Measurement of the coherence time of the Light from a Quasi-thermal Source

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The photocount distribution from a quasi-thermal light source, a moving ground glass disk (surface roughness; 9 μm) illuminated by a well-stabilized He-Ne laser, is measured by a photon counting system, and analyzed with theoretical calculations. The distribution approaches the Poisson distribution for the long coherence time τ_c compared to the measuring time T.

The coherence time τ_c of the quasi-thermal source can be changed by controlling the velocity v of the motor driving the glass disk. By the comparison of experimental results and theory for the condition of $T/\tau_c \gg 1$, the coherence time τ_c of the quasi-thermal source is turned out to be in the range of 31.43 μs~2.48 μs according to the circumferential velocity of the disk, and compared with the simple calculation of σ/v.

Chaotic light
(thermal cavity, filament lamp)

The different atoms are excited by an electrical discharge and emit their radiation independently of one another.

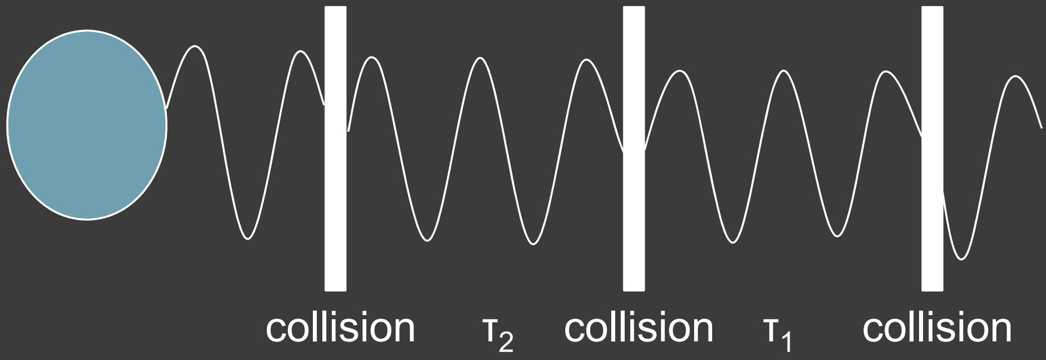
The shape of an emission line is determined by the statistical spread in atomic velocities and the random occurrence of collisions.

$\Delta \nu \gg$ $\Delta \nu = \frac{1}{\tau_c}$

Generally,

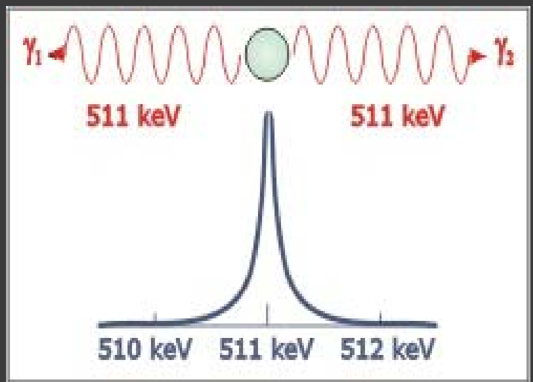
$\tau_c \leq 10^{-12} s$

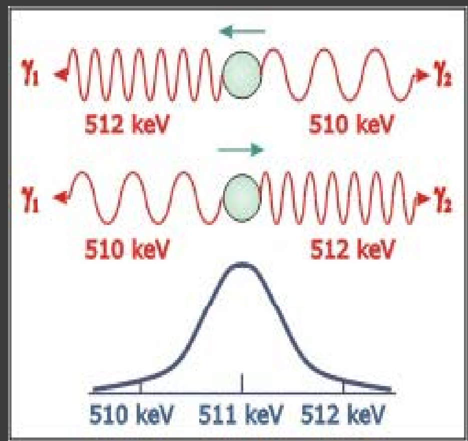
$\tau_c \ll$



Lorentzian lineshape

collision-broadened light source





Gaussian lineshape

Doppler broadening light source

Quasi-thermal Source

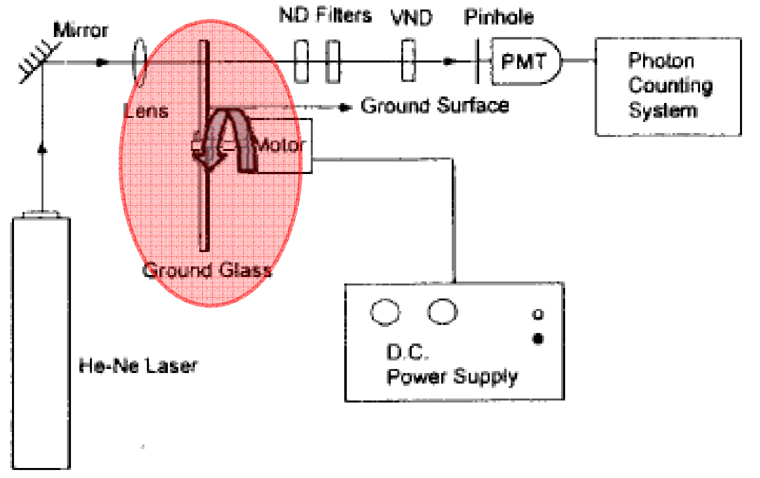


그림 1. Schematic Diagram of Experimental Set-up.

