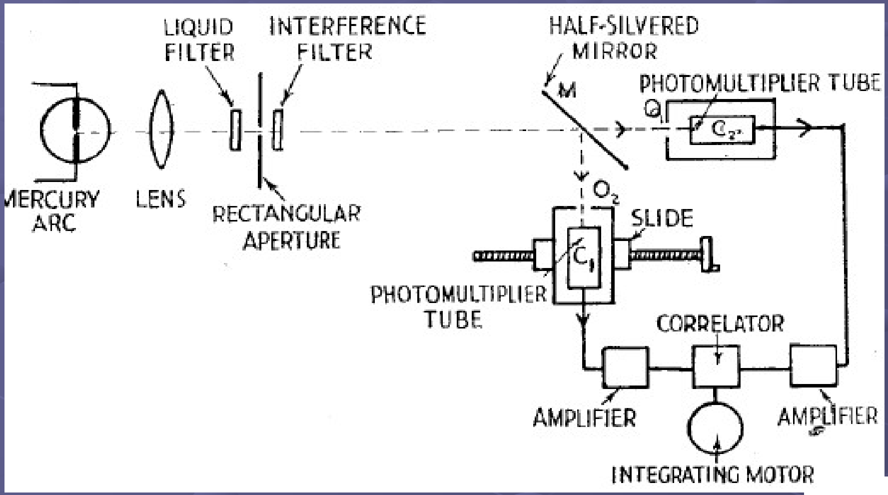
Single photon emission- Theory and devices.

התחום הקלאסי Bunching.

- 1956 Hanbury Brown and Twiss



Cathodes superimposed		Cathodes separated	
Experimental $S(0)/N$	Theoretical $S(0)/N$	Experimental $S(d)/N$	Theoretical $S(d)/N$
$+7.4$	$+8.4$	-0.4	≈ 0
$+6.6$	$+8.0$	$+0.5$	≈ 0
$+7.6$	$+8.4$	$+1.7$	≈ 0
$+4.2$	$+5.2$	-0.3	≈ 0

הסבר קלאסי (פשטני)

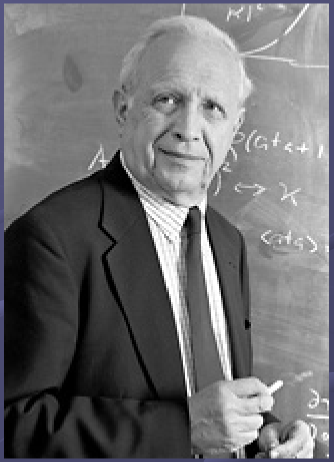
$$I_1 = E_0^2 \cdot \cos^2(\omega t)$$

$$I_2 = E_0^2 \cos(\omega t + \varphi) = E_0^2 \cdot (\sin(\omega t)\cos(\varphi) + \cos(\omega t)\sin(\varphi))^2$$

$$\langle I_1 I_2 \rangle = \lim_{T\to\infty} \frac{1}{T}\int_0^T I_1 I_2 dt = \frac{E_0^4}{4} + \frac{E_0^4}{8}\cos(2\varphi)$$

$$\langle \Delta I_1 \Delta I_2 \rangle = \langle I_1 I_2 \rangle - \langle I_1 \rangle \langle I_2 \rangle = \frac{E_0^4}{8}\cos(2\varphi)$$

Roy J. Glauber



קצת רקע

$$|\alpha\rangle = e^{-\frac{1}{2}|\alpha|^2} \sum_n \frac{\alpha^n}{n!} |n\rangle$$

$$|f\rangle = \frac{1}{\pi} \int |\alpha\rangle f(\alpha^*) e^{-\frac{1}{2}|\alpha|^2} d^2\alpha$$

$$T = \frac{1}{\pi^2} \int |\alpha\rangle \Im(\alpha^*, \beta) \langle\beta| e^{-1/2\alpha^2 - 1/2\beta^2} d^2\alpha d^2\beta$$

$$\rho = \frac{1}{\pi^2} \int |\alpha\rangle \Re(\alpha^*, \beta) \langle\beta| e^{-1/2\alpha^2 - 1/2\beta^2} d^2\alpha d^2\beta$$

$$tr\{\rho T\} = \frac{1}{\pi^2} \int \Im(\alpha^*, \beta) \Re(\alpha^*, \beta) e^{-\alpha^2 - \beta^2} d^2\alpha d^2\beta$$

