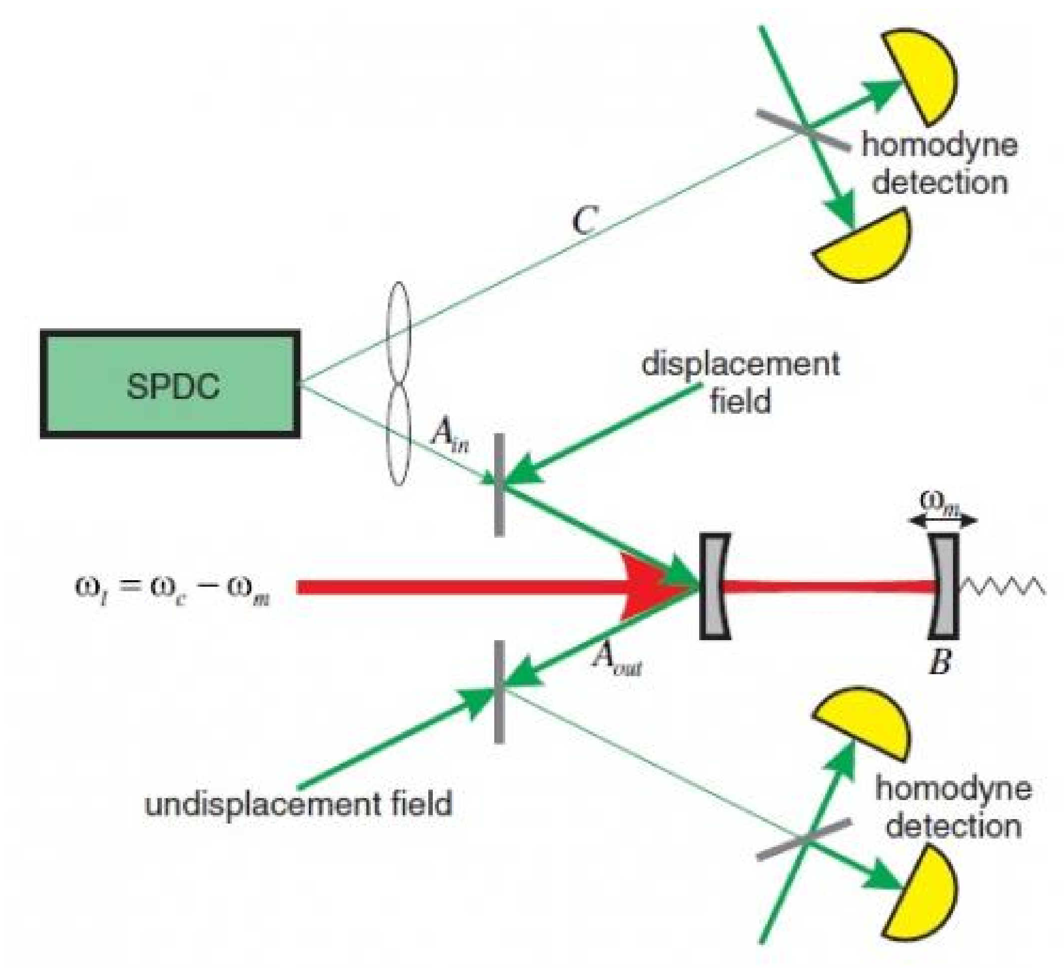
Micro-macro entangled 'cat states' could one day test quantum gravity

April 16 2014, by Lisa Zyga



Proposed setup for generating optomechanical "cat states," a form of micro-macro entanglement in which the quantum states of photons and phonons are in superposition. Credit: R. Ghobadi, et al. ©2014 American Physical Society

(Phys.org) —In Schrödinger's famous thought experiment, a cat's quantum state becomes entangled with the quantum state of a decaying nucleus, resulting in the odd situation that the cat is both alive and dead at the same time. The thought experiment was originally intended to convey the absurdity of applying quantum mechanics to macroscopic objects, but recently physicists have been questioning whether "quantum" effects such as entanglement and superposition may apply on all scales.

In order to extend quantum effects to the macroscopic level, physicists are working on creating entanglement between a macroscopic and microscopic system. This situation is very similar to that of the entanglement between the quantum state of the macroscopic cat and that of the microscopic decaying nucleus. So far, micro-macro entanglement has been experimentally demonstrated in optical systems, and is currently being pursued in other areas, such as electro-mechanical and opto-mechanical systems.

In a new study published in *Physical Review Letters*, physicists Roohollah Ghobadi, et al., have proposed a method for generating optomechanical micro-macro entanglement.

One of the most intriguing outcomes of bringing quantum effects to the macroscopic level using this approach is that it could allow researchers to test for wave function collapse due to quantum gravity, which is predicted to occur on a much shorter timescale than wave function collapse due to environmentally induced decoherence.

"Our proposal allows for observation of the genuine macroscopic superposition of massive objects," Ghobadi told *Phys.org*. "It also looks promising to test some collapse models."

The proposed method involves storing one component of an entangled state of light (consisting of just one or a few photons) in a mechanical resonator (consisting of billions of atoms). During this process, the initial microscopic entangled state of photons is amplified with a strong coherent beam, the photons are converted into phonons, and then the entangled states are retrieved.

This approach makes it possible to create optomechanical "cat states," in which the quantum states of the photons and phonons are in superposition.

The researchers write that the scheme is realizable with current technology, and if realized, would be the second demonstration ever of optomechanical entanglement.

To test proposals for quantum gravity-induced wave function collapse, future experiments could be performed that compare the collapse time (estimated to be on the order of microseconds) to the collapse time of environmentally induced decoherence (on the order of milliseconds).

"It is interesting to do the proposed experiment for different masses in order to distinguish the decoherence due to a collapse model from conventional environmentally induced decoherence," said coauthor Christoph Simon, Physics Professor at the University of Calgary.

In addition, by varying other factors such as the amplification and the number of phonons, researchers could use this method to look for other types of deviations from quantum physics in this little-explored regime of micro-macro entanglement and superposition.

"One possible direction is to apply the method proposed here to create cat states in other systems," Ghobadi said. "It is also interesting to look at its application in quantum information processing."

More information: R. Ghobadi, et al. "Optomechanical Micro-Macro Entanglement." *PRL* 112, 080503 (2014). DOI: 10.1103/PhysRevLett.112.080503