DLR Quantencomputing Initiative

Projekt ALQU

Algorithms for quantum computer development in hardware-software codesign

DLR Institute for Software Technologies

DLR Institute for Software Technology

IQM

HQS QUANTUM SIMULATIONS

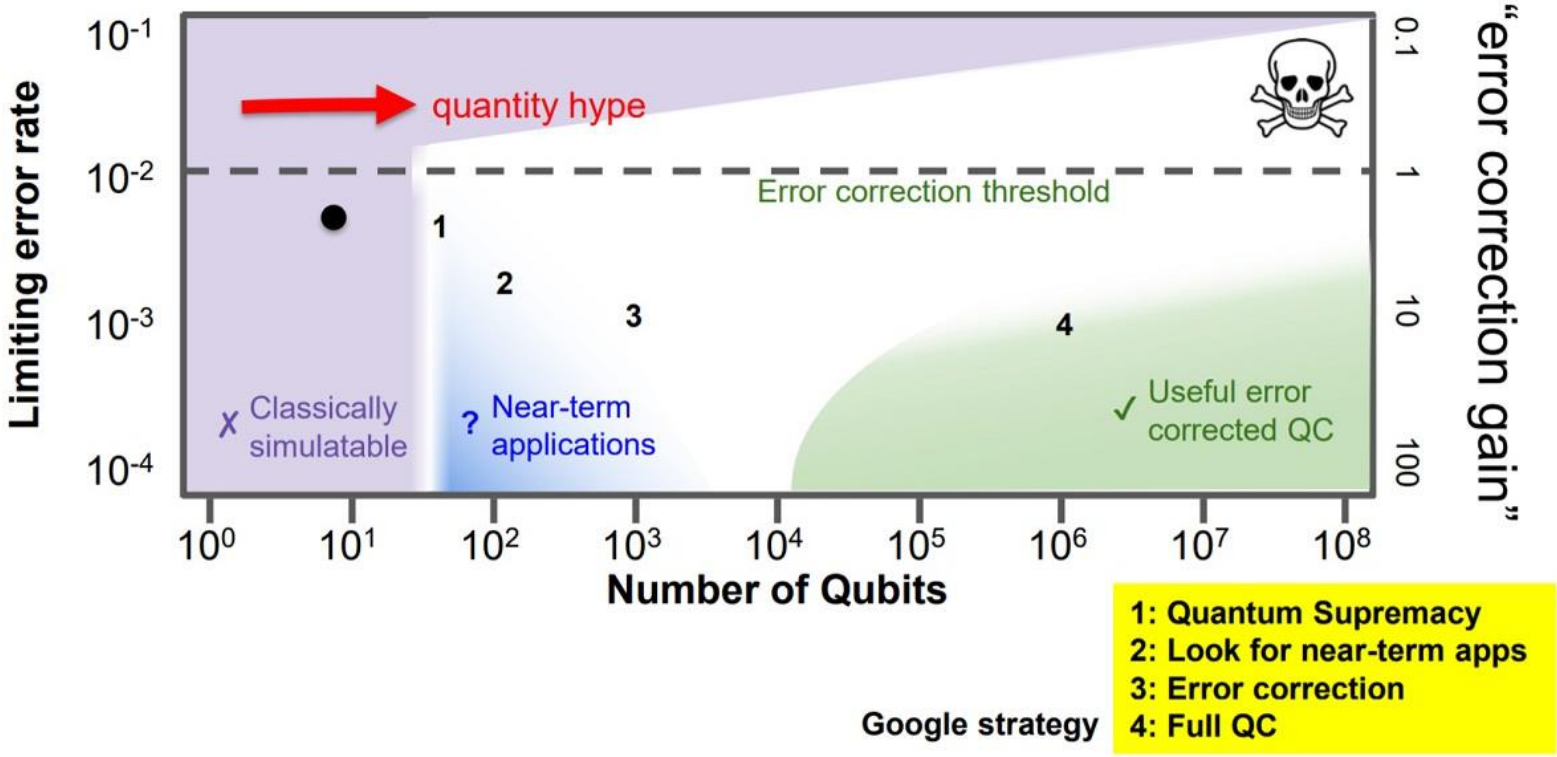
DLR

Figure: John Martinis, Google. (taken from https://medium.com/@quantum_wa/quantum-computing-near-and-far-term-opportunities-f8ffa83cc0c9)

