Subject: Catalysis of entanglement and general quantum resources

Supervisor: Alexander Streltsov, Institute of Fundamental Technological Research, Polish Academy of Sciences

Description

Quantum coherence and entanglement are fundamental features of quantum systems, separating quantum physics from its classical counterpart. In the early days of quantum mechanics entanglement has been considered as a puzzling phenomenon, and Einstein has famously termed it "spooky action at a distance". Over the last decades the situation has changed, with the existence of entanglement being confirmed in numerous experiments. Today, quantum entanglement is considered as a resource for the emerging quantum technologies, allowing us to surpass limitations of classical devices. This has led to the development of the *resource theory of entanglement*, allowing us to investigate the role of entanglement for technological applications, such as quantum teleportation and quantum cryptography.

Recent results show that not all quantum technological applications are based on the presence of entanglement, but require other types of nonclassicality. An important example is quantum computation: a process which uses the laws of quantum mechanics to solve problems which are not efficiently solvable on classical computers, e.g. prime factorization. As of today, we do not have a full understanding which quantum features are responsible for the advantage of quantum computers. While an ideal quantum computer – operating on noiseless quantum states – requires entanglement to show exponential speedup over classical computation, the role of entanglement for noisy quantum computation is unknown. This opens the possibility for quantum algorithms operating on unentangled noisy states at a high temperature, while the quantum algorithms still solve certain classes of problems exponentially faster than any known classical algorithm. Preliminary results show that *quantum coherence* might be more suitable than entanglement for capturing the performance of noisy quantum computation.

The research directions of the project cover the following areas:

- Catalysis of quantum resources: We aim to investigate the role of catalysis for general quantum resource theories. Concretely, we aim to provide a full characterization of possible state transformations in the presence of catalysts. For this, we will consider specific resource theories, including the theories of entanglement and coherence, with the goal to develop general results which are valid for all quantum resource theories.
- Speed limits for quantum resource generation: We aim to provide general speed limits on creation of quantum resources. Concretely we will consider resource theories of coherence, entanglement, and imaginarity, where we aim for tight speed limits, giving the minimal time for establishing a certain resource amount. For entanglement theory we aim to provide a complete solution for transitions between pure states and maximally correlated states, for which various entanglement quantifiers can be evaluated analytically.

Profile of the candidates

Applicants should have a master's degree in engineering, physics or related areas, and have a good understanding of quantum theory. Candidates are strongly advised to contact Alexander Streltsov before formal submission of the documents: astrel@ippt.pan.pl