***Associateship Scheme***

*(5/4/2012****)***

**VISITING ASSOCIATE REPORT - FORM B**

**Please complete this form carefully at the end of your visit and return it to the Associateship Office.**

**This information is vital for the continuation of the Scheme.**

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**(if different from permanent):**

**Tel. No.:**

**Address:**

**City:**

**Electronic mail address:**

**Country: Zip code:**

**Temporary address valid until:**

**Date of Arrival at ICTP:** 15/7/2015 **Date of Departure from ICTP:** 20/9/2015

**Period/s spent outside ICTP in connection with present Associateship visit:**

**Institute/Town/Country:**

**Reason for visit:**

**Field of Research:**

Quantum information theory promises many future engineering applications such as quantum cryptography and quantum computation. It also provides tools to investigate new paradigms for fundamental physics such as topological states of matter.  This field brings together two of the greatest discoveries of 20th century: quantum physics and information theory. Now, it is commonly accepted that quantum information science will a broad impact on fundamental science and subsequently on the technology exploiting the properties of multi-partite systems like the entanglement which constitutes  a basic resource for several quantum tasks such as quantum computing, quantum key distribution.  In this sense, it is necessary to establish a systematic approach to quantify, characterize and classify entanglement between multipartite systems.  Despite the considerable efforts deployed by the quantum information community, our understating remains limited. The complexity in investigating entanglement grows exponentially with the number of particles. In this context, with my collaborators, during the last three years, we are interested in investigating the  quantum correlations using different measures Introduced by different authors from different perspectives and for specific purpose. Each one has its advantages and drawbacks and might be useful for some appropriate task.  We mainly focused on the quantum correlations existing in coherent states.  The quantum correlation measures can be entropic or geometric . They quantify the distance between a quantum state and another one without the required property. Probably the most familiar among entropic measures is the quantum discord which goes beyond the entanglement of formation. It is given by the difference of total and classical correlations existing in a bipartite system. Now, it is well understood that almost all quantum states, including un-entangled (separable) ones, possess quantum correlations. On the other hand, the geometric distance are defined by geometric norms such Hilbert-Schmidt norm, trace distance and Bures distance. Recently, we developed a unified scheme to unify the different correlations (classical, quantum-classical and quantum) existing in a bipartite system using the linear relative entropy.

**Give a brief description of the research work carried out during your visit.**

**Robustness of quantum Fischer information:**

In quantum information science, the quantum metrology refers to science of precision quantum measurements. Recently, considerable efforts deal with the optimal phase estimation to address many practical problems in general and especially the decoherence phenomena. In this context, to understand the role of quantum correlation in quantum metrology beyond standard quantum limit, we used the concept of local quantum correlation. This gives the lowest bound on the error in quantum metrology, when the measurement is performed on one of the subsystems.  The explicit form of the lower bound is obtained for bipartite states invariant under parity symmetry.  Clearly, the entanglement is a key resource to improve the quantum phase estimation but it is fragile and as a consequence the precision gain becomes affected by the system-environment coupling. In this sense,  it is necessary to develop a scheme to prevent against the decoherence mechanism. As a preliminary step, we analytically computed the Fisher information of two-qubit system under decoherence in Fano-Bloch representation. We derived the explicit formulas for different type of decoherence channels. This allows us to analyze the freezing phenomena of quantum Fischer information to prevent against any undesirable lost of information.

**Characterization of non local correlations via local quantum uncertainty for X states**

 A class of two-qubit states called X-states is increasingly being used to discuss entanglement and other quantum correlations in the field of quantum information. Maximally entangled Bell states and ``Werner" states are subsets of them. The underlying symmetry is the su(2)xsu(2)xu(1) sub-algebra of the full su(4) algebra of two qubits. $X$-states are a seven-parameter family associated with this sub-algebra of seven operators. This recognition provides a route to preparing such states and also a convenient algebraic procedure for analytically calculating their properties. Indeed, using the concept of Local quantum uncertainty (Girolami et al Phys. Re. Lett 110 (2013)240402), we analyzed the non classical correlation existing in X states. Closed expressions of this correlations quantifier are obtained and are compared with the quantum discord and its geometric variants based on Hilbert-Schmidt distance and Trace norm.

**Phase operators, Graph states and stabilizer formalism**

The phase operators for a cluster of multi-qudit (quantum systems with d-dimensional Hilbert space) can be constructed following the procedure dealing with the phase operator for su(2) algebra. The corresponding eigenstates give a set of temporally stable phase states which are used to generate mutually unbiased bases (MUBs). Such bases are of considerable interest in quantum information, especially when dealing with entanglement in multi-qudit systems. A second facet of this work concerns the relation between the phase states and the so-called graph states. This relation provides a scheme to deal with the quantum error correction within the stabilizer states formalism.

These results will be submitted soon for publication.

**Give details of lectures and seminars given at ICTP and/or elsewhere during your visit.**

**List scientific activities attended at ICTP and/or elsewhere during your visit and the benefits obtained from such activities.**

During my visit, I have attended to the following activity:

1. School and Workshop on strongly correlated electronic systems-Novel materials and novel theories (10 August-21 August 2015)

**List titles of papers/preprints published or submitted for publication during your visit.**

1. **Entanglement versus Gaussian quantum discord in a double-cavity opto-mechanical system**,

International Journal of Quantum Information,Vol. 13, No. 6 (2015) 1550041, DOI: 10.1142/S0219749915500410

2. **Hilbert-Schmidt measure of pairwise quantum quantum discord for three-qubit X states**,

Reports on Mathematical Physics Vol 76 (2015) 207

**Give details of scientific collaborations/contacts made during your visit.**

I discussed with many scientists, visiting ICTP or/and attending some activities, the main of their research topics especially

with scientists working on subjects related to quantum information.

**Which research facilities at ICTP have you found most useful to your work?**

Online access to journals.

Computing facilities.

The permanent help of the ICTP staff (scientists as well as others)..

**To what extent have you accomplished the scientific programme you planned for during your visit?**

During two months visit, I realized almost 80% of my previously planned program.

**Comment on the relevance and impact of your scientific activity at the ICTP to your scientific work in your country.**

My regular visits to AS-ICTP are of great importance for my research activities and have also an important impact on my career.

In the other hand, visiting ICTP allows me to attend to high quality conferences, seminars organized by ICTP.

**VERY IMPORTANT:**

This is my second visit as associate member. I visited several times the centre before. Thanks to the different schemes support (federation, visiting program …), I benefited from the ICTP facilities and this helped me in many respects.

**- NUMBER OF REFEREED INTERNATIONAL JOURNALS/PROCEEDINGS AT START OF ICTP visits 10**

**- NUMBER OF REFEREED INTERNATIONAL JOURNALS/PROCEEDINGS PRODUCED SINCE THEN 80**

**TOTAL NUMBER TODATE 90**

**Please suggest ways in which the ICTP could be of greater assistance to your future research work.**

**Other comments and suggestions.**

I would like to thank all the AS-ICTP members and especially the condensed matter section and the associate office team.

***Signature: Mohammed Daoud Date: 16/09/2015***