Background: State of Development of Quantum Computers

Quantum Error Correction (QEC)

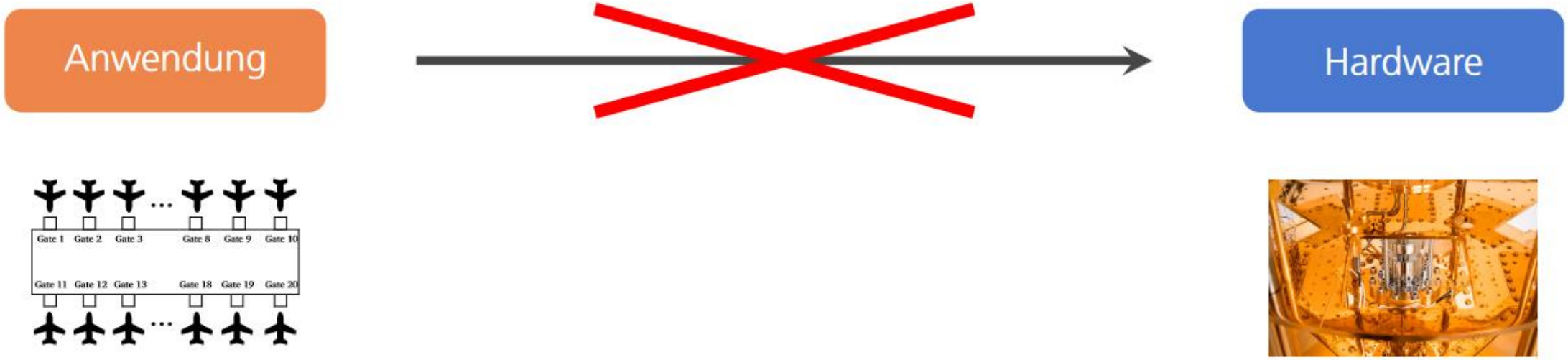
- Universal quantum computers are intrisically error-prone. To run killer apps like Shor's algorithm, we therefore need QEC.
- QEC relys on redundancy. Hence, it requires a significant overhead on reliable qubits and gates.



Quantum advantage within the near future → **Exploit the potential of NISQ devices!**

Noisy Intermediate Scale Quantum Devices

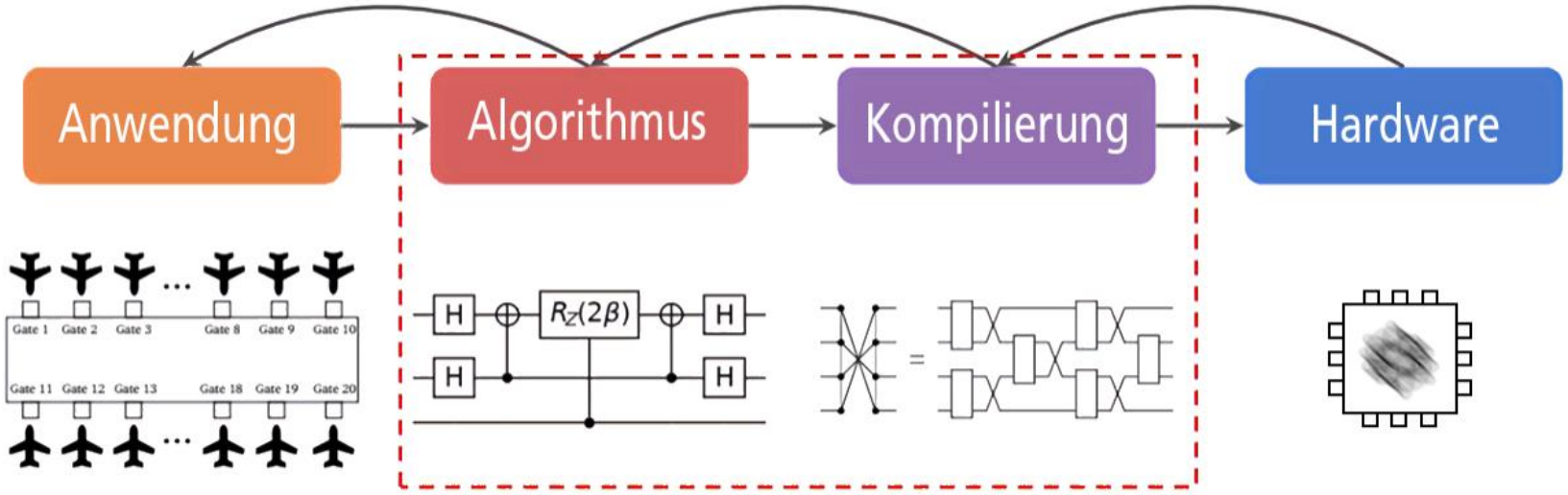
- State-of-the-art quantum computers are rather small, noisy and have limited connectivity.
- Within the next years, we will be restricted to quantum computers **without QEC**.
- However, is it still possible to achieve quantum advantage?



