Report on Focus Meeting on Few Qubit Applications
Budmerice, Slovakia, 11-14 December 2003

Organisers: V. Buzek and J. Twamley

Participants:

Invited lecturers and organizers: V. Buzek, T. Calarco, J. P. Dowling, C. Hammel, N. Imoto, R. LaFlamme, C. Monroe, E. Polzik, J. Schmidmeyer, T. Spiller, J. Schleimann, J. Twamley, G. Wendin, C. Williams, A. Zeilinger

Students and postdocs: M.Koniorczyk, J.Kosik, D.McHugh, M.Plesch, M.Rosko, P.Stelmachovic, M.Ziman

OBJECTIVES

The primary objective of the meeting was to identify possible useful applications of quantum information processing using only a few qubits. The term “useful” is somewhat vague but some potential use to society is intended. The intended few-qubit application must compete efficiently with the corresponding classically implemented process in terms of either resources used or in terms of goals achieved (e.g. achieved few-qubit application may have no counterpart in classical information processing: quantum cryptography). Realistically, this out-performance must compete with developments in classical information processing over the mid-term (five years). The term “few qubit” is also somewhat vague but the technical milestones for few-qubit applications were taken from the ARDA Roadmap: by 2007 ~ 5-25 qubits, by 2012 ~ 50 qubits, with concatenated quantum error correction. The term “qubit application” was intended to be technology independent as far as possible. Further, one might claim that the achievement of some type of few-qubit device, such as a quantum repeater, to be a valid few-qubit application. Part of the objective of the meeting was to consider such technical “applications” to be more akin to developing tools to achieve true few-qubit applications such as quantum cryptography or quantum secret sharing.

FORMAT

The format of the meeting was intended to be small and rather informal. This was aimed towards facilitating open and frank discussion on the topic. However, as (to our knowledge), there have been no previous meetings in Europe on this topic, some structure was felt to be appropriate and all participants gave short presentations on their subject area. This was interspersed with coffee breaks and lunch. The primary consolidation of the workshop’s conclusions took place during two open discussion sessions (Friday 5-7pm & Saturday 5:30-6:30pm), facilitated by J. Twamley. All the presentations have been uploaded onto the Meetings’s internal password protected website.

BROAD CATEGORIES

The potential few qubit applications were broken down into the following categories:

(A) Self-contained Quantum Computation applications

These are applications of few-qubit quantum information processors that are self-contained in that their operations can be described through a set of known and prescribed quantum gates. The corresponding quantum circuit has known inputs and results in an output which (typically), returns some property of the gates operating within the circuit, e.g. periodicity in Shor’s algorithm etc.

(B) Quantum Metrology for ultra-sensitive parameter estimation

These are applications that couple to a classical system and, through some interaction, a change in some parameter of the classical system can be estimated ultra-precisely. This is done essentially by running an initial quantum state through a quantum circuit whose gates depend on the parameter to be estimated and, e.g. a phase estimation circuit.

The corollary few qubit application, which we shall denote: quantum state parameter engineering, is the engineering of states of matter such that their dependence on particular parameters alters in a non-classical manner, e.g. squeezing, quantum state lithography.

(C) Quantum Communication applications

These are few-qubit multi-station applications (e.g. quantum games), where spatially separated stations, each possessing (possibly), a few-qubit information processing device, can perform applications which can either yield significant improvements over corresponding classical applications or can implement fundamentally different applications.

In addition to the above broad categories, once the workshop highlighted key few-qubit applications, the primary technical challenges were discussed.

CONCLUSIONS AND OVERVIEWS

In conclusion, the meeting identified a number of potential few-qubit applications. It could be said that the meeting concluded that the construction, and continual improvement, of a dedicated quantum internet for potential users to explore and programme, could constitute the primary few-qubit application that has excellent potential for potential commercial exploitation in the future.

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