Quantum
Learning Machine

Atos

Getting ready for the Quantum Revolution

Surviving the data deluge each day requires more and more processing power, but this race for higher performance has almost reached the limits of silicon technology, in terms of physics. The next step: quantum computing!

Moore's Law, which predicted that transistor density on a chip will double every 18 months resulting in doubling the performance, is affected by the silicon limits. As current technologies reach the physical limits of matter, with electronics components approaching the atom - fundamental limit of smallness, we need to go beyond, with a technological breakthrough: the quantum computer. It is planned to replace today's processors in around 2030, and we should see first practical applications in hybrid architectures in the coming decade. This is where quantum physics comes in.

The first quantum revolution has taken place at a microscopic level and brought some major innovations of the 20th century such as the transistor, the laser, superconducting devices and optical fibers. Many experts are convinced that the second quantum revolution, which will see quantum information emerging, is already upon us. Up until now, a binary digit is always in one of two definite states (0 or 1) however quantum computing uses qubits which can be in a superposition of states (1 and 0 superposed), enabling massively parallel computation. This multiplies capacity, so that quantum computers with a modest number of qubits, as little as 60, could solve problems that today's most powerful supercomputers cannot address with years or even millennia of computing time!

Advances in quantum science are extensive and demonstrate the reality of the tremendous opportunities to accelerate calculations, which together allow quantum superposition and quantum entanglement.

It is in this context that Thierry Breton decided to launch the 'Atos Quantum' R&D program at the end of 2015 and made it a strategic priority for the Group.

Atos Quantum R&D Program

'Atos Quantum', the first quantum computing industry program in Europe, was announced in November 2016. Its aim is to anticipate the future of quantum computing and to be prepared for the opportunities and also the risks that come with it: opportunities such as superfast algorithms for database search, artificial intelligence or discovery of new pharmaceutical molecules - and risks such as collapse of asymmetric cryptography. This global program aims to develop quantum computing solutions to understand the change in paradigm that quantum brings in the way algorithms are developed, but also to learn how to enhance cyber security products to anticipate quantum advantage and its impact on cryptography.

Atos' position as a leader in security and High Performance Computing, together with its experience and expertise, provide a solid base from which to launch 'Atos Quantum'. Atos' ambition is to be a quantum player in two domains: quantum programming and simulation platforms and, later, next-generation quantum-powered supercomputers, as well as quantum-safe cybersecurity.

The Atos Quantum program started with creating an R&D laboratory in France, as well as recruiting a team of highly-skilled researchers and developing academic partnerships with leading European research centers in quantum technologies. The first deliverable of this project, developed in-house in our Quantum R&D laboratory, is known as the Quantum Learning Machine.

Piloted by a Scientific Council with world-renowned members

The 'Atos Quantum' Scientific Council is enriched with the immense knowledge and visionary power of its members, all highly renowned researchers. It was set up to give direction and guidance to the research teams.

The Council is chaired by the Chairman and Chief Executive Officer of Atos and is made up of universally recognized quantum physicists and mathematicians:

- Alain Aspect, Professor at the Institut d'Optique Graduate School and Ecole Polytechnique, Université Paris-Saclay
- David DiVincenzo, Professor, Director of the Institute for Quantum Information at RWTH Aachen University, Director of the Institute for Theoretical Nanoelectronics at the Juelich Research Center
- Artur Ekert, Professor of Quantum Physics at the Mathematical Institute, University of Oxford
- Lee Kong Chian, Centennial Professor and Director, Centre of Quantum Technologies at the National University of Singapore
- Daniel Esteve, Research Director, CEA Saclay, head of Quantronics
- Serge Haroche, Professor emeritus at the Collège de France, Nobel laureate in Physics
- Cédric Villani, Member of French Parliament, Mathematician, Fields Medal laureate

Developing quantum applications today

The Atos Quantum Learning Machine (Atos QLM) is a complete on-premise environment designed for quantum software developers. It is dedicated to the development of quantum software, training and experimentation.

It embeds a programming platform and a high-performance quantum simulator. Its capabilities and performances are unmatched on the market.

The Atos Quantum Learning Machine allows researchers, engineers and students to develop and experiment with quantum software. Powered by a powerful dedicated hardware infrastructure, the Atos QLM will emulate execution as a genuine, quantum computer would. Software developed on the Atos QLM can run on simulated, as well as on future, quantum accelerators, without changing a line.

The Atos Quantum Learning Machine computes the exact execution of a quantum program, with double digit precision. It simulates the laws of physics, which are at the very heart of quantum computing.

This is very different to existing quantum processors, which suffer from quantum noise, quantum decoherence, and manufacturing biases, as well as performance bottlenecks. Simulation on the Atos Quantum Learning Machine enables developers to focus on their applications and algorithms, without having to wait for quantum machines to be available.

Thanks to the bespoke software and hardware developed by Atos, the Atos QLM has superior simulation capabilities, much more than any other affordable appliance. In its maximum configuration, it can simulate up to 40 qubits, which was until now, only possible on large supercomputers, despite the fact that the Atos QLM has the physical dimensions of a simple business server.