Projekt ALQU

Objective

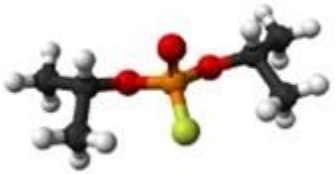
We are developing customised compilation strategies for the DLR QCI's quantum computers and customised quantum algorithms for industry-relevant computational problems.



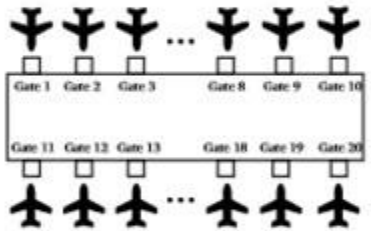
***Hardware-Software Co-Design**: Efficient compilation of quantum circuits and customised quantum algorithms for industrial application problems (Source: DLR).*

What are promising applications for NISQ devices?*

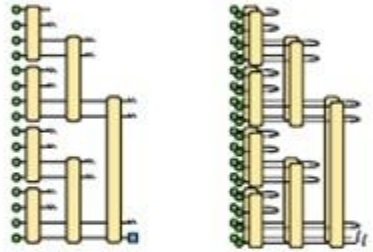
Quantum Simulation



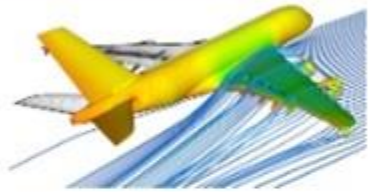
Discrete Optimization



Machine Learning



Classical Simulations



today — time in units of how much QEC is needed

*my own estimation without engagement

ALQU: Work Packages

HAP 1: Hardware focused

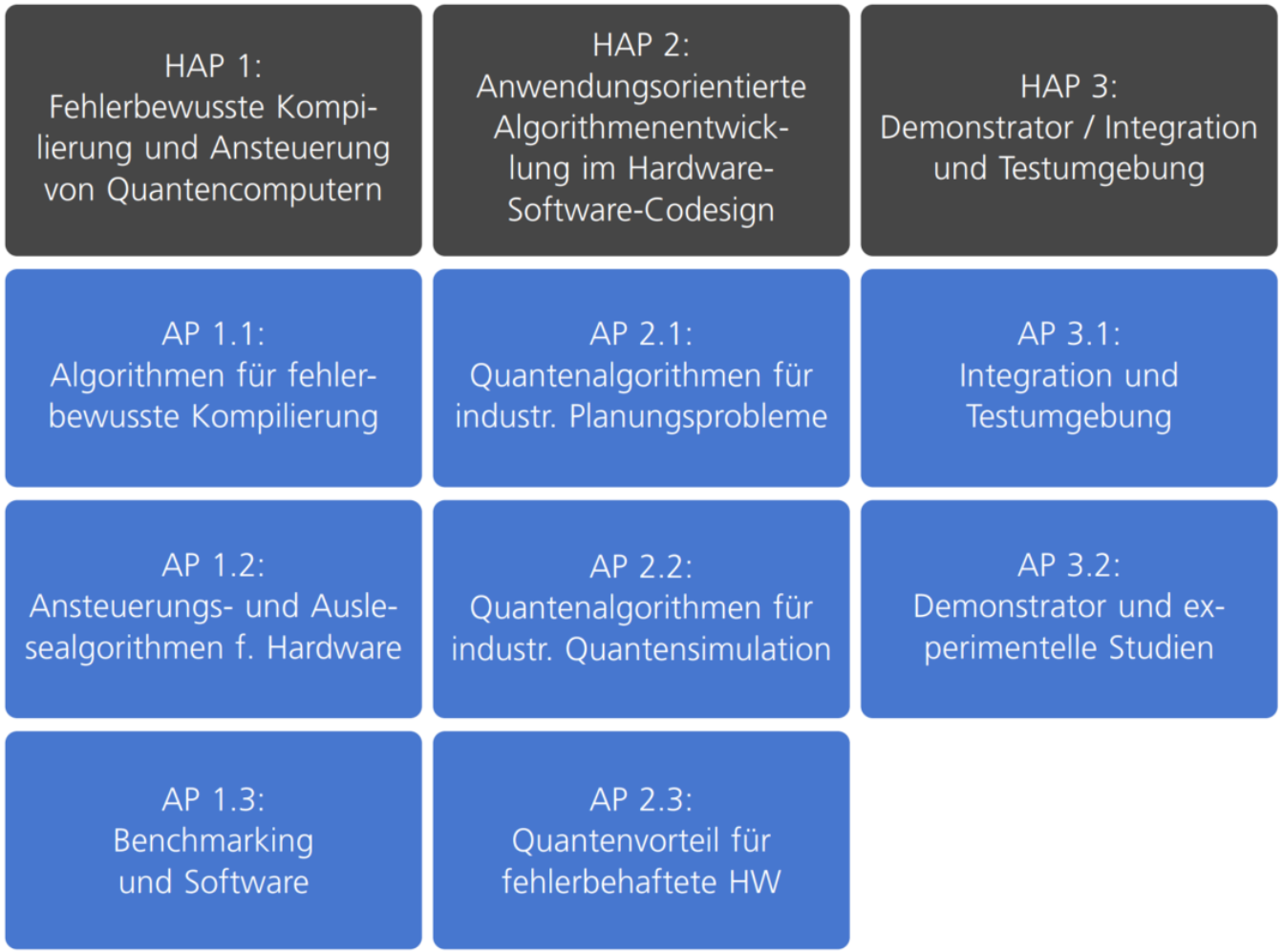
- Device aware compilation
- Control- and readout-algorithms

HAP 2: Application focused

- Industrial scheduling problems
- Quantum simulation

HAP 3: Software development

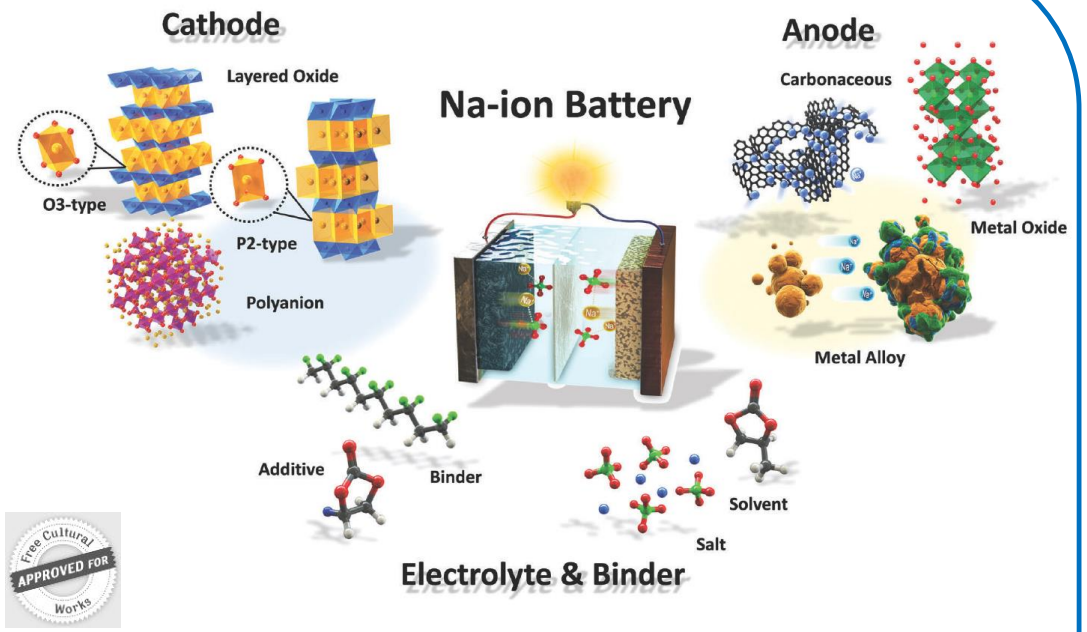
- Demonstrator
- Integration and test environment



