2.zh Szemináriumm

Biofiz (Grafiz)

$\lambda = 600\,nm = 600 \cdot 10^{-9}\,m = 6 \cdot 10^{-7}\,m$

1.) In monochromatic, 600 nm wavelength coherent plane wave the stream of photons is moving into the positive z direction. The transmited power is 1 pico-Watt. T or F?

$\hookrightarrow 10^{-12}$ Watt

$e = 1{,}602 \cdot 10^{-19}\,[As]$ $\hbar = 1{,}054 \cdot 10^{-34}\,[Ws^2]$ $m_e = 9{,}109 \cdot 10^{-31}\,[kg]$

e a: 17/19
20/20

a.) Energy of photon is $\approx 2{,}07\,eV$

ν = oscillator frequency

If the signal is

c.) The average number of photons, the coherent noise level is about 0,33 pico-Watt, and the SNR is about 3,02

coherent stream

$$SNR = \frac{\text{Mean Square}}{\text{Variance}} = \frac{\bar{n}^2}{\sigma_n^2} = \bar{n}$$

$$\bar{n} = \sum_{n=0}^{\infty} n\,p(n)$$

$$\sigma_n = \sqrt{\bar{n}} \quad ; \quad p(n) = \frac{\bar{n}^n e^{-\bar{n}}}{n!} \quad n = 0, 1, 2 \ldots$$

b.) The average number of photons are about 6,02 million photons/sec.

d.) The direction of the momentum vector is $-z$

$+z$ irányban mozdul: F

e.) In case of collision with a standing still hydrogen atom, the atom will gain a velocity of about 0,66 m/s

?

$$|P| = \underbrace{\hbar k}_{\text{photon}} = \underbrace{m v}_{\text{atom}}$$

k = hullámszám $= \frac{2\pi}{\lambda}$

$$v = \frac{\hbar\, 2\pi}{m \lambda} = \frac{1{,}054 \cdot 10^{-34} \cdot 2 \cdot 3{,}1415}{9{,}109 \cdot 10^{-31} \cdot 600 \cdot 10^{-9}}$$

2.) In a cavity the classical electromagnetic field can always be represented by the linear combination of the fields of its cavity modes.

T or F?

a.) The state variable in cavity is the vector potential satisfying the wave equation: $\Delta A(r,t) = \frac{1}{c^2}\frac{\partial^2}{\partial t^2} A(r,t)$ T

b.) From the known vector-potential the electric field of the cavity can be derived $E(r,t) = \nabla \times A(r,t)$

c.) Also magnetic field, which is $B(r,t) = -\frac{\partial}{\partial t} A(r,t)$

d.) The general solution of the wave equation is $A(r,t) = \sum_k f(k) A_k(r)$ where the eigenvalue problem $\Delta A_k(r) = -k^2 A_k(r)$ specifies the spatial turnucture of the mode functions.

T

e.) The time-dependent f_k function determine the Lagrangian of the cavity modes $L_k = E_{Ek} - E_{Mk} = \frac{1}{2}\varepsilon_0\left[\frac{df_k}{dt}\right]^2 - \frac{k_n}{2\mu_0} f_k^2$

T

előadás diából idézni!

③ T or F in a closed ideal cavity.

a) The energy of each cavity mode is proportional to the frequency of the mode.

↳ [illegible]

$$E_{\gamma_n} = \hbar\omega\left(\frac{1}{2}+n\right) \approx \hbar\omega n$$

↳ kis n esetén ↳ nagy n esetén

F T → indoklás kell.

b) If there were no photons in a mode the energy would be zero

F → mivel van null-ponti energia.

c) If the number of photons in a mode was doubled the energy stored in that mode would double.

