

BRIEF DESCRIPTION FOR THE GENERAL PUBLIC

The advent of quantum theory has not only changed our understanding of physics at the micro-scale but has also led to discovery of new phenomena that would have never been possible in the classical world. These are in particular quantum entanglement, nonlocality, quantum contextuality or measurement incompatibility, which in recent years have been recognized as powerful resources for interesting applications such as quantum cryptography, quantum teleportation, quantum computation, metrology, or, more recently, true randomness certification. These discoveries made us realize that quantum phenomena can be harnessed to design and perform tasks unknown to the classical world. Moreover, quite recently they gave rise to novel technological and commercial applications of quantum features such as quantum key distribution schemes or truly random number generators developed by such companies as idQuantique, quantum simulators offered by D-Wave Systems or the cloud-enabled quantum computing platform offered by IBM. However, a fundamental question permeating all these applications of quantum technologies is how the back-end user can ascertain that a given quantum device is working as specified by the provider in the sense that it generates the right output. Or, how one can certify that a given device is indeed quantum, that is, offers an advantage over purely classical methods?

It is thus clear that efficient methods allowing one to certify whether a quantum device does operate in the non-classical regime are urgently required. The main objective of the project is to respond to that need. We will provide certification methods taking into account the whole plethora of possibilities that quantum theory offers. We will consider different scenarios such as device-independent or semi-device-independent and depending on the scenario various quantum resources will be exploited such as entanglement, nonlocality or contextuality. First, we focus on Bell nonlocality and aim at designing self-testing methods that go significantly beyond the current state of the art, taking into account other quantum notions than entangled states (quantum measurements or entangled subspaces) for which certification methods have not been developed so far. We then consider certain generalizations of the standard Bell scenario such as quantum networks or the contextuality scenario and investigate whether and how the nonclassical correlations they feature can be used for certification. The final part of the project is concerned with semi-device-independent scenario in which at the cost of making certain assumptions on the considered quantum system, we hope to obtain certain simplifications in deriving certification methods as well as better robustness as compared to the device-independent scenario.