Quantum Information Processing and Communication: Quantum Information with Photons and Atoms

Alain Aspect

2013 Balzan Prize for Quantum Information Processing and Communication

Balzan GPC Adviser: Luciano Maiani
Researchers: Chris Westbrook (Research Coordinator); David Clément, Marc Cheneau; Sébastien Tanzili (YQIS project)
Affiliated Institution: Institut d'Optique Graduate School (IOGS)
Period: 2016-2017

Alain Aspect is Professor at the Institut d'Optique Graduate School and the École Polytechnique in Palaiseau, and CNRS Distinguished Scientist Emeritus at the Laboratoire Charles Fabry at the Institut d'Optique.

Aspect proposed two projects for the use of the second half of his Balzan Prize. The first was to promote a series of conferences, *Young Quantum Information Scientists (YQIS)*, based on the model of the Young Atom Opticians conference launched by Professor Aspect and Professor Mlynek over twenty years ago to enable PhD students and postdoctoral scholars working in cold atoms to gain experience by organizing conferences and creating a European community. The first edition of YQIS, initiated by Alain Aspect together with Sébastien Tanzilli of the Laboratoire de Physique de la Matière Condensée at Nice (CNRS and Université Nice Sophia Antipolis), France, was held at the Institut d'Optique Graduate School in Palaiseau, France. As a conference "made by young researchers for young researchers (PhD students and postdoctoral fellows)", YQIS makes it possible for young research fellows to exchange ideas and to communicate their research in the newly recognized field of Quantum Information. The conference was a great success, and although it was held immediately after the terrorist attacks of November 2015 in Paris, almost all of the eighty registered participants from many different countries showed up, and demonstrated their ability to form a genuine community.

The definitive mark of the success is the fact that the second and third editions of UQIS were held in Barcelona in 2016 (http://yqis16.icfo.eu/) and in Erlangen in 2017 (https://yqis17.sciencesconf.org/). As foreseen in the project, the conference has taken on its own impetus, but the Balzan Prize played a crucial role in its establishment.

The second proposal was to fund two young researchers, David Clément and Marc Cheneau, for projects on quantum simulators of quantum correlated matter. Quantum simulators are a variety of quantum computers proposed by Feynman in his milestone paper on quantum information. They consist of realizing systems to emulate quantum systems very difficult to study directly. Ultra cold atoms placed into optical potentials realized with laser beams are remarkable examples of such simulators, giving access to quantum properties of entangled many-body systems of condensed matter.

Marc Cheneau's project concerns a cold atoms quantum simulator of supersolids, and he intends to measure directly spatial correlations with resolution, enabling him to see each individual atom. The experiment started from scratch, and it is still under development. Until now, the funding allocated to the project led by Marc Cheneau was used mostly to set up the lab room by purchasing such equipment as research grade optical tables to set up the laser system and the vacuum apparatus. It was also used to purchase various electronic equipment, such as a custom high-speed Pound-Drever-Hall locking module, to lock one of the lasers on a high-finesse optical cavity. The funding is not yet exhausted, and will continue to serve as a resource for achieving the construction of the apparatus, expected towards the end of the year 2019. In the meantime, Marc Cheneau was awarded an ERC Starting Grant for his research project, and the funding by the Balzan foundation definitely played a role in this success by strengthening the credibility of the application.

David Clément's project concerns a quantum simulator of a strongly interacting quantum atomic gas, with the primary goal of measuring how quantum depletion depends on the strength of the interactions. This has been achieved, and the Balzan Foundation is acknowledged in the two corresponding publications (Bouton et al., Phys. Rev. A 2015, Chang et al. Phys. Rev. Lett. 2016).

Balzan funds have then allowed passage to a new stage, funding an Italian postdoctoral researcher's first year (Marco Mancini), and buying a laser and optics to implement an optical lattice on the Bose Einstein condensate of metastable helium. The installation

of the optical lattice is completed, and the first experimental signals of atoms released from the lattice are currently being recorded.

In conclusion, the Balzan Prize funds have played a major role in starting three different projects:

1. Launching a new series of conferences for young researchers in quantum information science: YQIS
2. Starting from scratch a new experiment on quantum simulation of supersolids
3. Speeding up the development of a new experiment on a quantum gas of ultra cold metastable helium atoms and allowing the team to obtain its first results and publish them in high level journals (Phys Rev A and Phys Reve Lett)

As a final note, it must be emphasized that the Balzan funds from Aspect's Prize were not only essential for the success of this project, but also facilitated the additional funding necessary to continue each of the three programmes.