F → null-ponti energia van duplázódik

d) If the ground state energy of cavity mode was E_0 eV, the energy of that mode could be $E_0 + 2nE_0$, where n is the number of photons in the cavity mode

T → $E_{\gamma n} = \hbar\omega\left(\frac{1}{2}+n\right)$

e) If we increase the number of photons in mode by one, the energy of the mode would increase by $2E_0$

$$E_0 = \frac{1}{2}\hbar\omega$$

$$2E_0 = \hbar\omega \quad \hookrightarrow \quad E_1 = \frac{3}{2}\hbar\omega$$

n db foton esetén $E_n = n\hbar\omega$

F

4.) Using the analogy between a classical harmonic oscillator and the time-dependence of a classical cavity mode, the Hamiltonian operator of a cavity mode can be established, and the quantum behaviour of the cavity can be explained ///

a.) The energy of a cavity mode not change continuously with the intensity of field, but it is quantized as $E_{k_n} = \hbar \omega_k (n + \frac{1}{2})$, where n is referring to the number of photons in cavity mode.

H ?

b.) For $n=0$ (no photons) there is no energy in the cavity.

F → ∃ ground state energy

c.) For $n=0$ there is energy in the cavity. We experience the zero-point fluctuation of the field.

T

d.) Both the electric and the magnetic fields can be zero in this zero-point state

T?

e.) The expectation values of the both the electric and magnetic fields can be zero, however, the variances can't be both zero, and thus the energy content of the zero point state fluctuation is finite.

T ?

5. In cubic ideal cavity resonator of size $a \times a \times a = 10^{-3}m \times 10^{-3}m \times 10^{-3}m$ there are 100 photons in a mode (1, 1, 1) and 14 in the next excited mode. The system is cooled down to 0,01 K.   T or F?

a) First mode resonance frequency is $\omega_{111} = \frac{\pi \cdot c}{a}\sqrt{3} = 2\pi \cdot 260\ GHz \rightarrow$

$\rightarrow 1{,}08 \cdot 10^{8}\ eV$

mennyiben a téglet

b) The resonance of the next excited mode is

$\omega_{211} = \frac{\pi \cdot c}{a}\sqrt{6} = 2\pi \cdot 366\ GHz \rightarrow$

$\rightarrow 1{,}52 \cdot 10^{-3}\ eV$

mennyiben a téglet.

c) The total EMAG energy is $E \simeq 0{,}13\ eV$

$$\left.\begin{array}{l} \omega_{111} = \ldots \rightarrow E_{111} = \hbar\omega_{111} \xrightarrow{\times 100} \\ \omega_{211} = \ldots \rightarrow E_{211} = \hbar\omega_{211} \xrightarrow{\times 14} \end{array}\right\} \Sigma = \ldots \text{ stb.}$$

d) The cavity state in occupation number representation is $|100, 14\rangle$

e) EMAG vacuum fluctuation is 3 orders of magnitude smaller than the classical noise level of the environment.

$\frac{1}{2}\hbar\omega_{111}$

$\frac{1}{2}\hbar\omega_{211}$

→ Absz. Höm.

klasszikus zajszint : kT

Boltzmann áll

⑥ We build a closed composite quantum system from two two-state atoms.

T or F?

a.) The time dependent state can be represented as $|\Psi(t)\rangle \rightarrow \begin{bmatrix} c_1(t) \\ c_2(t) \end{bmatrix}$

$$|c_1(t)|^2 + |c_2(t)|^2 = 1$$

T ?

b.) The time dependent state can be represented as $|\Psi(t)\rangle \longrightarrow \begin{bmatrix} c_1(t) \\ c_2(t) \\ c_3(t) \\ c_4(t) \end{bmatrix}$

$$|c_1(t)|^2 + |c_2(t)|^2 + |c_3(t)|^2 + |c_4(t)|^2 = 1$$

c.) The time-evolution of the state satisfies the time-dependent Schrödinger equation as : $j\hbar \dfrac{\partial|\Psi(t)\rangle}{\partial t} = H|\Psi(t)\rangle$

T → mert csak

d.) The Hamilton operator can be represented as $H \rightarrow \begin{bmatrix} E_1 & 0 \\ 0 & E_2 \end{bmatrix}$

Hiányzik 2 állapotú

F Mert a mátrix 1 áll. rendszerhez tartozik.

e.) The time-evolution of the state can be expressed as $|\Psi(t)\rangle = e^{j\frac{H}{\hbar}t} \cdot |\Psi(0)\rangle$

T → Literatúrában e negatív de a többiekben.