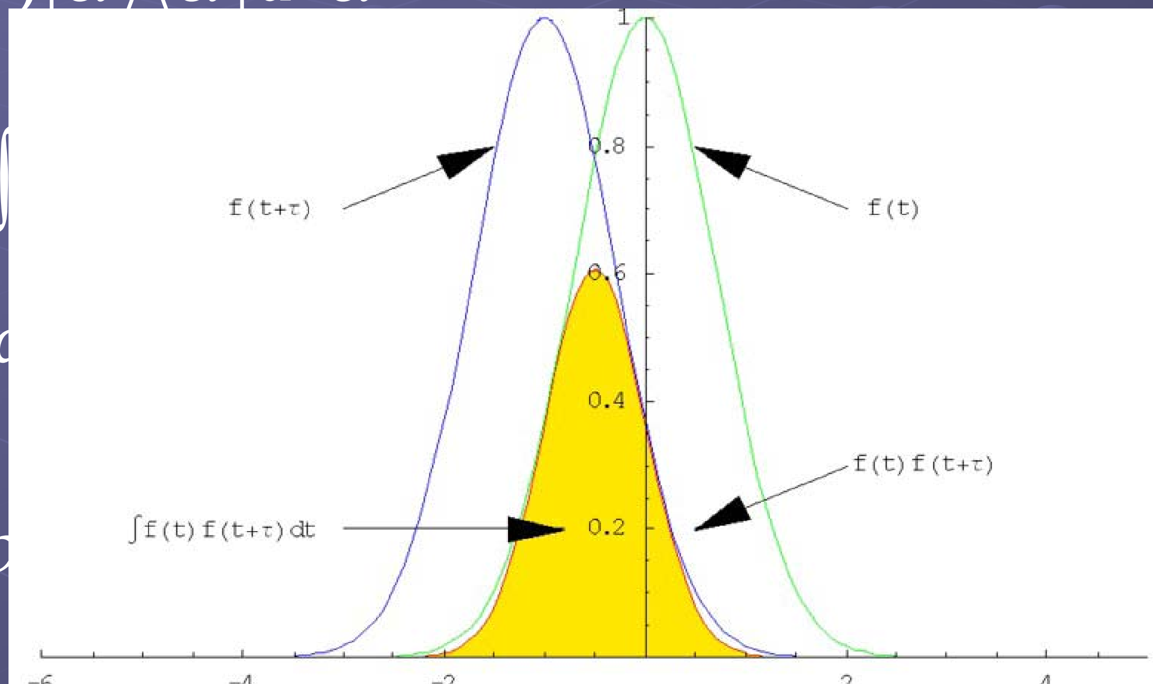
הצגת P- הסתברות

$$\rho = \int P(\alpha)|\alpha\rangle\langle\alpha| d^2\alpha$$

$$tr\{\rho\cdot 1\} = \int$$

$$tr\{\rho(a^\dagger)^n a \; \ldots \; (a^*)^n a^m d^2\alpha$$

$$\langle n\rangle = tr\{\rho$$



התפ

$$\rho = \frac{1}{\pi\langle n\rangle}\int e^{-|\alpha|^2/\langle n\rangle}|\alpha\rangle\langle\alpha| d^2\alpha$$

הערה על פונקציות הקורלציה

$$\langle f | E^{(+)}(rt) | i \rangle$$

$$G^{(1)}(rt, r't') = rt\{\rho E^{(-)}(rt) E^{(+)}(r't')\}$$

$$\sum_f |\langle f | E^{(+)}(rt) | i \rangle|^2$$

$$= \sum_f \langle i | E^{(-)}(rt) | f \rangle \langle f | E^{(+)}(rt) | i \rangle$$

$$= \langle i | E^{(-)}(rt) E^{(+)}(rt) | i \rangle$$

$$G^{(n)}(x_1 \ldots x_n, x_{n+1} \ldots x_{2n}) = rt\{\rho E^{(-)}(x_1) \ldots E^{(-)}(x_n) E^{(+)}(x_{n+1}) \ldots E^{(+)}(x_{2n})\}$$

$$[x_i = r_i t_i]$$

$$g^{(n)}(x_1 \ldots x_{2n}) = \frac{G^{(n)}(x_1 \ldots x_{2n})}{\prod_{j=1}^{2n} \{G^{(1)}(x_j x_j)\}^{1/2}}$$

