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Launch of PASQuanS2: Transforming the Landscape for Programmable Quantum Simulation in Europe

PASQuanS2 (Programmable Atomic Large-Scale Quantu Simulation) aims to develop next-generation programmable large-scale atomic quantum simulators operating with up t 10,000 atoms building on the successful European Quantu Flagship project PASQuanS

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Quantum technologies have evolved rapidly over the past years producing numerous substantial scientific breakthroughs. With several future application areas in sight, one of the most promising fields is the simulation of many-body quantum systems, such as quantum materials, molecules for drug research and the fundamental constituents of matter in extreme conditions. These problems can be addressed by dedicated quantum computers, known as quantum simulators. The development of analogue and digital quantum simulators has made significant progress in recent years. As different platforms become more mature in terms of scalability, stability and programmability, quantum simulation is moving from being a means for physicists to answer particular scientific questions towards a powerful tool to help address real-world problems and provide practical applications for industry. For instance, quantum simulators can potentially be used to develop new materials, analyse chemical processes, and solve optimisation problems in the future.
A research effort that has significantly contributed to the advancement of quantum simulation technologies and applications is the European Quantum Flagship project PASQuanS (2018-2022). Linking experimental groups, theoretical teams and industrial partners, the project successfully scaled up quantum simulation platforms based on atoms and ions, making them the most advanced to date. The mission initially started by PASQuanS is now continued and expanded by the successor project PASQuanS2.

Stimulating a vibrant ecosystem for quantum simulation across Europe
Teaming up most of the original consortium members with additional leading experts from research institutes, industry, small to medium-sized enterprises and start-ups from seven EU member states, PASQuanS2 sets out to transform the development of programmable quantum simulation in Europe further over the next seven years. Led by the Max Planck

Institute of Quantum Optics, the 25 partners have formed a Framework Partnership putting forward an ambitious seven-year research programme: the team will advance hardware and software for relevant scientific and industrial problems, so that verified next-generation, large-scale quantum simulators with up to 10,000 individual quantum systems can be demonstrated running stably in an end-user accessible form by the end of the Partnership. Following a two-stage approach, **PASQuanS2** is now kicking off its first project phase: the so-called PASQuanS2.1. Running for the next 3.5 years, one of the major objectives of this initial phase is the development of quantum simulators with at least 2,000 atoms and a path towards 10,000 while improving control, stability, and scalability. Alongside advancing the platforms technologically and developing a first version of a corresponding software stack to control the devices, PASQuanS2.1 will continue exploring industrial applications and mapping real-life problems while establishing a sustainable ecosystem of end-users and open quantum simulation platforms. i¿½**Addressing these challenges calls for a concerted effort between experimentalists and theorists from the academic world and engineers from industrial partners, including hardware and software technologists working together with prospective end-users**,i¿½ underlines Project Coordinator Immanuel Bloch, Director at t
e Max Planck Institute of Quantum Optics and Chair at LMU Munic
. Summing up the main activities and objectives of the next 3.5 years, he continues: i¿½**At the end of this first phase, we plan to have a quantum simulation ecosystem involving hardware platforms and corresponding bespoke software, enabling us to demonstrate a quantum advantage in academic and industrial problems in the second phase of PASQuanS2. Moreover, this ecosystem will comprise an integrated hardware supply chain helping to advance modular systems, which we will further implement as building blocks on experiments during PASQuanS2.2, and a pipeline transferring these building blocks to industrial partners for industry-driven production of quantum simulators and open online platforms**.i¿
? As part of the European Quantum Technology Flagship, PASQuans2 will continue
o exchange and liaise with other EU-funded quantum endeavours and national programm
s across Europe, thus enabling technology transfer and promoting collaboration betwe
n academia and industry on the technology and end-user leve

ICFO's contribution

ICFO researchers Prof. Antonio Acin, Prof. Maciej Lewenstein and Prof. Leticia Taurrell will be contributing both in the theoretical as well as the experimental aspects of the project. On one hand, they will develop a strontium optical lattice quantum simulator allowing for single-atom and single-site resolved imaging, in a compact setup of reduced experimental complexity. They will exploit this and other simulation platforms from the consortium to propose and perform science demonstrations. On the other hand, they will theoretically investigate the use of special-purpose quantum computing devices, such as simulators, to

solve relevant problems in science and optimisation, as well as provide methods for their certification.

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