Centre for Theoretical Atomic, Molecular, and Optical Physics

Ph.D. Project 2022-2025

Optimal control of quantum complex systems

Project supervisors: **Gabriele De Chiara**
Contacts: **g.dechiara@qub.ac.uk**

State of the art and motivations

The creation and manipulation of complex many-body quantum states form the basis of quantum simulations, which are expected to lead to substantial advances in, for example, quantum chemistry and condensed matter physics. Highly entangled many-body states furthermore provide substantial advantages for quantum sensing and metrology applications. However, the control of these complex systems is generally hindered by not only their inherent complexity, but also by dissipation, fluctuating environments, and their intrinsic disorder arising from imperfections in fabrication and/or in applied fields. The overarching goal of this proposal is to design new, experimentally viable techniques for the control of complex quantum systems that are resilient to the most relevant sources of noise and imperfections, while also ensuring that they are resource efficient and scalable.

Objectives & Methodology

The first objectives is the development of hybrid control algorithms that combine the advantages of existing methods. State-of-the-art control techniques can be broadly classified into two camps: (i) analytic approaches termed “shortcuts to adiabaticity” and (ii) numerical methods captured under “optimal control”, each of which come with their own inherent benefits and limitations. By combining these approaches while also assessing the resource intensiveness of the resulting techniques, a roadmap for scalable control will be laid out.

We will apply these new techniques for the control of complex quantum systems including open, critical, and disordered quantum many-body systems. The most promising techniques will be applied to systems of increasing complexity, where traditional control techniques typically struggle. In addition to providing a practical toolbox for control which can be applied, e.g., in useful metrological contexts, this will also provide novel means to study fundamental many-body phenomena such as localisation and phase transitions.

Collaborations

We anticipate collaborations with the theoretical group led by Prof. Steve Campbell at University College Dublin and with the experimental group led by Prof. Ulrich Schneider at Cambridge.

Required skills

A good knowledge of quantum theory is necessary. The candidate should be familiar with at least a programming language and basic numerical techniques.

Further information

For further information, please contact me, g.dechiara@qub.ac.uk.