Progress in nanotechnology have a substantial impact on our lives, and scientific exploration of the nanoscale area still continues. However, the world at shrinking nanodevices is governed by the laws of quantum mechanics, which are different from our everyday experiences and present many challenges to researchers. For example, electron, a component of atoms, have a quantum property called spin, which makes that electron behaves like a small magnet. Electron spin is used in spintronics. It is a branch of nanotechnology investigating role of electron spin, in addition to its fundamental electronic charge, in electronic transport, in solid-state devices, molecules, or single atoms. Spintronics have become an important part of science from both its fundamental as well as application point of view since it has a strong potential for modern technologies.

Nuclear spins are already used in medicine, for routinely conducted magnetic resonance imaging (MRI) for diagnostics. Conventional electron spin resonance (ESR) usually detects macroscopic number of atoms with unpaired electrons. Recent breakthroughs in spin polarized scanning tunnelling microscopy (SP STM) make it possible to probe the spin dynamic of individual atoms, either isolated or integrated in nanoengineered spin structures. The IBM research group combined the high-energy resolution of conventional electron spin resonance with scanning tunneling microscopy (STM-ESR) to measure the electron spin resonance of individual iron atoms placed on a magnesium oxide film. To obtain ESR spectra, experimentalists swept the frequency of the voltage applied between STM tip and sample. Next they monitored the time-average tunnel current, which on resonance increased. Surprisingly, there are still many open questions about the mechanism leading to the all-electrical ESR signal, which means that magnetic moment respond resonantly to an ac electric field. Thus, it is not necessary to apply an external oscillating magnetic field as in conventional ESR measurements. One of research objectives of this project is related to these questions.

We will show that also the constant external magnetic field can be replaced by the exchange field controlled by the local electric gate voltage. To this aim we adapt model of the quantum dot (an atom) tunnel coupled to the ferromagnetic electrode (a spin polarized tip of the STM) and to normal electrode (a silver Ag substrate with thin insulating layer of MgO that form the second tunnel barrier). We will investigate the influence of virtual particle exchange processes resulting in an effective exchange field, which were not included in the previous models. In our opinion the applied ac voltage can generate the ac exchange field, which can lead to the all-electrical ESR signal. We will study how the magnetic exchange interaction would function in the presence of the ac voltages applied to this system and we will test the hypothesis, whether such a voltage can cause the ac exchange magnetic field. Such the exchange magnetic field controlled by the voltage can be rather convenient, since it could allow to avoid generating strong and localized magnetic fields that is technically challenging in nano-devices and allows for scaling of this technology. This could provide a new path to harness spin in nanoelectronics.

The project's aim is in line with the current global research trend, related to the development of quantum computing and quantum technologies. Quantum technology is an emerging new area which might have a similar impact on our society as classical integrated circuit technology. In 2016 during the opening of the Quantum Europe conference in Amsterdam the "Quantum Manifesto" was presented. This Manifesto calls upon Member States and the European Commission to bold strategic investment now in order to lead the second quantum revolution. The planned theoretical study will lead to new results that can be used in spintronics, ESR measurements on single objects, or quantum computing and communication. The full potential of single spin ESR, has yet to be considered, thus further study are necessary.