by spin-orbit interactions. We utilize the Feynman disentangling technique to find such an expression for three different cases: (a) the pure Rashba case, (b) the pure Dresselhaus case, and (c) the case with equal strengthes of Rashba and Dresselhaus spin-orbit couplings. Finally, we note that for unequal strengthes of Rashba and Dresselhaus spin-orbit couplings, the solution for the unitary transformation is highly non-trivial and we develop a numerical procedure to determine the transition probability of electron spins in this latter case.

References:

[1] S. Prabhakar, J. E. Raynolds, A. Inomata and R. Melnik, Manipulation of single electron spin in a GaAs quantum dot through the application of geometric phases: the Feynman disentangling technique, *Physical Review B*, **82**, 195306, 2010.

[2] J.D. Koralek, et al, Emergence of the persistent spin helix in semiconductor quantum wells, *Nature*, **458**, 07871, 2009.

Mirrahimi, Mazyar, INRIA Paris-Rocquencourt

Approximate stabilization of an infinite dimensional quantum stochastic system

Abstract: We propose a feedback scheme for preparation of photon number states (also called Fock states) in a microwave cavity. Quantum Non-Demolition measurements of the cavity field and a control signal consisting of microwave pulses injected into the cavity are used to drive the system towards a desired target photon number state. The measured system is modeled through a discrete-time Markov chain on an infinite-dimensional Hilbert space. The feedback design is then based on an (unbounded) strict Lyapunov function whose expectation is minimized at each time step. We prove the weak convergence of probability measures induced by the dynamics, towards a propbability measure whose distribution is concentrated on the desired target state. Numerical simulations illustrate the efficiency of the feedback law and the robustness with respect to various experimental uncertainties.

Moore, Katharine, Princeton University

Are landscape traps lurking to impede quantum control?

Abstract: Quantum control landscapes have recently received much attention because their topology and structure determine the feasibility of performing successful and efficient control. The topology of quantum control landscapes can be shown to contain no sub-optimal extrema (traps) when the target system is controllable, the Jacobian $\delta U(T, 0)/\delta\varepsilon(t)$ is full-rank, and no constraints are placed on the controls. Recently, unusual control conditions have been identifed that lead to traps on the landscape. This talk will address the question of whether traps on the control landscape are encountered for realistic simulations in which care is taken to avoid placing constraints on the controls. Thousands of numerical simulations optimizing state-to-state population transfer and unitary propagator control were performed, all of which converged to the desired objective value upon allowing sufficient flexibility in the controls. Thus, no landscape traps were observed when no signicant constraints were imposed on the controls. The effects on the landscape topology are also discussed for circumstances where the controls are constrained by limiting the final time T or fixing the form of the control field with a few variable parameters.

Morris, Kirsten, University of Waterloo

Controller design for infinite-dimensional systems

Abstract: For many quantum control problems, for example controlling n-spins (such as in NMR-based quantum computing), the state-space is finite-dimensional. In other situations, the state space is an infinite-dimensional Hilbert space. The standard approach is to use the first two lowest energy levels. This is often justified when there is a large energy gap which inhibits transitions to the higher levels. In practice, higher energy levels often do get populated. One approach is to try to control the system so that the quantum state does not evolve to populate the higher energy levels. There are several approaches that have been tried, most of which incorporate using higher order modes. Even when the controller will be finite-dimensional, there are a number of issues that can only be addressed by considering the infinite-dimensional nature of the problem when designing the control. One problem occurs when attempting to control a system within a given subspace. Unlike finite-dimensional systems, generator invariance does not imply trajectory invariance. I will review briefly the results for invariance of linear infinite-dimensional systems. For most applications, a finite-dimensional approximation must be used when designing a controller. The hope is that the controller will have the desired effect when implemented on the original system. Some issues associated with this approach will be discussed.

Nersesyan, Vahagn, Versailles

Controllability for Schrödinger equations and applications

Abstract: We present some recent results on the controllability of Schrdinger equations. The control is a scalar function depending only on the time. In particular, we show that the system in question is exactly controllable in infinite time. Then the controllability properties are used in the study of the random Schrdinger equation: we prove that the system has at most one invariant measure and any trajectory is almost surely non-bounded in Sobolev spaces.

