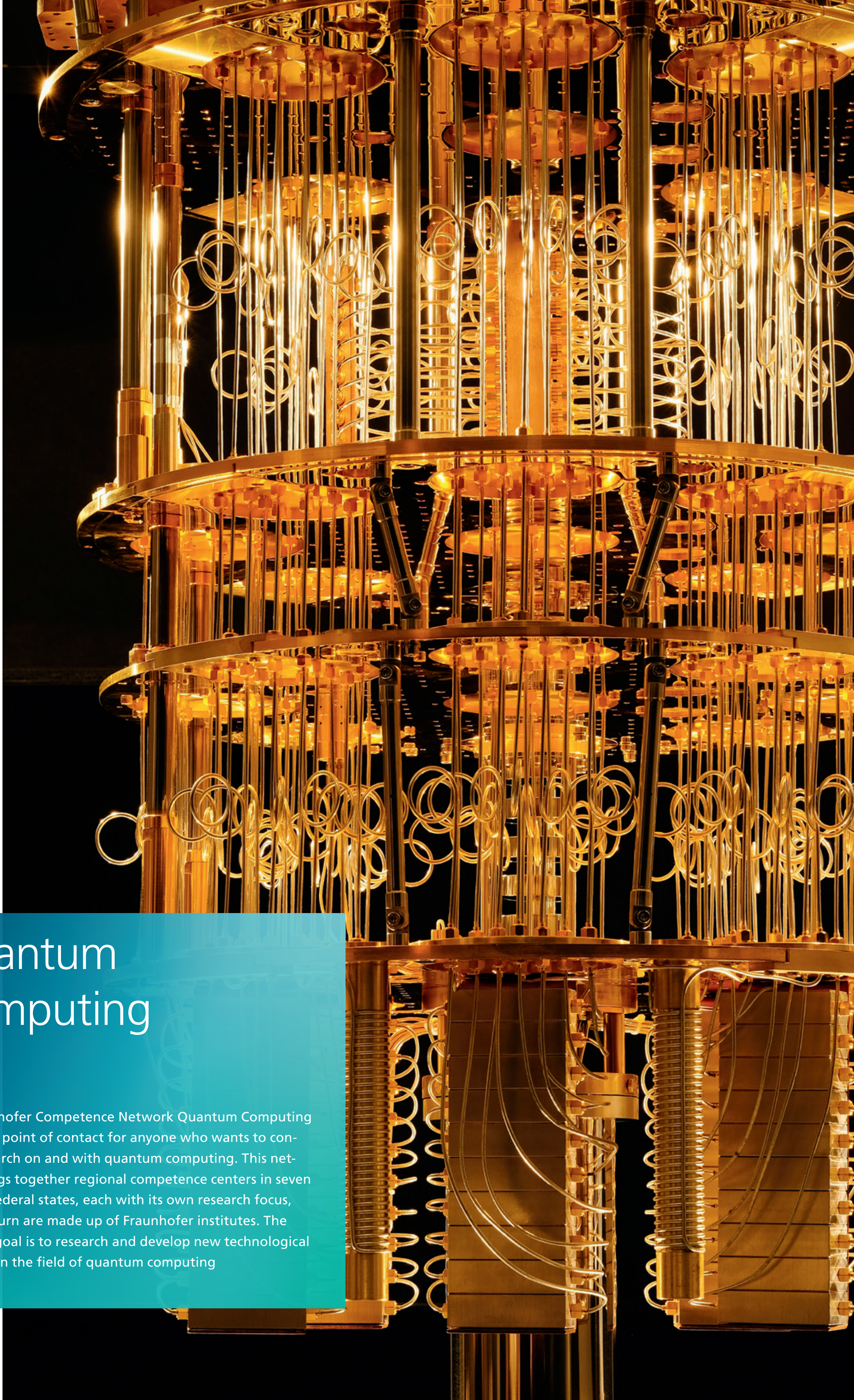
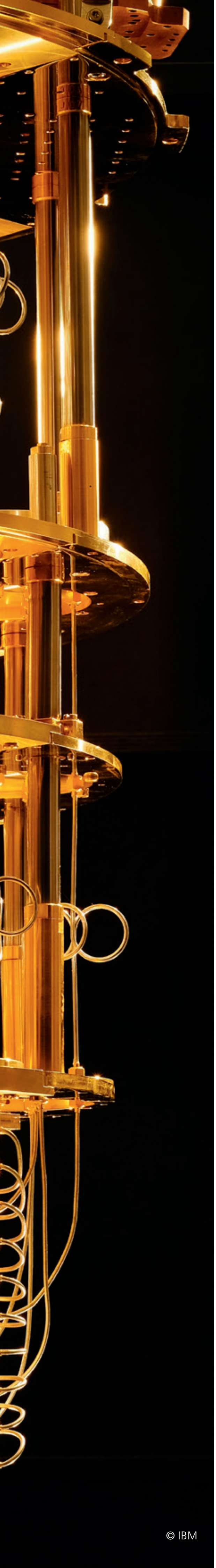


