YARMO’TKAZGICHLI TUZILMALARNING KVANTLASHGAN NUQTALARIDA YORUG’LIKNING YUTILISHI

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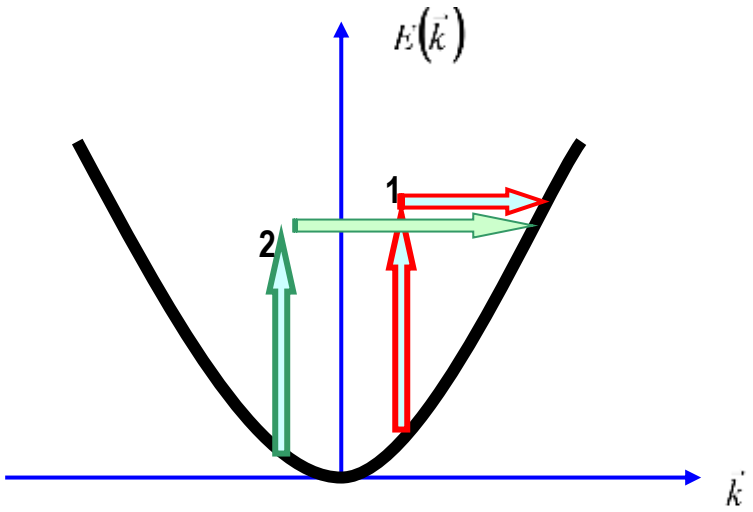
Kalit so’zlar: yorug‘lik, yutilish koeffitsiyenti, kvantlashgan nuqta, spektral tahlil, temperaturaviy tahlil, qutblangan fotonlar.

Annotatsiya: Umuman olganda ω chastotali yorug‘likning yutilish koeffitsiyenti kvant mexanikasining oltin qoidasiga ko‘ra aniqlanadi:

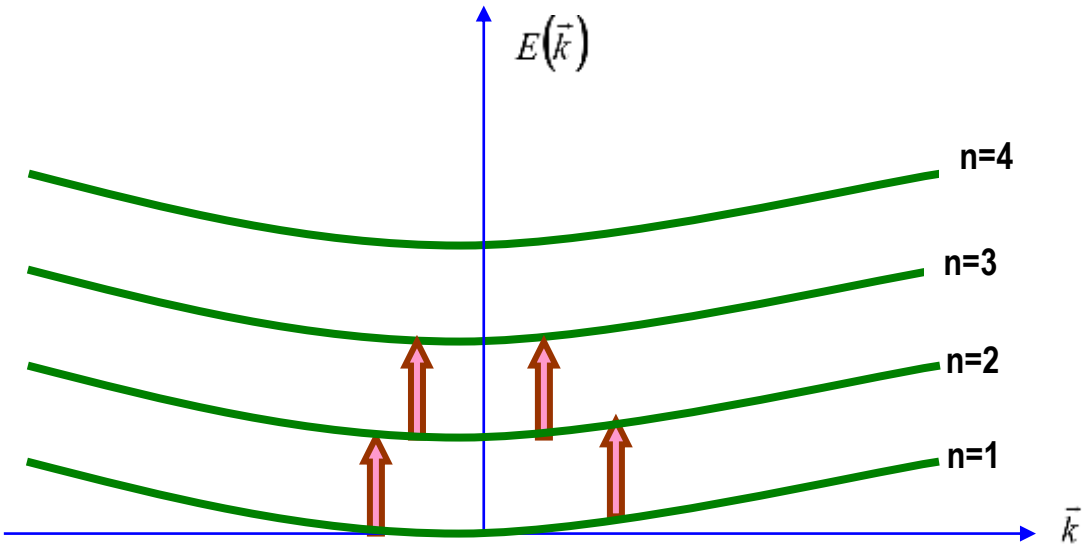
$$K(\omega)=\frac{4\pi^2e^2}{ncm_0^2\omega}\sum_{i,f}\left|\vec{e}\cdot\vec{p}_{fi}\right|^2\left[f(E_i)-f(E_f)\right]\delta(E_f-E_i-\hbar\omega)\ . \qquad (1)$$

Bu munosabatda n_ω – yarimo‘tkazgichning sindirish koeffitsiyenti, m_0 – erkin elektron massasi. Yorug‘likning yutilishiga barcha boshlang‘ich (i) va oxirgi (f) holatlar bo‘yicha optikaviy o‘tishlarning ulushlari e’tiborga olinadi, $f(E)$ - Fermi to‘lqin funksiyasi, $\vec{e}$ – fotonning qutblanish vektori. Yorug‘likning sirtda yutilish koeffitsiyentini (1) ifoda yordamida aniqlash mumkin, chunki kvantlashgan nuqtalar, odatda, bitta tekislikda o‘stiriladi.