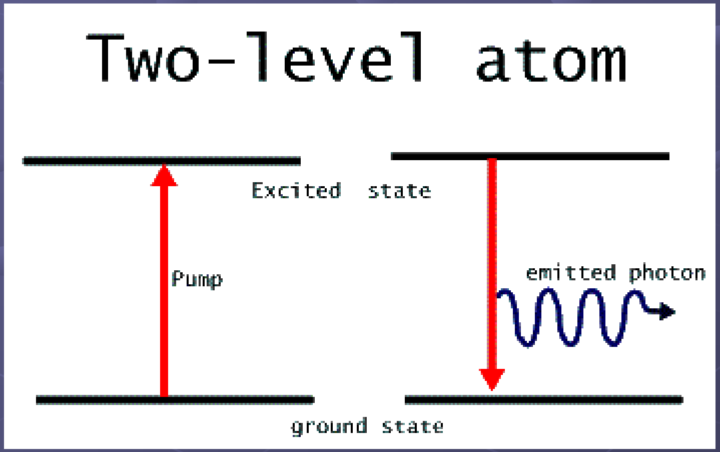
$$\sum_f |\langle f | E^{(+)}(r't') E^{(+)}(rt) | i \rangle|^2$$

$$= \langle i | E^{(-)}(rt) E^{(-)}(r't') E^{(+)}(r't') E^{(+)}(rt) | i \rangle$$

$$rt\{\rho E^{(-)}(rt) E^{(+)}(rt)\}$$

התחום הקוונטי- Antibunching

הסבר פשטני



Antibunching -התחום הקוונטי

$$P_2(t,t+\tau) = A^2 \left\langle I(t)I(t+\tau)\right\rangle_p$$

$$\lambda(\tau) = \left\langle \Delta I(t)\Delta I(t+\tau)\right\rangle_P / \left\langle \Delta I(t+\tau)\right\rangle_P \left\langle \Delta I(t+\tau)\right\rangle_P$$

$$P_2(t,t+\tau) = A^2 \left\langle I(t)\right\rangle_p \left\langle I(t+\tau)\right\rangle_p [1+\lambda(t)]$$

