Generation of the Spatially Multimode Squeezed Light in Hot Rb Vapor

I Novikova$^1$, N Prajapati$^1$, N Super$^1$, M A Guidry$^1$, M Zhang$^1$, R N Lanning$^2$, Z Xiao$^2$, J P Dowling$^2$, and E E Mikhailov$^1$

$^1$Physics, College of William and Mary, Williamsburg VA, USA. Contact Phone: +17572213500
$^2$Physics, Louisiana State University, Baton Rouge LA, USA
Contact Email: inovikova@physics.wm.edu

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, we found non-trivial dependence of the measured polarization self-rotation squeezing 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. As further confirmation we observed different squeezing behavior when we use two different methods for increasing the atomic optical depth.

We also experimentally explore the generation of multimode intensity-correlated optical fields via the four-wave mixing (FWM) process in the hot $^{85}$Rb vapor. 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), and study the relationship between the input and output states of the optical fields.

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.