Quantum Computing

The Fraunhofer Competence Network Quantum Computing is the first point of contact for anyone who wants to conduct research on and with quantum computing. This network brings together regional competence centers in seven German federal states, each with its own research focus, which in turn are made up of Fraunhofer institutes. The common goal is to research and develop new technological solutions in the field of quantum computing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Quantum Computing – The Future Calls

A “game changer” – the potential of quantum technologies can hardly be predicted. Compared to traditional computing, quantum computing promises an exponential acceleration of selected algorithms as well as the possibility to deal with complex problems. Together with Prof. Dr. Manfred Hauswirth, Director of Fraunhofer FOKUS Institute, ITWM Institute Director Prof. Dr. Anita Schöbel is responsible for the topic of quantum computing at Fraunhofer. In cooperation with IBM, a national competence network has been established to develop quantum-based computing strategies for the next generation of high-performance computers.

Competence network with Rhineland-Palatinate participation

The Rhineland-Palatinate competence center “Quantum High Performance Computing” was opened at our institute in August 2020. We contribute our expertise in the fields of mathematics, physics and high performance computing as well as our good networking with industry. Among other things, the competence center will assess the conditions under which practical problems can be solved on quantum computers and applied in the industry. In addition, new quantum-based technologies, application scenarios and algorithms can be tested through cloud access to IBM quantum computers. We focus on quantum chemistry, finance and energy as well as material simulation, quantum image processing and quantum machine learning.

Fraunhofer operates “Quantum System One”

However, quantum computing has also been possible in Europe since June 2021: Together with IBM, Fraunhofer operates the quantum computer Quantum System One under local data protection law. It is available to companies and research organizations to develop and test quantum algorithms in an application-oriented manner and to build up know-how.

Solutions for imaging and energy

The Fraunhofer lead project “QUILT” (Quantum Methods for Advanced Imaging Solutions) already started in 2018. In close cooperation with industry, six Fraunhofer institutes are jointly researching imaging methods in the terahertz spectral range based on quantum optics. Initial successes, the generation of suitable photon pairs, have already been recorded and the next steps planned. Researchers from our institute play a key role in the project in modeling, simulating and optimizing quantum-based contact-free methods.

Another project is the joint project “EnerQuant”. It uses the advantages of quantum computing for optimization problems in the energy industry. Funded by the German Federal Ministry for Economic Affairs and Energy (BMWi), researchers are developing algorithms for qubit-based quantum computers and quantum simulators. These are to be used to solve a fundamental model of the energy industry with stochastic influencing variables.

More information at www.itwm.fraunhofer.de/quantum-computing

EnerQuant: Quantum Computing for the Energy Industry

Complex optimization problems with many variables are difficult for classical computers to solve. Only recently have certain quantum computers achieved promising results in solving optimization problems – with the potential to handle even discrete variables. In the joint project "EnerQuant: Energy Economics Fundamental Modeling with Quantum Algorithms", our researchers from the departments "Financial Mathematics" and "High Performance Computing" are exploiting advantages of quantum computing for the energy industry.

