G-44-A53
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Theoretical studies of the generation, detection, and applications of massively entangled states of Bose condensed atoms

Task Information:

Discipline/ Program:	FUNDAMENTAL PHYSICS		
Subdiscipline/ Element:	Laser cooled atomic physics		
Project Type:	GROUND	**Solicitation**	02-OBPR-03
Project Title:	Theoretical studies of the generation, detection, and applications of massively entangled states of Bose condensed atoms		
Start Date:	2004-04-01 00:00:00.0	**Expiration:**	2006-09-30 00:00:00.0
Required Hardware:		**Monitoring Center:**	JPL
Number of Post Doctors:	2	**Number of PhDs Degree:**	1
Number of PhD Candidates:	0	**Number of MS Degree:**	
Number of MS Candidates:	1	**Number of BS Degree:**	
Number of BS Candidates:	0	**Key Personnel Changes / Previous PI:**	A postdoc in the group,Dr. Peng Zhang was briefly supported on this program for about 6 months.
CenterContact Name:	Maleki, Lute	**CenterContact Phone:**	818-354-3688
Center Contact Email:	lute.maleki@jpl.nasa.gov	**Monitoring Center:**	JPL
Joint Agency:			
Flight Program:			
Grant/Contract Number:			

PI Information:

Name: You, Li **Phone:** 404-894-2107 ext

Email: Li.You@Physics.gatech.edu **Fax:** 404-894-9958

Institution Type: UNIVERSITY

Institution: Georgia Institute of Technology

Address1: School of Physics, Mail Code 0430

Address2: 837 State Street

City: Atlanta **State:** GA **Zipcode:** 30332-0430

Congressional District: 5

Comments:

Task Description:

The experimental success in 1995 that produced the first dilute atomic Bose-Einstein condensate has led to an explosive growth of interests in this new type of degenerate quantum matter. As a testing ground for many fundamental issues in physics, in particular, in our understanding of interacting many body systems, atomic quantum gas has attracted much recent theoretical and experimental efforts. Ultimately, to grow beyond the novelty of being just another many body quantum mechanic phenomena, useful applications must be found that can take advantage of the macroscopic collective coherence of Bose condensed atoms, as well as the demonstrated abilities for the control of their interactions and the manipulation of their quantum states.

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At the frontier of atomic quantum gas research, a substantial topic of current interest is the creation of quantum correlated states of condensed atoms for several potential applications ranging from quantum computation to high precision quantum limited atom interferometry. In this proposal, we will investigate in detail the generation, detections and application of quantum correlated states of Bose condensed atoms. We will focus our efforts on two particular types of states that display inseparable quantum correlations: spin squeezed states and maximally entangled states. We will also study their relevance to several potential applications of trapped quantum gases. Our primary scientific objective to address the fundamental understanding of the proposed topics. We will develop new theoretical ideas and provide explicit estimate for parameters and conditions relevant to their technological applications. We expect our program will indirectly benefit experimental groups.

To understand non-classical correlation and/or entanglement properties of Bose condensed atoms, and to develop effective means for their generation and detection.

Spin squeezing and entanglement in an ensemble of fixed numbers of atoms can be used to enhance signal to noise ratios of certain atomic population based measurements, particularly for the atomic clock/frequency measurements based on the Ramsey interference scheme.

Research Impact/Earth Benefit:

This study constitutes an important part of the theoretical efforts in support of improved atomic clock technology.

Task Progress:

We have made two significant progresses during this reporting period.
First, we have developed a protocol for the measurement of certain collective operators for a multi-party quantum state. More specifically, we implemented a party check operation, that is a key step for realizing the Heisenberg limited sensing capabilities of massively entangled states. It turns out that our protocol can be directly implemented with present ion trap technologies. A paper on this work has been published at PRL.
Second, we have made a significant step towards defining a quantum correlation measure among an arbitrary number of partitions of a Multi-qubit quantum state. This is a significant theoretical breakthrough as it allows for the first time a consistent comparison and calibration of quantum entanglement resources inside an arbitrary N-qubit quantum state. Previous measures can only be applied to measure these inseparable resources when the N-qubit system is partitioned into two parties only. A paper has now been submitted to PRL.
During this last phase of no-cost extension after the sudden cancellation of our program, we have summarized and published a few articles.
A postdoc in the group, Dr. Peng Zhang was briefly supported on this program for about 6 months.

Flight Assignment Description:

COI Information:

COI Name	COI Institution

Bibiography Information:

Bibliography Type	Bibliography Description
Articles in Peer-reviewed Journals	Zeng B, Zhou DL, You L. "Measuring the parity of an N-qubit state." Phys Rev Lett. 2005 Sep 9;95(11):110502. PMID: 16196991, Sep-2005

Theoretical studies of the generation, detection, and applications of massively entangled states of Bose condensed atoms

Articles in Peer-reviewed Journals	Zhou DL, Zeng B, Tang JS, Xu Z, You L. "N-qubit entanglement from the J(2/y)-type collective interaction." Phys. Lett. A. 2005 Sep;345(1-3):38-44., Sep-2005
Articles in Peer-reviewed Journals	Sun B, Zhou DL, You L. "Entanglement between two interacting atoms in a one-dimensional harmonic trap." Phys. Rev. A. 2006 Jan;73(1): 012336., Jan-2006
Articles in Peer-reviewed Journals	Chang MS, Qin Q, Zhang W, You L, Chapman MS. "Coherent spinor dynamics in a spin-1 Bose condensate." Nature Phys. 2005 Nov;1(2):111-6 ., Nov-2005
Articles in Peer-reviewed Journals	Zhou DL, Zeng B, You L. "Quantum information cannot be split into complementary parts." Phys. Lett. A. 2006 Mar;352(1-2):41-4., Mar-2006
Articles in Peer-reviewed Journals	Zhang P., You L. "Geometric phase of an atom inside an adiabatic radio frequency potential" Phys. Rev. A 76, 033615 (2007), Oct-2007
Articles in Peer-reviewed Journals	Zhang P, Jen H. H., Sun C. P., You L. "The angular momentum of a magnetically trapped atomic condensate" Phys. Rev. Lett. 98, 030403 (2007), Feb-2007
Articles in Peer-reviewed Journals	Zhang P, You L. "Geometric phase of an atom in a magnetic storage ring" Phys. Rev. A 74, 062110 (2006), Mar-2007
Articles in Peer-reviewed Journals	Zhang M., Zhang P., Chapman M. S., You L "Controlled splitting of an atomic wave packet" Phys. Rev. Lett. 97, 070403 (2006), May-2007