1.) 100 photons one by one are transmitted through a beam-splitter of transmittance, $T = 0{,}5$. T or F

a.) Exactly 50 photons will be transmitted and 50 reflected in such way, that the transmission and reflection of the photons alternate.

b.) First 50 photons will be transmitted, then 50 reflected

c.) Each photon will be split, half of its energy will be transmitted, the the other half will be reflected

d.) We do not know exactly how many will be transmitted and reflected photons ($\bar{n}_T = \bar{n}_R = 50$), and the variance will depend on the source of the photons

e.) If the photons arrive independently to the beam-splitter, the variance of the photon number would be 10.

have two

$a \times a \times a = 10^{-3} m \times 10^{-3} m \times 10^{-3} m$

... excited mode.

2.) A linearly +X polarized photon travels in the +z direction. T or F

a.) We let the photon through an X linear polarizer. The probability of transmission is 0,5 (50%)

T

b.) We let the photon go through an Y linear polarizer. The probability of transmission is 0 (0%)

T

c.) We let the photon go through a right circular polarizer (RCP). The probability of transmission is 0,5 (50%)

T

d.) We let the photon go through a left circular polarizer (LCP). The probability of transmission is 0,5 (50%)

T

e.) We let photon go through a right circular polarizer (RCP) then go through an X linear polarizer. The probability of transmission is 0,25 (25%)

T

datoset

fa_ale

4:

⑥ We build a . . .

9. We have a weak electromagnetic field in a plan-parallel cavity (two mirrors) of size $d = 300$ nanometer. T or F

$3 \cdot 10^{-7}$ m

$\to 6 \cdot 10^{-7}$ meter

a. If the number of first mode photon ($\lambda = 0{,}6$ micron) is about 1000, then we could find about 200 first mode photon in a 30nm long interval near the center of the cavity

$3 \cdot 10^{-8}$ m

$\to 3 \cdot 10^{-7}$ m

b. If the number of second mode photon ($\lambda = 0{,}3$ micron) is about 1000, then we could find about 200 photon in a 30nm long interval near the center of cavity.

$\to 6 \cdot 10^{-7}$

c. If the number of first mode photon ($\lambda = 0{,}6$ micron) is about 1000, then ~~we could~~ at the left mirror in 30nm long interval the number of first mode photon is always zero.

$\to 6 \cdot 10^{-7}$

d. If the number of first mode photons ($\lambda = 0{,}6$ micron) is about 1000, then at the left mirror in a 30nm long interval the number of photons is not zero, however the mean value is less than 5 photons

$\to 2 \cdot 10^{-7}$

e. If the number of third mode photons ($\lambda = 0{,}2$ micron) is about 1000, then we could find about 100 photons in a 30nm long interval near the center of the cavity

T ?

two dataset

Mesil fa jale

6 We build a closed con...

8

10. We have a weak electromagnetic field in a plan-parallel cavity (two mirrors) of size $d = 300$ nanometer. T or F

a.) The distribution of the photons in the cavity is homogeneous. i.e. probability of finding a photons in the cavity is the same as everywhere in the cavity.

b.) If the number of photons in the cavity is about 1000, the prob. of finding photons in an interval at the center of the cavity does not depend on the cavity mode

c.) The probability of finding photon at the mirrors is always higher than the probability of finding them near the center

d. The probability of finding photons at the mirror is always zero, and it does not depend on the cavity modes

e.) The probability of finding photons in an interval of thickness Δx can be estimated by the formula $\left(\frac{2}{d}\sin^2\frac{n\pi}{d}x\right)\Delta x$

Biofiz (Csufiz) hanus I

1.) Ground state of e^- in 1D pot box is 3,5 eV.
which of the following energies can be the energy of an excited state?

