Università degli studi di Firenze

Dipartimento di Fisica e Astronomia

PhD Diessertation

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A spin squeezed atom interferometer

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The operation of atom interferometers is based on the coherent splitting and recombination of matter waves achieved through the interaction of laser radiation with atomic wave packets. At the end of the interferometer, the quantum phase accumulated in the interferometer arms is translated into the presence of interference fringes. The interferometer phase carries valuable information about the physical interactions which occurred during the interferometer time. The phase measurement can thus provide precise and accurate measurements of electromagnetic interactions as well as of inertial interactions. When a phase measurement is performed with N independent particles, an atom interferometer can operate at most at the standard quantum limit where the phase uncertainty is $1/\sqrt{N}$. This limit, also known as the shot noise limit, derives from the quadrature sum of the phase noises of the independent particles. Thanks to the ability to suppress many sources of technical noise, state-of-the-art atom interferometers are presently operating at the shot noise limit [1]. Overcoming this limit requires creating correlations between the noises of the interfering particles, thereby creating entangled spin squeezed states and potentially achieving the Heisenberg limit, with phase uncertainty $1/N$.

In this talk I will show that spin squeezed states can be generated by the interaction of light with atoms. Because the size of this interaction scales with the effective optical depth of the ensemble, the performance of light-interaction-based spin squeezing can be greatly enhanced by the interaction of the atomic ensemble with light circulating in an optical cavity [2]. I will then discuss the possibility of expanding the demonstrated spin squeezing techniques to include atom interferometers where the atoms are allowed to travel large distances in free space and where the interferometer states differ only by their velocity. I will finally discuss the main challenges and limitations of spin squeezing for free space atom interferometers.

[1] G. Rosi, F. Sorrentino, L. Cacciapuoti, M. Prevedelli and G. M. Tino, *Nature*, **510**, 518-521 (2014)

[2] H. Tanji-Suzuki, I. D. Leroux, M. H. Schleier-Smith, M. Cetina, A. T. Grier, J. Simon and V. Vuletic (2011), **arXiv:1104.3594v2**