Generation of the spatially multimode squeezed light in hot Rb vapor

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An increasing number of applications, such as quantum information and quantum sensor technologies rely on strong coupling of optical fields to long-lived atomic spin states via multi-photon Raman processes. Traditional theoretical description utilizes the plane-wave approximation or, at best, a single spatial mode description for all optical fields involved in the process. Our recent results, however, highlight the importance of considering the multimode spatial structure for proper quantum description.

For example, it is typically assumed that any nonlinear effect should be enhanced with increasing number of interacting atoms [1]. In experiments, however, we found non-trivial dependence of the measured polarization self-rotation squeezing (PSR) [2] on optical depth of the atomic ensemble, in which squeezing level increases with atomic density up to some optimal point, and then rapidly deteriorates. Our previous experiments suggest that the amount of observed squeezing at higher optical depths may be limited by the contamination of the squeezed vacuum output with higher-order spatial modes, also generated inside the cell [3]. As further confirmation we observed different squeezing behavior when we use two different methods for increasing the optical depth in practice, either by increasing the density of atom (by increasing the temperature of the vapor cell), or by increasing an effective propagation length (by letting the light propagate through the multiple lengths of the cell) [4].

We also experimentally explore the generation of intensity-correlated optical fields via the four- wave mixing (FWM) process in the hot ^{85}Rb vapor [5]. By introducing the topological charge into either pump or probe optical fields (or both), we demonstrate generation of intensity squeezed optical fields carrying different optical angular momenta (OAM). We also observe the relationship between the OAM conservation and the degree of quantum correlations.

For both experiments, we are investigating methods to improve squeezing and control the quantized output by tailoring the spatial profile of the optical fields before the interaction.

References

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