Introduction to Quantum Optics

Winter term 2006/07
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Problem set 6 Hand out: 11 Jan 2007
Talks scheduled: 26 Feb 2007

Problem 6.1 – Radiation forces on 'dressed states' (20 points)

The 'dressed states' introduced in the lecture can be used to compute and understand the forces exerted on an atom by laser light. Recall that the dressed states are eigenstates of a two-level atom that is driven by a laser field; they are superpositions of the ground and excited states, with coefficients involving the Rabi frequency.

This discussion is summarized in the seminal paper (more than 300 citations) by Dalibard and Cohen-Tannoudji, "Dressed-atom approach to atomic motion in laser light: the dipole force revisited", J. Opt. Soc. Am. B 2 (1985) 1707. The talk would present selected sections of this paper.

Problem 6.2 – An operator for the phase (20 points)

'Phase' has an unusual status in quantum theory because it is not straightforward to construct a hermitean operator that is conjugate to the photon number. The talk would present the reasons for this difficulty and recent attempts to define operators that come close to a phase operator.

Literature:

M. Orszag, "Quantum Phase", chap. 15 in *Quantum Optics* (Springer 2000);
M. L. Arroyo Carrasco and H. Moya-Cessa, "A Hermitian operator conjugate to the number operator", Quant. Semiclass. Opt. 9 (1997) L1.

Problem 6.3 – The Glauber representation of the density operator (20 points)

In the paper "Coherent and Incoherent States of the Radiation Field", Phys. Rev. 131 (1963) 2766, where R. J. Glauber introduces the famous coherent states, the main issue is how to characterize the density operator of the photon field. The talk presents selected sections of this paper, in particular the so-called 'Bargmann states'

$$|f\rangle = f(a^\dagger)|0\rangle$$

where $f(z)$ is a polynomial with coefficients $\sum_n |c_n|^2 = 1$.

Problem 6.4 – Dephasing of qubits (20 points)

In a quantum computer, 'dephasing' is the process where the relative phase in a superposition state $|0\rangle + \alpha\, e^{i\phi}|1\rangle$ is getting randomized and lost. This can be described by a coupling to an environment (a 'bath') of the form

$$H_{\rm int} = \sum_k g_k \sigma_3 \left(a_k + a_k^\dagger\right)$$

where the environment modes eventually form a continuum. The density matrix of the qubit as a function of time can be found in a closed way, as would be presented in the talk.

Literature:

N. G. van Kampen, "A soluble model for quantum mechanical dissipation", J. Stat. Phys. 78 (1995) 299

G. M. Palma, K. A. Suominen, and A. K. Ekert, "Quantum computers and dissipation", Proc. Roy. Soc. Lond. A 452 (1996) 567 [quant-ph/9702001]