a
1 14.0 eV ✓
2 21 eV ×
3 31,5 eV ✓
4 42 eV ×
5 56,0 eV ✓

mo: 1D pot box:

$$E_n = \frac{h^2}{8ma^2} n^2 \qquad n = 1,2 \ldots$$

$\hookrightarrow E_n = n^2 E_1$

$\hookrightarrow E_1 = 3,5 \, eV$

$E_2 = 14 \, eV$

$E_3 = 31,5 \, eV$ különbség 23,5

$E_4 = 56 \, eV$

$$\Psi_n(x) = \sqrt{\frac{2}{a}} \sin\left(n \frac{\pi x}{a}\right)$$

$$\Psi_n(x,t) = \sqrt{\frac{2}{a}} \sin\left(n \frac{\pi x}{a}\right) e^{\left(-i \frac{E_n}{\hbar} t\right)}$$

2.) Ground state energy of harmonic oscillator is 1,4 eV of the following energies can be the energie of an excited state?

1 2,8,0 ×
2 7,0 eV ✓
3 14,0 eV ×
4 19,4 eV ✓
5 26,6 eV ✓

mo: $E_{pot}(x) = \frac{1}{2} c x^2$

$E_n = \hbar \omega \left(n + \frac{1}{2}\right) \qquad n = 0, 1, 2 \ldots$

$$E_n = (2n+1) \cdot E_0$$

$\hookrightarrow$ $E_0 = 1{,}4\ eV$ $\quad E_3 = 9{,}8\ eV$ $\quad E_6 = 18{,}2\ eV$

$E_1 = 4{,}2\ eV$ $\quad E_4 = 12{,}6\ eV$ $\quad E_7 = 21\ eV$

$E_2 = 7\ eV$ $\quad E_5 = 15{,}4\ eV$ $\quad E_8 = 23{,}8\ eV$

$E_9 = 26{,}6\ eV$

3.) Cubic box of size $a = 0{,}613\ nm$. We cast $7e^-$ after each other into the box at absolute zero temp. We investigate the e^- energies and the state functions. (T or F)

1 $E_1 \cong 3eV$ ✓ 2 $E_2 \cong 6eV$ ✓ 3 $E_3 \cong 12eV$ ✓

4 $\Psi_{111}(x,y,z,t) = 0{,}73 \cdot 10^{-12} \sin(5{,}1 \cdot 10^{-3} x) \sin(5{,}1 \ldots$

5 vmi lesrulé $\ldots \cdot e^{-i\, 0{,}724 \cdot 10^{-13} t}$.

$$E_{n_1 n_2 n_3} = \frac{h^2}{8ma^2}(n_1^2 + n_2^2 + n_3^2)$$

$$\Psi_{n_1 n_2 n_3}(x,y,z,t) = \underbrace{\left(\sqrt{\frac{8}{a^3}} \sin\frac{n_1 \pi}{a} x \sin\frac{n_2 \pi}{a} y \sin\frac{n_3 \pi}{a} z\right)}_{\psi(x,y,z)} e^{-i \frac{E_{n_1 n_2 n_3}}{\hbar} t}$$

mo.: thát normalni zell (1,1,1)

$$n_1 n_2 n_3 = 1, 2 \ldots \rightarrow (1,1,1) \Rightarrow \frac{(6{,}625 \cdot 10^{-34} [Ws])^2}{8 \cdot 9{,}109 \cdot 10^{-31} \cdot (0{,}613)^2 \cdot 10^{-18} [m]}(3) \Rightarrow 1{,}6029 \cdot 10^{-19} \ldots \cong 3eV$$

() veretés most nem lényeges (att mozgás)

$(121) = (211) = (112) = 2E_{111}$

$(221) = (212) = (122) = 3E_{111}$

$(311) = (131) = (113) = \frac{11}{3} E_{111}$

$(222) = 4 E_{111}$

4.) Assume that the atoms C (Z=6) are Hydrogen like. We calculate orbitals.

$$E_n = -\frac{m Z^2 e^4}{8 \varepsilon_0 h^2 n^2} \qquad r_1 = \frac{\varepsilon_0 h^2}{\pi \cdot Z e^2} \qquad \Psi_{new} = \ldots$$