Sodium beam- Kimble, Dagenais and Mandel

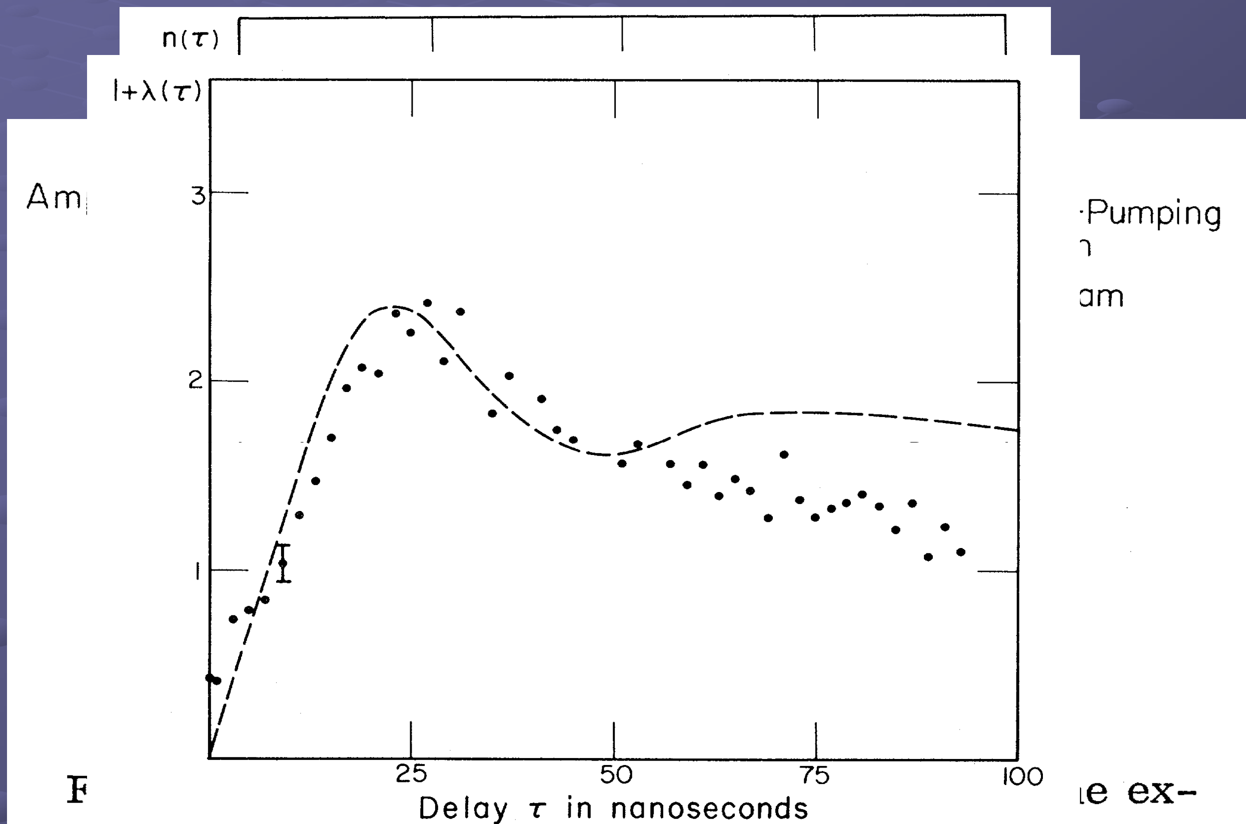


FIG. 3. Values of $1 + \lambda(\tau)$ derived from the data. The broken curve shows the theoretically expected form of $\langle \hat{I}_G(\tau) \rangle$ (with $\Omega/\beta = 4$) for a single atom, arbitrarily normalized to the same peak.

