Qubit from the editor

Ron Folman

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Dear friends,

When Howard Brandt approached me and suggested that I act as guest editor for a special issue on quantum computing, I hesitated. Beyond the usual lack of time, I hesitated since it does not seem that we are close to a working device with significant capabilities, at least yet. Nevertheless, I eventually agreed as I felt it would be helpful to review the state-of-the-art at the beginning of the twentyfirst century and to take a broad view of the existing roadmaps. In addition, I have no doubt that in the process of working towards the quantum computer we are gaining new insight into theoretical and experimental physics and this too makes such a special issue attractive.

Quantum computing has always fascinated me for reasons far beyond the impressive technological ability to achieve complex quantum preparation, manipulation and measurement. My interest also lies beyond the rewards of quantum computing as they may present themselves in quantum algorithms that have been or will be constructed. The appreciation I have for the field of quantum computing stems mainly from the impression that this field has given rise to the widest and deepest look we have ever taken at quantum theory. I therefore believe that it is this field, above any other, which has a chance to reveal the inner workings of the theory and to perhaps lead, one day, to a possible extension of the paradigm.

This issue is devoted to isolated massive neutral particles, where by particle we refer to an atom (hot or cold, ground state or excited) or a molecule, and where by isolation we refer to vacuum. As hybrid apparatuses show great promise in enabling synergism between systems, we have also invited work on hybrid configurations.

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Let me note that although not all papers discuss direct application to an atom chip, I believe that the demand for robustness, accuracy, integration and scalability, will eventually lead any quantum computing methodology to utilize a solid state device. It will be interesting to see how the definition of the atom chip—once regarded as a tool dedicated solely to neutral ground state atoms in magnetic traps—develops. Indeed, chip fabrication technology is reaching a stage where any type of experimental realization can be implemented on a chip. It is therefore plausible to assume that the interplay between quantum optics and material science will play a major role as the field of quantum computing develops.

Quantum simulations, or more precisely analog simulations, are not included in this issue. Obviously, they are extremely interesting and may fulfill Feynman's original vision faster and with more impact than we expect. However, as the wide scope of simulations requires numerous papers in order to be well represented, we decided that perhaps a special issue in the future, dedicated to simulations, would better serve the reader.

For much the same reason we have excluded many other possible realizations of quantum computing such as trapped ions, super conducting qubits, NV centers in diamond, and so on. It may well be that one of these systems will eventually outperform the systems described in this issue.

The structure of this special issue is as follows: Following a detailed introduction into the field and its different implementations such as ground state atoms in optical lattices, we present the Rydberg gate and its possible implementation on an atom chip. We then move on to discuss implementations with molecules and ensembles. Next, we note the possibility of new types of systems with the particular example of group II atoms. We then give one example of a digital simulation. After discussing optical traps we take a broad look at atom chips. As noted, we also examine possible interfaces and hybrid systems.

Finally, the outlook at the end of this special issue is presented by Peter Zoller. Peter is undoubtedly one of the founding fathers of the field of quantum computing, and as such, I am grateful that he agreed to conclude this issue.

One of my students once asked me: "Our Parents say they grew up without the television. We say we grew up without the PC and the mobile phone. Will our children say they grew up without the quantum computer?". It remains to be seen. But in any case, it is reasonable to expect wonderful new insights.

I hope you enjoy reading this special issue.

Warm regards

Ron Folman.