⑥ 4/n

5., Ez e^- is confined in 1D pot box of size $a = 1\,nm$ We calculate the expectation
↳ Bezárt
value of the pos & momentum (T or F)

a, The expectation val are the same in all states, namely $\langle x\rangle = \frac{a}{2}$ $p = 0$

$$\int_0^a \Psi^* L \Psi\,dx : \bullet : \int_0^a \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right) \cancel{e^{+j\frac{E_n}{\hbar}t}} \cdot x \cdot \sqrt{\frac{2}{a}} \sin\left(\frac{n\pi x}{a}\right) \cancel{e^{-j\frac{E_n}{\hbar}t}}\,dx =$$

$$= \frac{2}{a}\int_0^a \sin^2\left(\frac{n\pi x}{a}\right) x\,dx = \frac{\cancel{2}}{a}\int_0^a \frac{1}{\cancel{2}}\left(1 - \cos 2\frac{n\pi x}{a}\right) x\,dx =$$

$$= \frac{1}{a}\cdot\frac{x^2}{2}\Big|_0^2 - \frac{1}{a}\Big[\underbrace{\frac{a}{2n\pi}\sin\frac{2n\pi x}{a}\Big|_0^a}_{0-0} - \int_0^a \underbrace{\left(\frac{a}{2n\pi}\right)' \sin\frac{2n\pi x}{a}\,dx}_{\left(\frac{a}{2n\pi}\right)^2(1-1) = 0}\Big] = \frac{a}{2}$$

$$\bullet\ \frac{2}{a}\int_0^a \sin\left(\frac{n\pi x}{a}\right) \cancel{e^{\dots}}\left(-j\hbar\frac{d}{dx}\sin\left(\frac{n\pi x}{a}\right)\right)\cancel{e^{-\dots}}\,dx =$$

$$= \frac{2}{a}\cdot\left(-j\hbar\frac{n\pi}{a}\right)\underbrace{\int_0^a \sin\frac{n\pi x}{a}\cos\frac{n\pi x}{a}\,dx}_{\int_0^\pi \sin x \cos x\,dx = 0} = 0$$

c, If the e^- were in it's ground state then the exped. val. can be calculated from $\langle x\rangle = \frac{a}{2}$ $\langle p\rangle = h\nu = m\sqrt{\frac{2E}{m}} = \sqrt{2m E_n}$

F

d

b, If the e^- was ground state then exp. val, are $\langle x\rangle = \frac{a}{2}$ $\langle P\rangle = 0$ T

d, — " — second state — " — $\langle x\rangle = 0$, $\langle P\rangle > 0$

F

e, — " — g.s — " — $\langle x\rangle = \frac{a}{2}$ $\langle P\rangle = 0$ T

6., We perform Stern-Gerlach experiments after each other (A_g) rel.

a, $L = ?$

c, $A_g \xrightarrow{} +\hbar$, $\to (-\hbar)$ d, and S-G + X ugh..., with a ...

$A_g \to +x$, $\to -x$

↳ merőleges jól leírtam jegyzetbe ⑤

d).

7.) In an orthonormal basis lin. Hermitian or lin. Ve. matrix repr. are the following operators w. matrix repr. H. or not?

a.) $\hat{A} = \begin{bmatrix} a & ie^{i\varphi} \\ e^{i\varphi} & b \end{bmatrix}$ F

$c \cdot e^{i\varphi} \neq (c \cdot e^{i\varphi})^*$

b.) $\hat{B} = \begin{bmatrix} a & ce^{i\varphi} \\ ce^{-i\varphi} & b \end{bmatrix}$ T

c.) $\begin{bmatrix} a+jb & c \cdot e^{i\varphi} \\ c \cdot e^{-j\varphi} & b-jn \end{bmatrix}$ F

$\downarrow$

$\notin \mathbb{R}$

8.) T or F

a.) Outer product: $|a\rangle\langle b| = \begin{pmatrix} 3 \\ 2 \\ 1 \end{pmatrix} \begin{bmatrix} 1 & 2 & 4 \end{bmatrix} = \begin{bmatrix} 3 & 6 & 12 \\ 2 & 4 & 8 \\ 1 & 2 & 4 \end{bmatrix}$ T

b.) self-adjoint (Herm.) op: $\langle a|\hat{x}|b\rangle = \langle b|\hat{x}|a\rangle^*$ T