Industrial Contribution 1: IQM

Accelerating battery design with fermionic simulation

- **Goals:** improve energy storage capabilities (equilibrium voltage profile), charging and discharging speed (ionic mobility) and the resistance to degradation over time (thermal stability).
- **Approach:** side-stepping/accelerating time- and money- intensive lab testing with quantum simulation capabilities.
- ***The cathode is a strongly correlated (highly entangled) fermionic system***, i.e. an ideal problem to be efficiently solved on quantum computers.

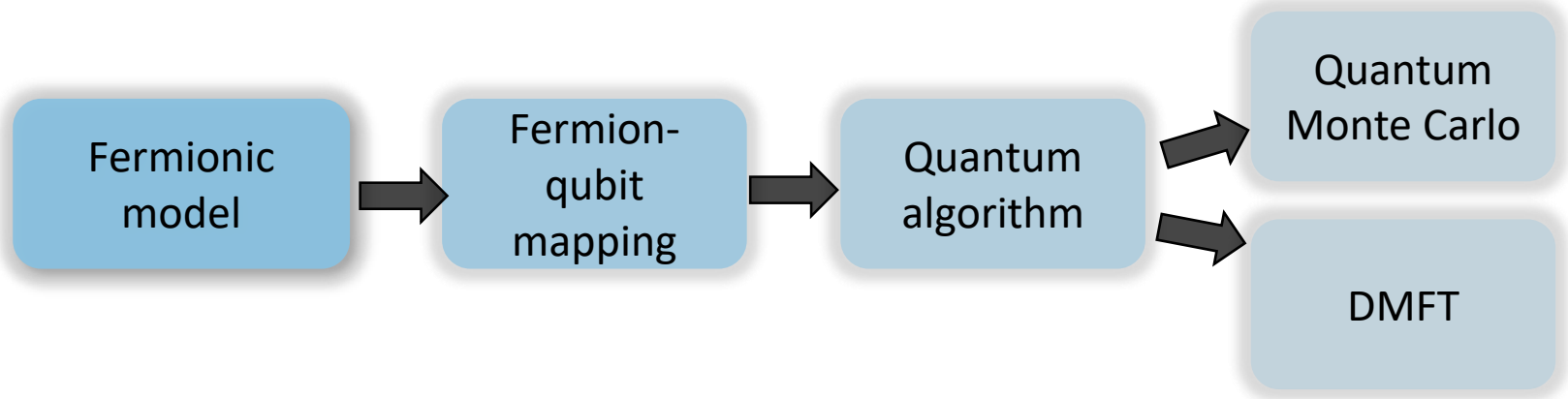


Chemical Society Reviews: Sodium-ion batteries: present and future, Issue 46, Number 12, Page 3531, Scheme 1, doi:10.1039/C6CS00776G

Industrial Contribution 1: IQM

Accelerating battery design with fermionic simulation

- Solving (simulating) these fermionic models would have a significant impact on battery design, but also on developing new high-temperature superconductors, fertilizers, and pharmaceuticals.
- Central task of this simulation problem is to reduce the needed number of quantum resources (qubit count/number of gates).