Privat, Yannick, Ecole Normale Suprieure de Cachan
Modelling and control of a loop shaped nanowire
Abstract: We investigate the problem of describing the possible stationary configurations of the magnetic moment in a loop shaped nanowire, or in a network of ferromagnetic nanowires with length L connected by semiconductor devices. The dynamical model that we use is based on the one-dimensional Landau-Lifshitz equation of micromagnetism. We compute all L-periodic steady-states of that system, define an associated energy functional, and these steady-states share a quantification property in the sense that their energy can only take some precise discrete values. Then, based on a precise spectral study of the linearized system, we investigate the stability properties of the steady-states. In turn, we derive some controllability results, showing that it is possible to pass from any steady-state to any other one by means of an external (scalar) magnetic field.

Rangan, Chitra, University of Windsor
Role of complex control matrices in the adiabatic control of sequentially connected quantum states
Authors: Chitra Rangan, Mustafa Sheikh and John Donohue
Abstract: We examine the adiabatic control of finite-dimensional quantum systems whose field-free eigenstates are sequentially connected by the control Hamiltonian. In particular, we study the situation when one (or more) of the control Hamiltonians is complex. Contrary to the case when the control Hamiltonians are real, the dynamics do not separate into two real control problems, but into two complex control problems nevertheless. The example of STIRAP in this system is also analyzed.

Schirmer, Sophie, University of Cambridge
Optimal control algorithms and landscape issues
Abstract: In this talk I will briefly touch on some core landscape issues and the convergence behaviour of different types of algorithms and some key differences between the continuous optimal control and discretized control optimization problem. I will also discuss control optimization in the Markovian vs Non-Markovian regime if time permits.

Tannor, David, Weizmann Institute
Overview of the control of physical quantum systems
Abstract: TBA

Turinici, Gabriel, Université Paris Dauphine
Multi-polarization quantum control of rotational motion through dipole coupling
Abstract: In this talk we analyze the quantum controllability of rotational motion under the influence of an external laser field coupled through a permanent dipole moment. The analysis takes into consideration up to three polarization fields, but we also discuss the consequences for working with fewer polarized fields.

Wang, Quan-Fang, The Chinese University of Hong Kong
Numerical Quantum Control
Abstract: In the study of quantum system control in theoretical, computational and experimental aspects, numerical approach play a much more important role. Combining with the theoretic conclusion, numeric always can predict the right direction in the real particle control. It just like a “bridge to make non-understanding points clear, and connected “theory investigation with “practical realization smartly. This presentation is lay on the interesting in the “Numerical Control of quantum system in single particle as well as (poly) multi–particles case. Particularly, computer aided numerical analysis; simulation; demonstrations would be our target to be considered. It is hoped that computational issues would have huge developing space and wide applicable place in quantum control field.

Wu, Re-Bing, Tsinghua University
Quantum Control Landscapes
Abstract: In the talk I will give a brief survey over the theory of quantum control landscapes, which were developed recently for understanding the “ease” of quantum control in the large amount of experiments and simulations. The basic questions and their origins will be introduced. Then, I will summarize what has been done in this field and what it implies in quantum control. Finally, open questions will be discussed.

Young, Kevin, Sandia National Labatories
Quantum control for noise spectroscopy
Abstract: I will discuss a procedure for direct characterization of the dephasing noise acting on a single qubit by making repeated measurements of the qubit coherence under suitably chosen sequences of controls. I show that this scheme allows a numerical reconstruction of the short time noise correlation function and that it can be combined with a series of free evolution-type experiments to allow for a characterization of the noise correlation function over many orders of magnitude range in timescale. I will also present an analysis of the robustness and reliability of the estimated correlation functions.

Zuazua Iriondo, Enrique, Basque Center of Applied Mathematics
Control and Numerics: Continuous versus discrete approaches
Abstract: Control Theory and Numerical Analysis are two disciplines that need to be combined when facing most relevant applications. This is particularly the case for problems involving Partial Differential Equation (PDE) modelling. There are two possible approaches. The continuous one, consisting on developing the control theory at the PDE level and, once controls are fully characterized, to implement the numerical approximation procedure. And the discrete one, consisting in doing the reverse, i.e. first discretizing the model and then controlling the resulting discrete system. In this lecture we shall compare these two approaches in two relevant examples: The control of vibrations and the control of flows in the presence of shocks. As we shall see, a number of unexpected phenomena occur and challenging problems arise both from a mathematical and applicational viewpoint.