$\hookrightarrow \hat{x} \leftrightarrow \hat{x}^{+}$ van lévo mi? uni?

c.) Eigen kets constitute a complete ~~orth~~ orth. norm. basis:

$|a\rangle = \sum_n c_n |n\rangle = \sum_n |n\rangle\langle a|n\rangle$ T

d.) $\sum_n |c_n|^2 = \sum_n |\langle n|a\rangle|^2 = 1$ F   only for spec $|a\rangle$

$(\langle a|a\rangle = 1)$

e.) Elements of the matrix repr. of op. $\hat{x}$ are $x_{nm} = \langle n|\hat{x}|m\rangle$ T

9.) Let us consider a ~~two~~ 2-dim 2D Hilbert space $|\psi\rangle \in \mathcal{H}$

in this H-s the self adjoint op of a 2-state quantum system

is $\hat{H}_0 = \begin{bmatrix} E_2 & 0 \\ 0 & E_1 \end{bmatrix}$ which generate an ortho. norm. basis $|1\rangle, |2\rangle$ ...

$$\hat{H}_0|1\rangle = E_1|1\rangle \qquad \hat{H}_0|2\rangle = E_2|2\rangle$$

a.) If there is no external interaction, and at initial time $t=0$ the state of the system evolves as $|\Psi(t)\rangle = c_1 e^{-i\frac{E_1}{\hbar}t}|1\rangle + c_2 \cdot e^{-i\frac{E_2}{\hbar}t}|2\rangle$ T

b.) If $t=0$ $|\Psi(0)\rangle = |1\rangle$ then the system remains in it's initial state forever. i.e. $|\Psi(t)\rangle = e^{-i\frac{E_1}{\hbar}t}|1\rangle$

$$P_1(t) = |\langle 1|\Psi(t)\rangle|^2 = |e^{-i\frac{E_1}{\hbar}t}\langle 1|1\rangle|^2 = 1$$

T ? ext. interaction

c.) Let the initial state be $|\Psi(0)\rangle = 0{,}6|1\rangle + 0{,}8|2\rangle$ The prob. that in a measurement the state is found to be $|1\rangle$ will remain constant in time, namely $P_1 = \langle 1|\Psi_1\rangle|^2 = 4\,h\ldots$

$$P_1(t) = |\langle 1|0{,}6\cdot e^{-i\frac{E_0}{\hbar}t}|1\rangle + \langle 1|0{,}8\, e^{\cdots}|2\rangle =$$

$$= |0{,}6\cdot e^{\cdots}\langle 1|1\rangle + e^{\cdots}\,0{,}8\,\overbrace{\langle 1|2\rangle}^{0}|^2 =$$

$$= |0{,}6\, e^{\cdots}\cdot\overbrace{\langle 1|1\rangle}^{1}|^2 = 0{,}36 \rightarrow T$$

d.

d.) T or F that in c.) prob. of finding the sys in state $|2\rangle$ is also const & $Q_2 = |\langle 2|\Psi(t)\rangle|^2 = 0{,}64 = 1 - P_1$ T

e.) The two eig-states evolve independently thus $|\Psi(t)\rangle = 0{,}6 \cdot e^{-i\frac{E_1}{\hbar}t}|1\rangle + 0{,}8\cdot e^{-i\frac{E_2}{\hbar}t}|2\rangle$ T

10.) Let the $\hat{H}_0$ sys be perturbed by a constant interaction, thus the Hamiltonian of the sys changes to $\hat{H} = \begin{bmatrix} E_2 & W_{12} \\ W_{21} & E_1 \end{bmatrix}$ when

$E_2 = 4\,eV$ $E_1 = 1\,eV$ $W_{12} = 1\,eV$ (5)

(6) 1.1.

