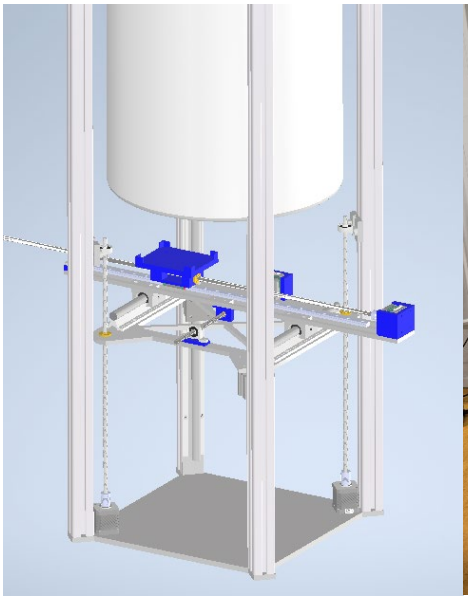
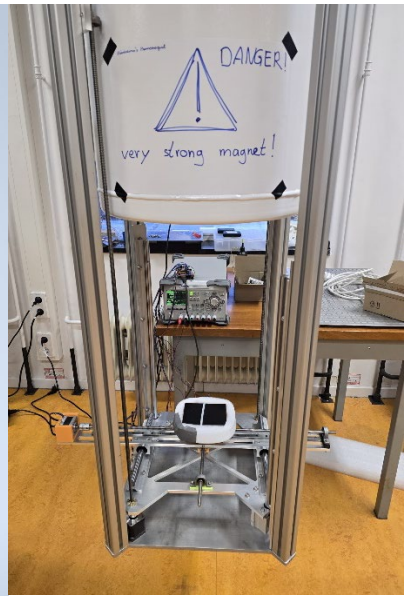
Magnet Positioning Stage for Large Scale Qubit Experiments





Title of the case	Magnet Positioning Stage for Large Scale Qubit Experiments
Institute/department/section providing the case	QuTech – Quantum Computing Division – Veldhorst Lab
Challenge provider/scientific supervisor	Sasha Ivlev – PhD Student – a.s.ivlev@tudelft.nl
(Other stakeholders involved)	Members Veldhorst lab. Qutech Technical Staff & Mechanical Workshop
Location	QuTech – QCLab 2 & 3
Challenge description	In this project you will be designing, building and testing a electromechanical XYZ positioning stage for a permanent magnet, used to control the magnetic field of semiconducting qubit experiments with 1000 quantum dots. Spin qubits hosted in gate-defined semiconductor quantum dots are among the most promising platforms for building future quantum computing processors. Not only have they shown promising qubit performance, but their inherit compatibility with modern semiconductor manufacturing technologies makes them a prime candidate for scaling up the many thousands of qubits needed for useful quantum computation.

	Scaling quantum computers is however not only challenging from the quantum physics point of view, but most definitely also from an engineering perspective. Fitting an ever larger quantum chip into the experimental setup together with all the required control lines is a proper challenge. Single spin qubits moreover have the additional hurdle that they require an external magnetic field, ideally one that can be oriented in any direction. Currently this is provided by a superconducting solenoid magnet, multiple if you want 3D control, which takes up valuable space in the dilution refrigerator. To tackle this hurdle, we recently developed a prototype setup consisting of a permanent magnet outside of the fridge, moving in 3 dimensions using several stepper motors, controlled by an Arduino. By positioning the permanent magnet we can precisely control the magnetic field magnitude and orientation, without sacrificing scarce space within the cryostat. Your task will be to convert this prototype into a robust product that can be used more readily across several spin qubit setups, in particular one that is designed for a 1000 quantum dots experiment which will be reliant on this external magnet positioner.
Multi-disciplinary nature of the case	- Mechanical Engineering: CAD Designing. Think about alignment, stiffness, reliability, manufacturability, compatibility across different setups. - Electrical Engineering: Working with Arduinos, powering the electromotors, possibly implementing feedback loops. - Software Engineering: Write drivers to control the motors. Create to manipulate the magnetic field exactly as desired, by translating the permanent magnet. - Systems engineering: Everything needs to work together at the end and tested, and debugged, for edge cases. Safety is also an important aspect, as the work will involve a strong magnet.
Relation to QIST	Setup enables to perform large scale spin qubit experiments.

Resources needed/provided	Needed: Understanding that you need to work safely in the lab, these magnets are not toys. Resources provided: - CAD license. - Budget for off-the-shelf components - Custom components will be manufactured in-house by the mechanical workshop (if there is interest, we can discuss with the workshop to manufacture yourself, but not guaranteed). - Expertise from technical staff on how to design safely.
Expected impact	Allow to manipulate the qubit magnetic field in magnitude and direction, over a range sufficient to perform high quality qubit experiments across multiple setups