Einführung in die Quantenoptik I

Wintersemester 2016/17
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Ideas of Quantum Optics #1 Hand out: 18 October 2016
Hand in: after the Lecture

No test, no marks, just an attempt to capture your 'pre-knowledge' about quantum optics. At the end of the semester you may look again at this sheet and check how your ideas have developed. – Read through all questions first. Write down all answers that come to your mind immediately. For each questions, one or two sentences are sufficient. A sketch says more than a thousand words. – This test online at moodle: click here!

Problem 1.1 – What is a photon? Give three physical properties of a photon.

Problem 1.2 – What happens with a photon at a beam splitter? (Make a sketch.)

Problem 1.3 – A green laser beam illuminates a detector that counts single photons, giving 10^6 clicks per second, say. What is the power of the laser beam? How large is the probability to find in one second $990\,000 \pm 100$ clicks? Sketch

the probability distribution $p(n)$ for the number of clicks n per second.

Problem 1.4 – There are two (or more) meanings to the word 'polarization'. Give three examples of the polarization of a photon. Another meaning is related to electric dipole moments in a piece of matter. What is the physical unit of polarization (in this sense)? At a given position, is the polarization a scalar, vector, tensor? Estimate a number when in water, all molecules have their dipole moments aligned in the same direction.

Problem 1.5 – Remember the stationary states of an alkaline atom, Lithium, for example. Give a few properties of the ground state and of one electronically excited state. Which is the excited state that the atom can jump to when a photon impinges on the ground state? Hold it: what is jumping here? (Memories on Lithium: three electrons, three protons, three to four (or more) neutrons.)

Problem 1.6 – Be A an observable of a quantum syste. Give a formula for the expectation value (average) of A. What is the probability that measuring A returns a value a?

Problem 1.7 – You just invented a device that prepares hydrogen atoms in the state $2p_x$. What is the entropy of this state? How does your answer change when the device prepares with an error probability of 3% the state $2s$?

Problem 1.8 – Be a and $a^\dagger$ the ladder operators of the harmonic oscillator from your Quantum Mechanics I lecture. Compute the commutator $[a^\dagger, a]$.

Problem 1.9 – Write down the interaction energy of an electric dipole with the electromagnetic field. What happens when the dipole is moving? What about a magnetic dipole?

Problem 1.10 – Consider the following frequencies (o) visible light, (i) musicians' favorite a' note, (ii) blackbody radiation at room temperature, (iii) sunlight, (iv) X rays, (v) cosmic radiation, (vi) electromagnetic waves in the mobile

phone network. Without giving precise numbers, arrange the frequencies in increasing order.