1-rasm. Hajmiy yarim o`tkazgichda elektronlarning energiyaviy spektri va bir zonali optikaviy o`tishlar. 1 ⟹ –elektronlar, 2 ⟹ -fononlar.

Asosiy qsm: Fermining kvant mexanikaviy oltin qoidasidan foydalansak,



2-rasm. O`lchamli kvantlashgan tizimlarda tok tashuvchilarning vertikal (to`g`ri) optikaviy o`tishlari. Uzluksiz egri chiziq tok tashuvchilarning energiyaviy spektrlari, n=1, 2, 3, 4 –o`lchamli kvantlashgan energiyaviy spektrining tartib raqamlari. Tik vektorlar yordamida optikaviy o`tishlar tasvirlangan.

$$\Delta I = \frac{2(eF)^2 h}{m_0^2 (h\nu)} \sum \left| P_{eh}^i \right|^2 \delta\left(E_e^i - E_h^i - h\nu\right),$$

F – tushayotgan elektromagnit to‘lqin elektr maydoni kuchlanganligi, $^{i}_{eh}$ - ***i*** -nchi kvantlashgan nuqtadagi o‘lchamli kvantlashgan sathlararo sodir bo‘layotgan optikaviy o‘tishni ifodalovchi impuls operatorining matritsaviy elementi:

$$\left|P_{eh}^{I}\right|^2 = |P|^2 \int \chi_h^{i*}(r)\chi_e^i(r)dr = |P|^2\left|\mathrm{X}^i\right|^2,$$

$\left|\mathrm{X}^i\right|^2$ - ***i*** -nchi kvantlashgan nuqtadagi berkitish integrali, P – to‘lqin funksiyalarning tez ossillyasiyalanuvchi qismiga nisbatan hisoblangan impuls operatorining matritsaviy element. Keyn modeliga nisbatan $E_g>>\Delta$ hol uchun

$$\frac{|P|^2}{m_0^2} \approx \frac{E_g}{2m_e},$$

munosabat o‘rinlidir; E_g – potensial to‘siqni yuzaga keltiruvchi material(*GaAs)*ning ta’qiqlangan zonasining kengligi.

X^i kattalikning *i* kattalikka kuchsiz bog‘langanligi va $I_0=c\varepsilon^{1/2}F^2/2ni$ e’tiborga olsak

$$\beta^{QD}(h\nu) = \frac{he^2\pi}{cm_e\sqrt{\varepsilon}}\left|\mathrm{X}\right|^2 g(h\nu), \tag{2}$$

$g(h\nu)$ – kvantlashgan nuqtada kombinatsiyalangan holatlar zichligi.

Agar yutilish koeffitsiyentining spektral bog‘lanishidagi cho‘qqi kvantlashgan nuqtadagi bittagina optikaviy o‘tish bilan tavsiflansa, u holda sirtiy holatlar zichligi quyidagi ifodadan aniqlanadi

$$N_{Ds} = \frac{1}{2}\int g(h\nu)d(h\nu) = \frac{cm_e\sqrt{\varepsilon}}{2he^2\pi\left|\mathrm{X}\right|^2}\int \beta^{QD}(h\nu)d(h\nu). \tag{3}$$

Bunda integrallash maksimum atrofidagi oraliq bo‘yicha olib boriladi, chunki shunday holdagina integral osti funksiyasi integralga asosiy ulushini beradi.

Yutilish koeffitsiyentining spektral bog‘lanishidagi cho‘qqisining ap-proksimatsiyasini Gauss funksiyasi yordamida ifodalasak, $\beta^{QW} \approx \frac{2\gamma\pi}{\sqrt{\varepsilon}}$. munosa-batni quyidagi ko‘rinishda qayd qilish mumkin

$$\beta_m^{QD} = \sigma^{QD} N_{Ds}, \tag{4}$$

bu yerda

$$\sigma^{QD} = \frac{2\sqrt{\ln 2\pi} he^2}{cm_e\sqrt{\varepsilon}\Gamma}|\mathrm{X}|^2 \tag{5}$$

fotonni kvantlashgan nuqtada tutib qolish yuzasi mazmunini beradi, β_m^{QD} – cho‘qqi balandligi, G – uning yarim balandligiga mos keluvchi kengligi.

Xulosa: Oxirgi (4) va (5) ifodalardan kvantlashgan nuqtalarda qutblangan fotonlar yutilishining spektral va temperaturaviy tahlili ko‘rinib turibdi, ya’ni u $|X|^2$ kattalikning tabiati bilan aniqlanadi.

Foydalanilgan adabiyotlar:

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