Over a hundred years ago our world underwent a quantum revolution. According to the quantum theory, a single atom cannot be treated as a microscopic billiard ball. What is surprising, the behavior of a single quantum particle resembles the behavior of a wave. Quantum atoms can interfere and diffract – just like the surface of water. The quantum theory has achieved a tremendous success since its beginnings and contributed to the development of new branches of science and technology. So why don't we see quantum effects with the naked eye in our daily life experience? Atoms are in a constant motion, they collide and scatter. Hence, their quantum individuality is covered by thermal effects (in one liter of air there are over 10 000 000 000 000 000 000 000 of particles!). Only in temperatures near absolute zero (when thermal effects are minimal) they quantum nature reappears. Diluted and cooled to extremely low temperatures gas may form a collective, macroscopic quantum matter wave state.

The aim of this project is to analyze the phenomenon of Anderson localization of matter waves in fractal dimensions. Fractal is a self-similar object with a fractional dimension (left picture). Having a fractional dimension, for example 1.585 (just like the object on the picture), means that that the object is certainly not one dimensional, but at the same time has too hollow structure for two dimensions. But what is Anderson localization? Consider a quantum particle moving on a lattice (right picture). As it turns out such a particle does not have a definite position – as a wave it can be evenly smeared on the whole area. Assume now that the lattice is a little irregular, i.e. that we added some disorder. It turns out that the scenario is change dramatically. In one dimension even infinitesimally small amplitude of disorder leads to the breakdown of transport in the system – particles become localized. We call this phenomenon the Anderson localization.

The research on the ultracold quantum matter not only allows to understand the modern quantum theory more deeply, but also permits to simulate phenomena present in diverse branches of physics. In particular the Anderson localization, which was primarily proposed to describe the transport of electrons in metals, cannot be directly observed in metals because of the presence of complicated electron interactions. On the other hands, effects related to the Anderson localization are broadly investigated in ultracold quantum gases, which led to the experimental observation of the localization of matter waves. In the project we aim to investigate and understand the mechanisms behind the Anderson localization in fractal dimension and with nonstandard source of disorder, which is related to the geometry of the system.