# Cover letter

Dear Austrian Academy of Science,

I am writing you as a PhD student to apply for the DOC Fellowship.

There is a huge demand nowadays to speed up information processing. By exploiting the laws of quantum mechanics, a quantum computer could lead to an exponential speed-up of some information processing tasks (e.g.: Shor’s algorithm for factoring an n-digit number). Fascinated by this fact I am happy to be a part of the research community which is trying to make a step towards the realization of such a technological breakthrough.

The basic unit of a quantum computer is the so-called qubit. Demands like high **coherence vs manipulation time ratio and scalability** are major obstacles for realizing a usable quantum processor. Several different approaches to a qubit realization are been followed worldwide. The approach in our group bases on the spin of a hole confined in silicon germanium quantum dots. Due to the low hyperfine interaction and high spin-orbit coupling for heavy holes in germanium a high coherence vs manipulation time ratio is expected. Furthermore the compatibility of silicon germanium with the CMOS processes helps to solve one part of the scalability issue. **The previously listed advantages of the spin qubit studied in our scientific group, makes me motivated to work on solving the other part of the scalability issue related to the qubit state readout.** A “scalability friendly” state readout can be achieved by using the already predefined gates for sensing the state of the qubit. Such a state readout technique is called gate reflectometry which is also in title of this project. If it proves to be very sensitive, as we expect, it would enable me to move towards performing single-shot experiments to determine the characteristic spin lifetimes of the silicon germanium nanowire based double quantum dot qubit. Namely, the spin relaxation time T1, the spin dephasing time T2\*, the spin echo T2ECHO time and the CPMG T2CPMG time.

**In my previous work** as a research assistant in the group of dr.sc. Georgios Katsaros I started working on the development of an ohmic reflectometry system, which is slightly different in respect to the gate reflectometry. This system was used for charge readout of the silicon germanium quantum dots. During this project I have gained some knowledge in printed circuit board designs and in developing python codes for controlling various DC and high frequency signal instruments. I also performed 4 Kelvin measurements on a single hole transistor based on the Ge hut-wire quantum dots fabricated in our group by Hannes Watzinger. In October 2015, and for three months, I went on a research visit to the Center for Quantum Devices lead by Prof. Marcus at the Niels Bohr Institute in Copenhagen. I worked in the group of Ferdinand Kuemmeth. During my research stay, I learned about state of the art instruments including cryogen free dilution refrigerators, waveform and signal generators, RF equipment (amplifiers, filters, special type of coaxial cables…) and had many interesting discussions about the physics of confined spins.

**Previously, I finished undergraduate studies** at the faculty of electrical and computer engineering, at the University of Zagreb, Croatia. For my bachelor thesis I have been measuring ECL ring oscillators based on horizontal current bipolar transistor (HCBT). This allowed me to deepen my knowledge in electronic instrumentation. For my master thesis, performed with professor Tomislav Suligoj, I have focused on design and analysis of the RF circuits in 180 nm BiCMOS technology with the HCBT, which gave me a background in performing simulations, design and analysis of the electronic circuits.

**Currently I am PhD student** in the group of Georgios Katsaros, at the Institute of Science and Technology (IST) in Austria. It is very international institution with very high and ambitious goals and it makes me happy to be a part of it. Senior scientists here are highly qualified which has an impact on the development of my scientific skills through a direct communication, various talks and journal clubs organized at the institute. Working on the gate reflectometry as a spin qubit readout system will involve expanding my knowledge in high frequency signal components, high frequency circuit design and possibly COMSOL simulations.

In the past decade, the research related to quantum computation both on the theory and experimental side, has enormously grown. It seems that there will be a huge demand for scientists and engineers who will be able to solve problems related to incorporating standard electronics with qubits. With the knowledge gained from the gate reflectometry design and from performing all the above spin manipulation experiments, **I hope** I can be a good candidate **to continue my work in this emerging area.** In academia as a post doc or in industry as a quantum hardware engineer.

**The DOC fellowship** would **make me more independent** in my research meaning that I would have more freedom in choosing projects, workshops, scientific visits, enabling thus the **development of my skills in quantum information hardware**. In addition this prestigious fellowship will strengthen my CV and will give me better job opportunities for the future.

With best regards,

Josip Kukučka