The modern technological revolution is driven by miniature semiconductor structures operating at the scale of individual atoms. Quantum dots — man-made structures that can confine charge carriers — are among the most promising components of this revolution. This project focuses on a new class of quantum dots known as crystal phase quantum dots (CPQDs), which are formed by deliberately switching between two crystal structures (so-called zinc-blende and wurtzite) during the growth of semiconductor nanowires. These dots enable atomically precise control over their properties and offer significantly better reproducibility than conventional quantum dots made from chemically different materials.

The project aims to develop a theoretical foundation for understanding the behavior of these CPQDs, particularly in the presence of external electric and magnetic fields. We will investigate how these fields affect the electronic and optical properties of CPQDs. To this end, we will develop advanced numerical tools combining atomistic simulations, many-body techniques, and machine learning. One of the central challenges is to model multi-dot systems (so-called stacks) composed of several coupled quantum dots, and to assess their potential as building blocks for future quantum computers.

Despite experimental progress, theoretical models capable of predicting how CPQDs behave under external fields are still lacking. In particular, it remains unclear how effectively quantum states in these systems can be manipulated using external electric and magnetic fields. Our research seeks to answer these questions and to deliver tools essential for designing next-generation quantum devices.

The final outcome will be a set of advanced models and very complex simulations capable of predicting the behavior of multiple quantum dots in various spatial configurations. The results will be validated against experimental data through close collaboration with research groups in France and Denmark. The project may pave the way for scalable quantum light sources, quantum logic components, and most importantly: a deeper understanding of fundamental physical processes at the nanoscale.