Quantum Entangled Images

We have developed a technique for generating non-classical light by 4-wave mixing in atomic vapors. We have generated “twin beams” of light that are more closely correlated than for any classical sources. One particularly useful feature of this technique is that the non-classical light can easily be made in multiple spatial modes. That is, *images* with quantum correlations can be produced. Pixel-by-pixel, the light in these pairs of images is correlated to levels better than the shot noise for the photon numbers involved. Light in the corresponding pixels is not just correlated in intensity, but also in phase. The intensity-difference and the phase-sum are quadrature variables displaying quantum entanglement at levels that violate the inequality expressing the Einstein-Podolsky-Rosen paradox. Measurements showing such entanglement were reported in 2009.

Quantum-correlated and entangled images might be used for faint-object detection (a small absorption or scattering from one of the beams, even at a level below the shot noise, can be detected in the difference between the beams). Another future use of such images is in information storage. The parallel storage of quantum information in images has not yet been demonstrated, however, we have taken the first steps in that direction with the “slowing” of quantum images. A vapor cell with a dispersion (change of index with frequency) can display a large group index, which corresponds to a very small pulse velocity in the medium. We have demonstrated the slowing and delay of continuous beams carrying quantum-correlated images, while preserving the quantum correlations, for times of 20 -30 ns. Future work will pursue stopping, holding, and releasing pulses of light carrying images in a quantum memory configuration.

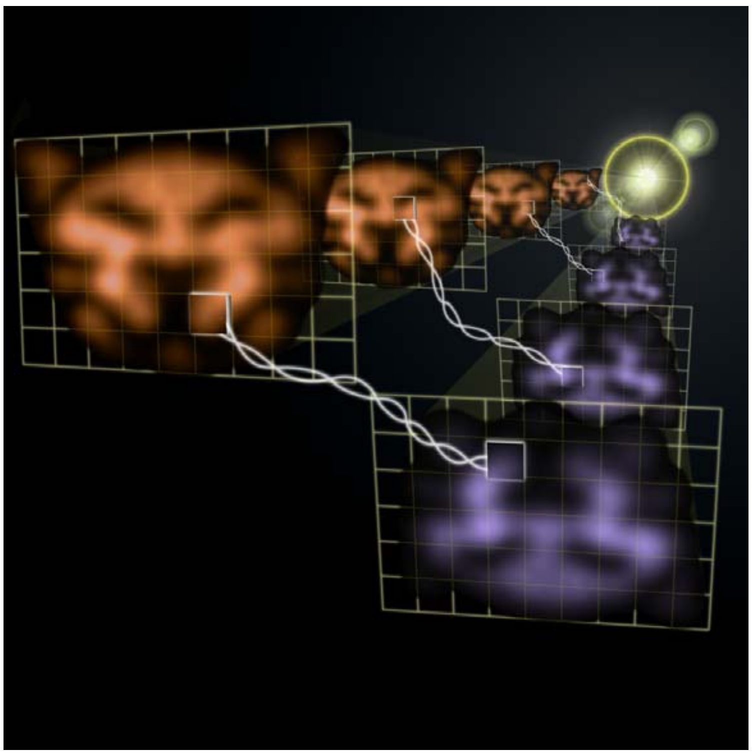

Figure 3.3: Composite of quantum-correlated images indicating approximate regions of quantum correlations between the “twin” images. The pair of images is created by sending a seed image through an atomic vapor cell in which the 4-wave mixing process amplifies the seed and also generates the twin image.

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