Optical system for laser cooling and control of ultracold sodium atoms in the laboratory at the Kirchhoff Institute for Physics Heidelberg

"In short, in the EnerQuant project we are developing algorithms for qubit-based quantum computers and quantum simulators for the solution of a fundamental model of energy economics with stochastic influencing variables," explains Kerstin Dächert, member of the "Financial Mathematics" department at Fraunhofer ITWM and project coordinator. Together with colleagues from the department "High Performance Computing", she and her team are conducting research in the joint project with universities and companies from industry.

As a basis, the researchers define a simple fundamental model that can be translated into a quantum mechanical problem and realized on a quantum simulator. This is implemented in a prototype made of cold atoms and tested for its performance in order to successively further develop the fundamental model and quantum simulator. The long-term goal is to model the German electricity market with sufficient stochastic accuracy.

Exploiting new potential

EnerQuant makes it possible to exploit the potential of new computing technologies for energy-economy modeling. The researchers show how fundamental models can be formulated to use the computing power of quantum simulators and thus make a long-term contribution to the further development of energy system modeling. The results will be incorporated into the software platform of the partner JoS QUANTUM and will be available to industry after the end of the project. Furthermore, EnerQuant provides an analysis of the potential of quantum computers and compares their efficiency with classical hardware and alternative approaches to solve optimization problems.

EnerQuant started in September 2020 with a duration of three years and is funded by the German Federal Ministry for Economic Affairs and Energy (BMWi). In addition to Fraunhofer ITWM, Fraunhofer IOSB-AST, the Universities of Heidelberg and Trento, and Jos QUANTUM are also part of the network.

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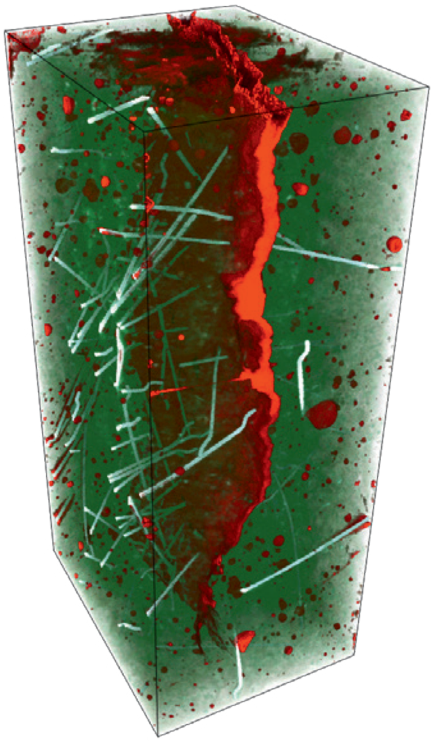
Observing the Inner Structure of Concrete Beams During Bending – Quantum Computing Accelerates the Evaluation of CT Data

Higher resolution, faster and new acquisition methods – the amount of image data is growing faster than the speed of analysis methods. This poses new challenges for industrial image processing. Quantum image processing promises a remedy. One example is computed tomography during mechanical tests.

Gulliver, the computed tomography portal of the TU Kaiserslautern, is a unique experimental facility that will make it possible to image the internal structure of concrete beams during bending tests. Gulliver generates approximately 120 GB to 2 TB of image data per experiment. The aim of the current research is to analyze the structural changes like crack initiation and growth while the test is in progress.

Bringing theory and practice closer together

Skillful use of the special properties of qubits makes it possible in principle to represent such large image data with just a few qubits, e. g. 1024 × 1024 pixels with 21 qubits. If the currently used processing and analysis algorithms were replaced by quantum counterparts or quantum physical pendants, more efficient processing of enormous amounts of data as produced by Gulliver would be possible. Theoretically, both storage and computational requirements could be reduced exponentially.



3d rendering of cracks in a concrete sample with reinforcing steel fibers.

Practically, encoding the image and running algorithms require a huge number of individual quantum operations. The results of simple image processing steps on small images are therefore often noisy beyond recognition at present. Like in quantum computing in general, noise models and algorithms that require as few basic operations as possible are therefore the subject of current research.

More information at www.itwm.fraunhofer.de/surface-and-material-characterization

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