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Comment on

Quantum backaction of optical observations on Bose-Einstein condensates by U. Leonhardt, T. Kiss, and P. Piwnicki

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PACS. 03.75.Fi Phase coherent atomic ensembles; quantum condensation phenomena – 03.65.Bz Foundations, theory of measurement, miscellaneous theories (including Aharonov-Bohm effect, Bell inequalities, Berry's phase – 42.50.Dv Nonclassical field states; squeezed, antibunched, and sub-Poissonian states; operational definitions of the phase of the field; phase measurements

Dispersive imaging with off-resonant light is an important technique for observing Bose-Einstein condensates [1,2]. Compared to absorption imaging it causes much less heating, and hence, allows the recording of non-destructive real-time "movies" of the dynamics of Bose-Einstein condensates [3]. We observed that a limitation of dispersive imaging comes from residual absorption or Rayleigh scattering. The momentum transfer to the condensate atoms depletes the condensate and heats the cloud due to the transferred recoil energy [1,2].

In contrast, a recent paper [4] emphasized that the limit of dispersive imaging is not residual absorption, but a different form of quantum backaction of the probe light which was determined with a new approach to quantum-optical propagation. This note points out that these conclusions are incorrect, and that Rayleigh scattering is the dominant quantum backaction of dispersive imaging.

First, the absorption rate cannot be completely suppressed by imaging with far-detuned light. For a desired signal-to-noise ratio, a further detuning has to be compensated by higher laser intensity in such a way that the rate of far-wing absorption is constant [2]. The absorption rate per atom is simply the Rayleigh scattering rate $\gamma_\mathrm{s} = \mathit{\Gamma} f_\mathrm{exc}$, where $\mathit{\Gamma}$ is the natural linewidth and the excited state fraction $f_\mathrm{exc} = (\omega_\mathrm{R}/2\mathit{\Delta})^2$ is given by the Rabi frequency ω_R of the probe light and its detuning $\mathit{\Delta}$. The recoil due to the scattering of photons knocks atoms out of the condensate and depletes it with a rate γ_s.

Leonhardt *et al.* [4] derived an expression for the depletion of the condensate γ_L (their Eq. (62)). The rate γ_L turns out to be proportional to the absorption rate γ_s but is smaller by a factor of (3/16) [5]. This indicates that the calculated backaction is related to Rayleigh scattering. It seems that it is just Rayleigh scattering with the smaller prefactor caused by approximations of the theory. Therefore, the statement by the authors that their result is *qualitatively* different from Rayleigh scattering is inconsistent with their results.

Another major result of reference [4] is that the phase diffusion rate is always smaller than the depletion rate. Our experiments [1,3] were not sensitive to perturbations of the phase, and we didn't estimate this effect.

In conclusion, residual absorption or Rayleigh scattering is the dominant perturbation of dispersive imaging, and this process is the dominant quantum backaction of the probe light on the Bose-Einstein condensate.

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