***Fermionic Quantum Simulation**: Workflow of an hybrid quantum-classical algorithm.*

Industrial Contribution 2: HQS

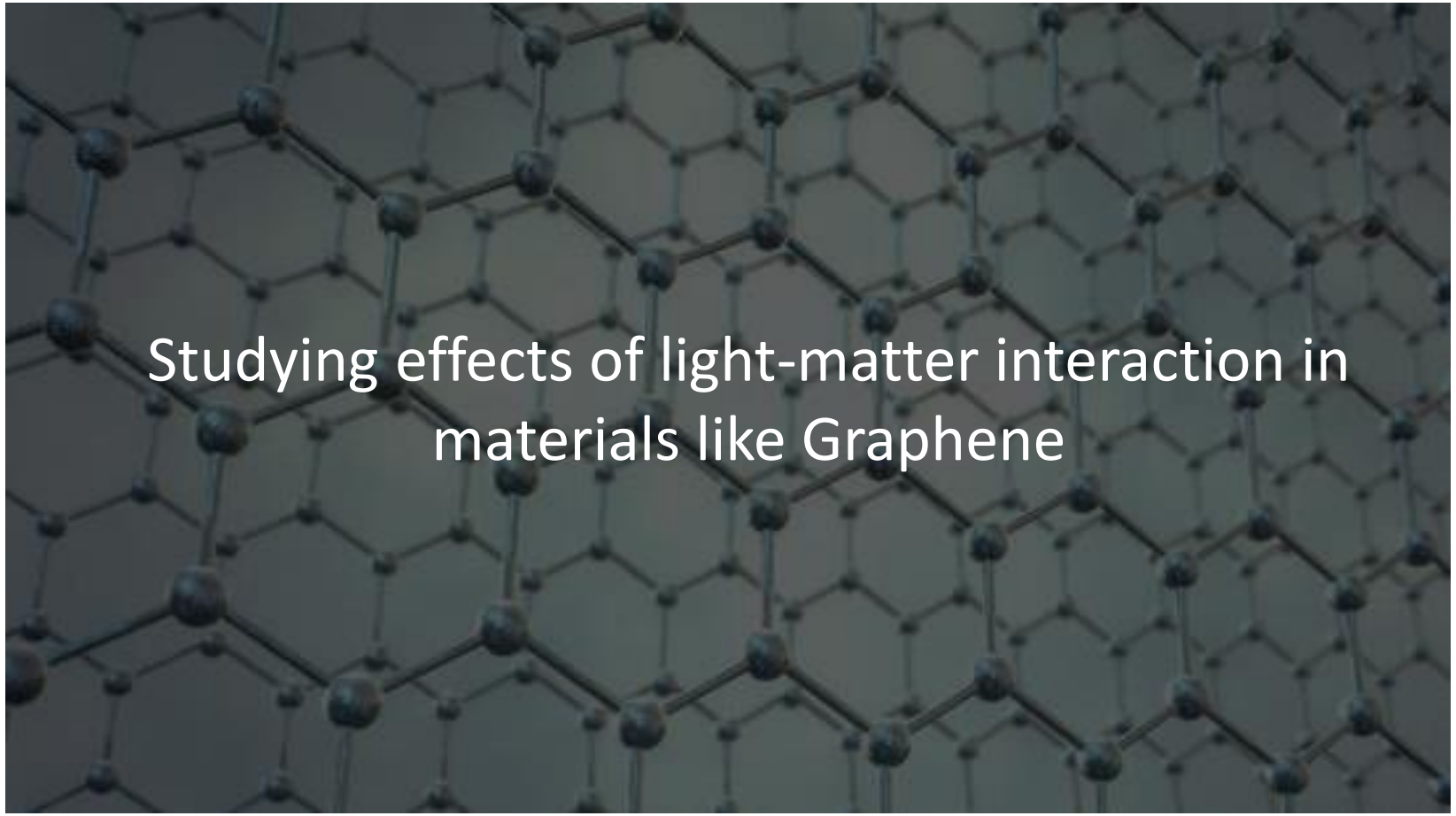
Time-dependent phenomenons in the Fermi-Hubbard-model

Simulating quantum mechanics is a fast-growing market connected to huge trends.

Material science problems	DLR project
Battery materials	ALQU
Optoelectronical sensors	BASIQ

Industrial Contribution 2: HQS

Time-dependent phenomenons in the Fermi-Hubbard-model



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