

About a century ago, the physical theory describing the physical phenomenon in the micro scale was introduced. It differs a lot from our everyday conceptions and intuitions. Nevertheless, its success was undoubted in both describing physical phenomenon as well enabling new practical applications that we now use in everyday life.

One of the most intruding notions in quantum physics is quantum entanglement. It involves non classical correlations between two quantum systems. The idea to use them to storage, transfer and processing of information led to the new field of science, called quantum information theory that combines physics, mathematics and information theory. Quantum entanglement was employed in e.g. quantum cryptography, quantum computing or quantum teleportation, to which this project is devoted.

In the quantum teleportation protocol proposed in 1993 two parties, called Alice and Bob, want to transfer an unknown quantum state without moving it physically. They use the shared entanglement (so-called maximally entangled state), the measurement on Alice's side, the classical communication channel and the correction procedure on Bob's side. The teleportation found many applications, for example in quantum computing.

The necessity of the correction in the last step is however an important limiting factor. In 2008 a protocol that did not require it was proposed, so called Port Based Teleportation (PBT). It employs N shared maximally entangled pairs (the resource) called ports, the measurement on Alice's side on the state she wants to teleport and her halves of the resource and the classical communication. When Alice performs the measurement, she communicates the result to Bob via classical channel, basing on which he knows at which port the teleported state has arrived.

The lack of correction in the last step allows the PBT protocol to be used as co-called universal programmable quantum processor, performing an arbitrary operation on a given input state. It was also applied to propose some novel cryptographic attacks, the bound on the ability of discrimination of quantum channels and to simulate quantum channels.

However, due to non-programming theorem, the ideal teleportation takes place only if the resource is infinitely large. In reality we also possess a limited resource, so it is important to use it in an effective way. It is the aim of the two tasks proposed in this project.

The first one is entanglement recycling, the procedure that comes to the multiple use of the same resource state in successive PBT teleportations. Up till recently, it was considered to be an efficient protocol, but in the light of recent results, its usefulness is an open problem that we will study. If it proves useful it would enable more economic and universal use of the limited resource in the PBT protocol.

The second task concerns the preparation procedure performed by Alice on her halves of the resource that increase the quality of the teleportation. The operation obtained so far is the formal one, and it has unclear physical meaning. The aim of the research is to impose the conditions that make this operation physically significant and to examine how it relates to the known one. Obtaining such physical procedure would make the use of the limited resource much more economic.

Summing up, both tasks are a step towards more practical approach to the PBT protocols, which benefits were so far of more conceptual nature.