The Atos Quantum Learning Machine is a complete appliance

- A specific hardware infrastructure, with large in-memory capacity and – available soon – a dedicated hardware accelerator
- An extensible quantum circuit model (data representation model)
- A universal quantum assembly programming language (AQASM, Atos Quantum Assembly Language)
- A high-level quantum hybrid language, built on top of the popular Python language

The Atos Quantum Assembler is an important component of the Atos QLM appliance. AQASM is designed in the Atos R&D labs.

AQASM is Atos implementation of the universal quantum software development language: QASM. Programs using AQASM can be used on the quantum simulator today, as well as on the physical quantum computers of tomorrow. AQASM is configurable; it has the ability to program new quantum gates or to mix existing gates. AQASM offers high-level wrappers for developers and accepts quantum programs from other frameworks thanks to a versatile software development kit.
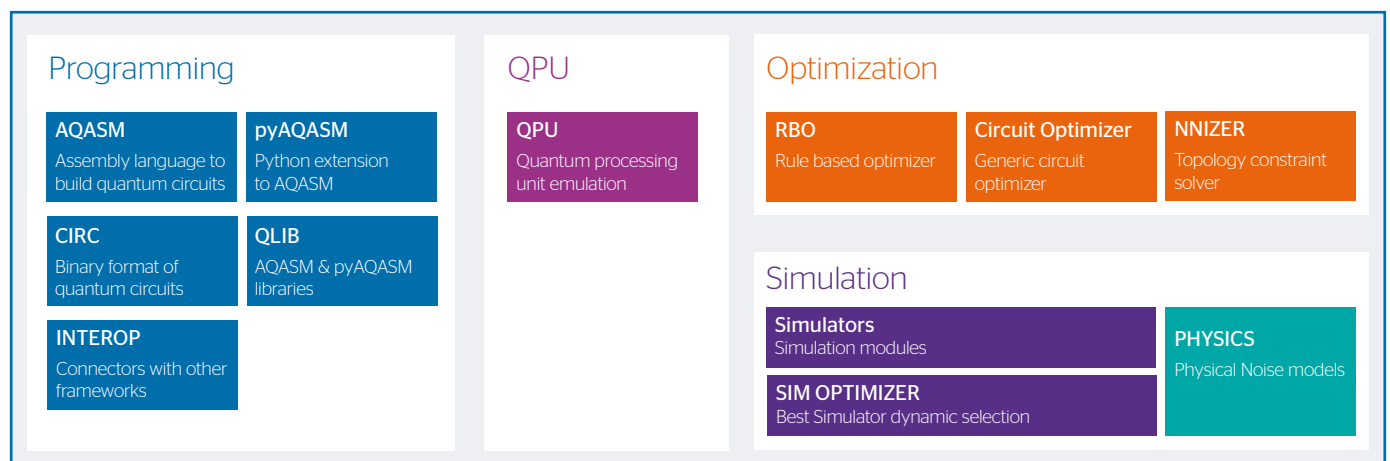
Atos offers a range of Atos QLM appliances dependent on power level: from 30 to 40 QBits.

Atos QLM can be upgraded seamlessly once deployed without having to reinstall or migrate the data. A "simple" additional cabinet can be plugged into the existing appliance to bring new capabilities.

Quantum noise simulation

The simulation of physics include different models for quantum noise. Should the underlying technology be trapped ions, supraconducting circuits or semiconducting silicon, the noise models can be chosen and used to be as close as possible to reality.

Atos Quantum Learning Machine functional scope

Programming

AQASM
Assembly language to build quantum circuits

pyAQASM
Python extension to AQASM

CIRC
Binary format of quantum circuits

QLIB
AQASM & pyAQASM libraries

INTEROP
Connectors with other frameworks

QPU

QPU
Quantum processing unit emulation

Optimization

RBO
Rule based optimizer

Circuit Optimizer
Generic circuit optimizer

NNIZER
Topology constraint solver

Simulation

Simulators
Simulation modules

SIM OPTIMIZER
Best Simulator dynamic selection

PHYSICS
Physical Noise models

About Atos

Atos is a global leader in digital transformation with approximately 100,000 employees in 73 countries and annual revenue of around € 12 billion. European number one in Big Data, Cybersecurity, High Performance Computing and Digital Workplace, the Group provides Cloud services, Infrastructure & Data Management, Business & Platform solutions, as well as transactional services through Worldline, the European leader in the payment industry. With its cutting-edge technologies, digital expertise and industry knowledge, Atos supports the digital transformation of its clients across various business sectors: Defense, Financial Services, Health, Manufacturing, Media, Energy & Utilities, Public sector, Retail, Telecommunications and Transportation. The Group is the Worldwide Information Technology Partner for the Olympic & Paralympic Games and operates under the brands Atos, Atos Consulting, Atos Worldgrid, Bull, Canopy, Unify and Worldline. Atos SE (Societas Europaea) is listed on the CAC40 Paris stock index.

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