Trapped Ions

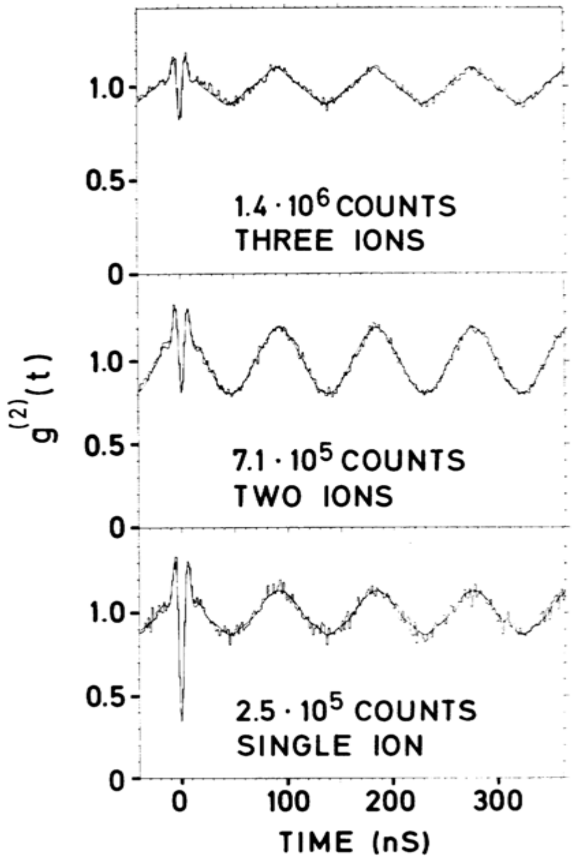
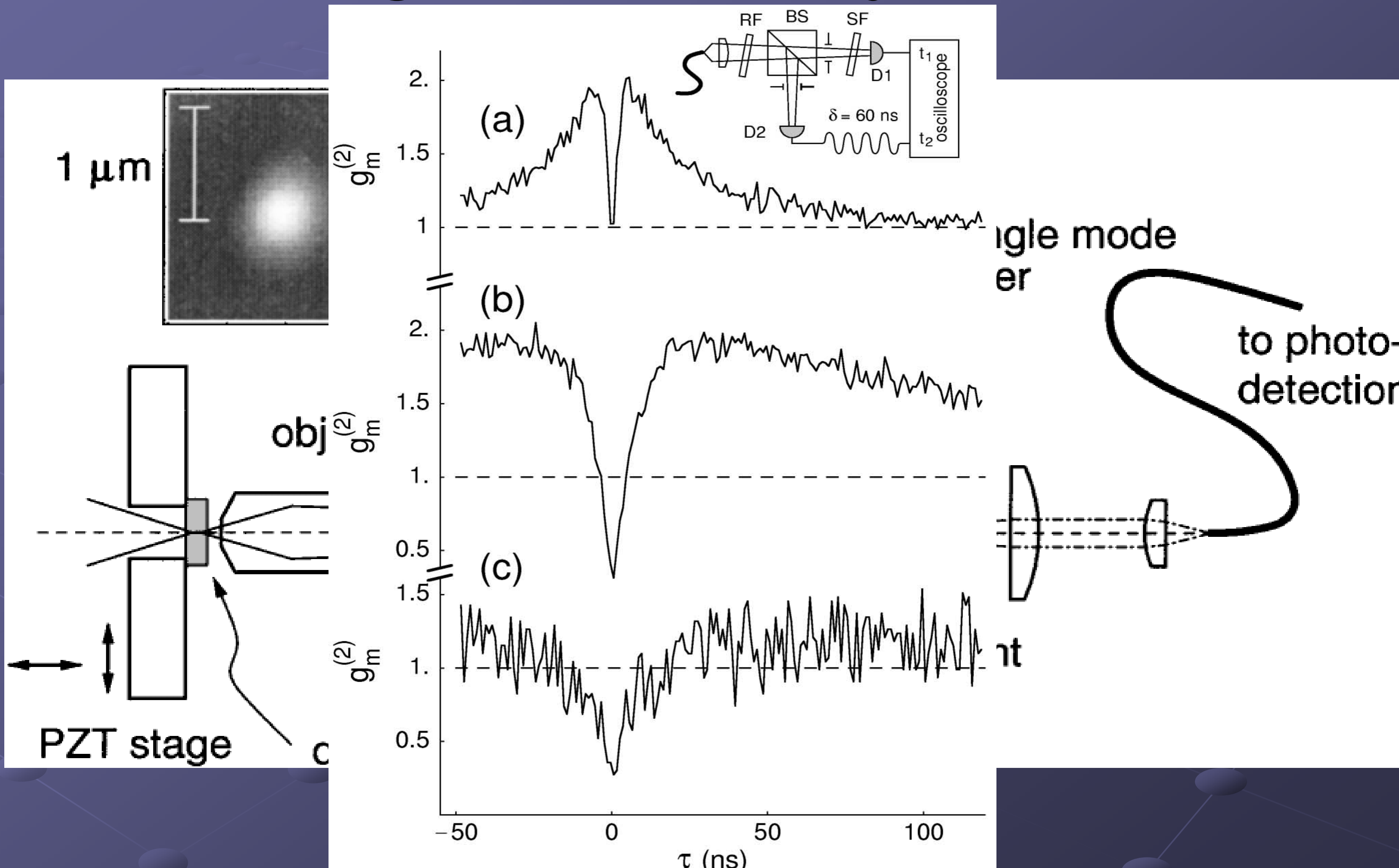


FIG. 2. Intensity correlation for one, two, and three ions. The antibunching signal occurs around $t=0$ and decreases with increasing ion number. The periodic signal at larger t is a result of the micromotion of the ion. The triangular shape obtained for three ions is caused by the increased Coulomb repulsion. The deviation from zero at $t=0$ is caused by accidental coincidences due to stray light. The number of ions is discriminated by discrete steps in the fluorescence radiation.

