Quantum Computing 2.0: the next generation

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The search for new quantum computers designed to outperform classical computers is driven by the end of Moore's law and the quantum advantages obtainable. A new generation of application specific quantum computers has shown great promise in providing this quantum leap. These threaten to bypass the older `universal' designs, by going directly to solve the problem at hand. One is already commercially available, and now undergoing trials at Google and NASA. This talk will discuss three new designs being investigated at SUT, with experiments planned at Swinburne and elsewhere.

The largest quantum computer in the world is the Stanford/Tokyo `Ising' machine. But can it really outperform classical computers at NP-hard optimization? We discuss the meaning of computational complexity, the physics of this novel device, and how it is theoretically modeled. An alternative hardware model is the `XY' machine, which uses a different type of photonic interaction, with experiments at the Weizmann Institute in Israel: although these are so far essentially classical. Preliminary theory at SUT of a novel parametric *quantum* `XY' machine will be given.

It is important to have quantum computers with both computational advantages and verifiable results. Boson sampling photonic networks are examples of this, with experiments in Oxford, Vienna, Rome and Queensland. These solve #P hard problems, which are more challenging still. We have developed both a quantum simulation of a boson sampling quantum computer, and analytic results. Surprisingly, we can simulate the experimental correlations much faster and with less error than in the experiments. This does not solve a #P hard problem – but gives signatures that can verify the computational output.

Finally, the emulation of the quantum decay of a relativistic scalar field from a metastable state (“false vacuum decay”) is a fundamental idea in quantum field theory and cosmology. We propose that this can be simulated using an ultra-cold spinor Bose gas. This will demonstrate that an exponentially complex, high energy theoretical model can be solved on a table-top quantum computer, even with energies far higher than any future CERN LHC, under conditions impossible to achieve in terrestrial experiments. Short movies of our simulations of the planned Swinburne laboratory demonstration will be given.