10. We have a weak electromagnetic field in a plan-parallel cavity (two mirrors) of size $d = 300$ nanometer. T or F

and initial state is $|\Psi(0)\rangle = |1\rangle$

a) the eigen energies of the perturbed sys remain the same as in the unperturbed case namely E_2 & E_1 F

b) The evolution of the perturbed sys can be written as:

$$|\Psi(t)\rangle = C_1(t)\, e^{-j\frac{E_1}{\hbar}t} |1\rangle + C_2(t)\, e^{-j\frac{E_2}{\hbar}t} |2\rangle$$

with un < lem $C_2(t)$ & $C_2(t)$ F

c) The perturbed sys's eig energies $E_+ = 4,3\,eV$

$E_- = 0,7\,eV$ T

d) The prob that the pert sys starting from state $|\Psi(0)\rangle = |1\rangle$ will evolve and after it will be in state $|2\rangle$ will change periodically w. the Rabi freq as $P_{1\to 2} = 0,308 \sin^2\left(\frac{E_+ - E_-}{\hbar}t\right)$

$P_{2\to 2} = \sin^2 \ominus \sin^2$

T

e) Prob

$P_{1\to 1} = 1 - P_{1\to 2}$

T?

d. We do not know exactly how many will be transmitted and reflected, we can p
only the mean value of the transmitted and reflected photons ($\overline{n}_T = \overline{n}_R = 50$
the variance will depend on the source of the photons;

e. If the photons arrive independently to the beam-splitter, the variance of the
number would be 10. σ^2_λ 50+50 = 100 $\sqrt{100} = 10$

A linearly $+x$ polarized photon travels in the $+z$ direction. Is it true or false that

a. We let the photon go through an x linear polarizer. The probability of trans
0.5 (50%);

T

b. We let the photon go through an y linear polarizer. The probability of tran
0 (0%);

c. We let the photon go through a right circular polarizer (RCP). The probabili
transmission is 0.5 (50%);

d. We let the photon go through a left circular polarizer (LCP). The probabilit
transmission is 0.5 (50%);

$\boxed{T}$

e. **The time-evolution of the state can be expressed as** $|\psi(t)\rangle = e^{-j\frac{H}{\hbar}t}\cdot|\psi(0)\rangle$.

9. **We have a weak electromagnetic field in a plan-parallel cavity (two mirrors) of size $d = 300$ nanometer. Is it true or false that**

   a. **If the number of first mode photons ($\lambda = 0.6$ micron) is about 1000, then we could find about 200 first mode photons in a 30 nm long interval near the center of the cavity;**

   b. **If the number of second mode photons ($\lambda = 0.3$ micron) is about 1000, then we could find about 200 photons in a 30 nm long interval near the center of the cavity;**

   c. **If the number of first mode photons ($\lambda = 0.6$ micron) is about 1000, then at the left mirror in a 30 nm long interval the number of first mode photons is always zero;**

   d. **If the number of first mode photons ($\lambda = 0.6$ micron) is about 1000, then at the left mirror in a 30 nm long interval the number of photons is not zero, however the mean value is less than 5 photons;**

   e. **If the number of third mode photons ($\lambda = 0.2$ micron) is about 1000, then we could find about 100 photons in a 30 nm long interval near the center of the cavity.**

...tic field in a plan-parallel cavity (two mirrors) of size

... mode photons ($\lambda = 0.2$ micron) is about 1000, then we could find about 100 photons in a 30 nm long interval near the center of the cavity.

. We have a weak electromagnetic field in a plan-parallel cavity (two mirrors) of size $d = 300$ nanometer. Is it true or false that

a. The distribution of the photons in the cavity is homogeneous, i.e. the probability of finding a photons in the cavity is the same everywhere in the cavity;

b. If the number of photons in the cavity is about 1000, the probability of finding photon in an interval at the center of the cavity does not depend on the cavity mode;

c. The probability of finding photon at the mirrors is always higher then the probability finding them near the center;

d. The probability of finding photons at the mirrors is always zero, and it does not dep on the cavity modes;

e. The probability of finding photons in an interval of thickness Δx, can be estimate the formula $\left(\frac{2}{d}\sin^2\frac{n\pi}{d}x\right)\Delta x$