Nitrogen-Vacancy centers



Quantum dot in a micropost microcavity

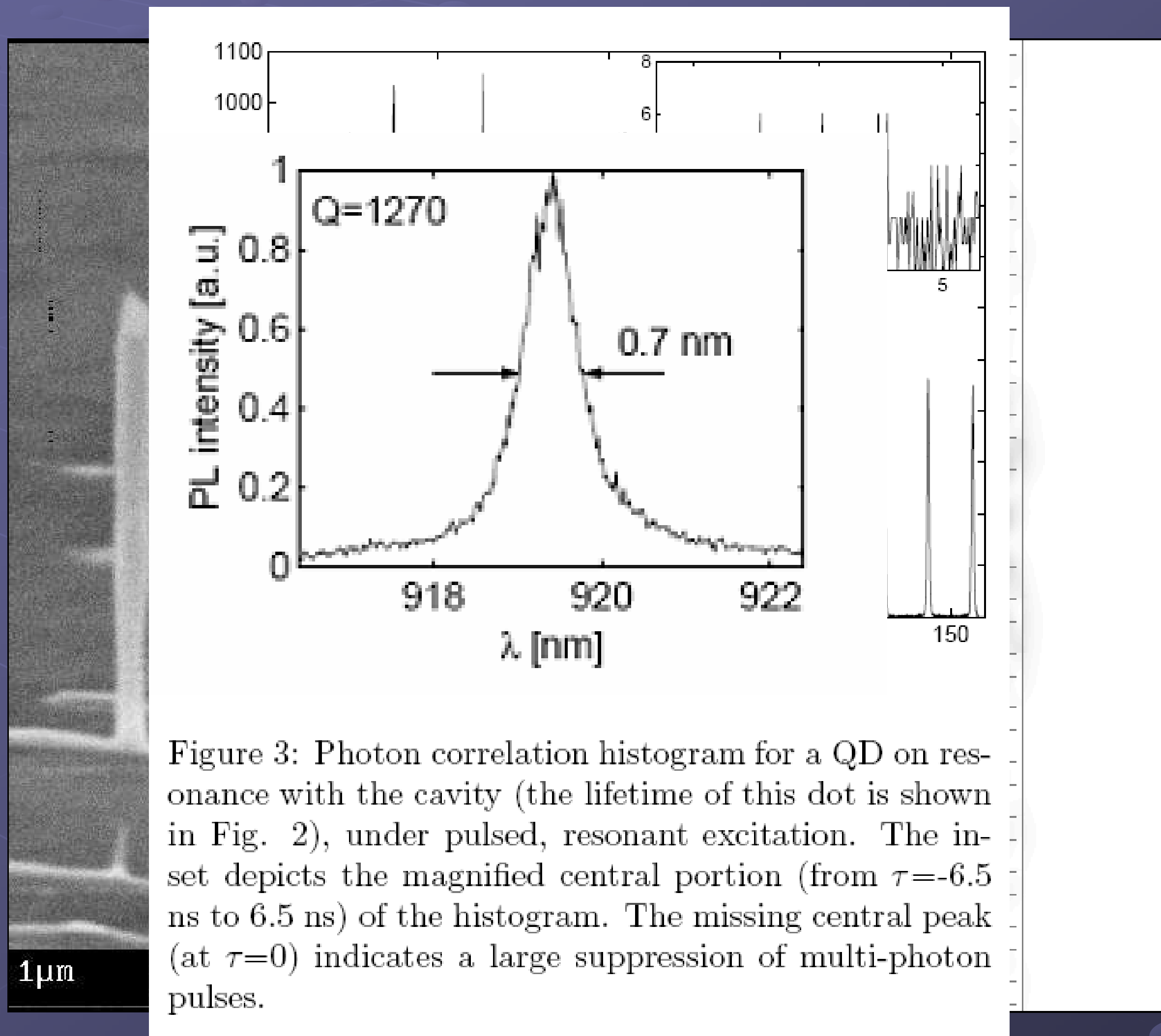
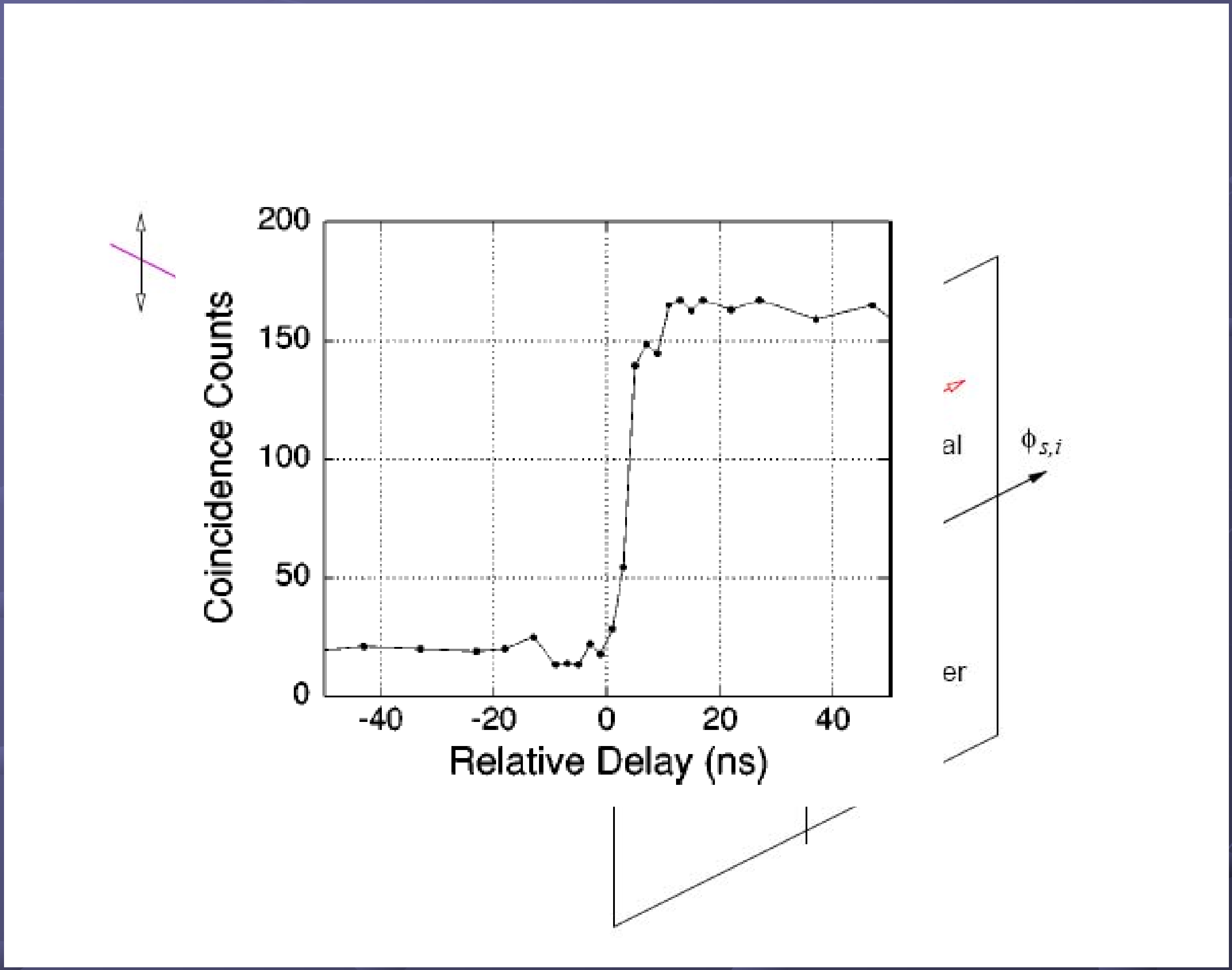


Figure 3: Photon correlation histogram for a QD on resonance with the cavity (the lifetime of this dot is shown in Fig. 2), under pulsed, resonant excitation. The inset depicts the magnified central portion (from τ=-6.5 ns to 6.5 ns) of the histogram. The missing central peak (at τ=0) indicates a large suppression of multi-photon pulses.

Parametric down convertion



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שאלות?