It has property of chaos light, but coherence time is longer than chaos light.

Used rotating ground glass disk (surface roughness: 9㎛)

τ_c of the quasi-thermal source can be changed by controlling the velocity *v* of the motor driving the glass disk.

$$\tau_c = \frac{\sigma}{v}$$

σ (surface roughness)

v (rotating speed)

$\bar{I}(t,T)$ is the mean intensity that falls on the phototube during the period from t to t+T, then,

$$\bar{I}(t,T) = \frac{1}{T}\int_{t}^{t+T} \bar{I}(t)dt'$$

The probability of detecting n number of photons during time duration T is

$$P_n(T) = \langle P_n(t,T) \rangle$$

$$= \left\langle \frac{\left[\zeta \bar{I}(t,T)T\right]^n}{n!} \exp\left[\zeta \bar{I}(t,T)T\right] \right\rangle$$

This result is Known as the Mandel formula. ζ (efficiency of detector)

So Mean number of photocounts is

$$\langle n \rangle = \sum_{n=0}^{\infty} nP_n(T) = \langle \zeta \bar{I}(t,T)T \rangle = \zeta \bar{I}T$$

And the second moment of the distribution given by

$$\langle n^2 \rangle = \sum_{n=0}^{\infty} n^2 P_n(T) = \langle \zeta \bar{I}(t,T)T \rangle + \langle \left[\zeta \bar{I}(t,T)T \right]^2 \rangle$$

$$= \langle n \rangle + \langle \left[\zeta \bar{I}(t,T)T \right]^2 \rangle$$

The variance of the photocount distribution is therefore

$$\langle (\Delta n)^2 \rangle = \langle n^2 \rangle - \langle n \rangle^2 = \langle n \rangle + \zeta^2 T^2 \left(\langle \bar{I}(t,T)^2 \rangle - \bar{I}^2 \right)$$

Line width $\gamma(=1/\tau_c)$ Lorentzian lineshape function

Its second order coherence function is,

$$g^{(2)}(\tau) = 1 + e^{-2\gamma|\tau|}$$

The average of integration time T is

$$\left\langle g^{(2)}(0)\right\rangle - 1 = \frac{1}{T^2}\int_0^T\int_0^T e^{-2\gamma|t_2 - t_1|}dt_1 dt_2$$

$$= \frac{1}{2\gamma^2 T^2}\left[e^{-2\gamma T} + 2\gamma T - 1\right]$$

$$\left\langle g^{(2)}(0)\right\rangle = \frac{\left\langle \bar{I}(t,T)^2\right\rangle}{\bar{I}^2}$$

$$\left\langle (\Delta n)^2 \right\rangle = \langle n \rangle + \frac{\langle n \rangle^2}{2\gamma^2 T^2}\left[e^{-2\gamma T} + 2\gamma T - 1 \right]$$

$$T \ll \tau_c$$

$$\left\langle (\Delta n)^2 \right\rangle = \langle n \rangle + \langle n \rangle^2$$

$$T > \tau_c$$

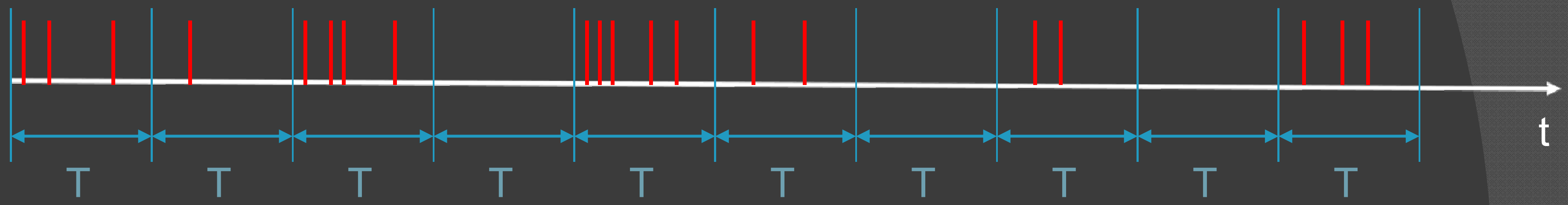
$$\left\langle (\Delta n)^2 \right\rangle = \langle n \rangle + \frac{\langle n \rangle^2}{\gamma T}$$

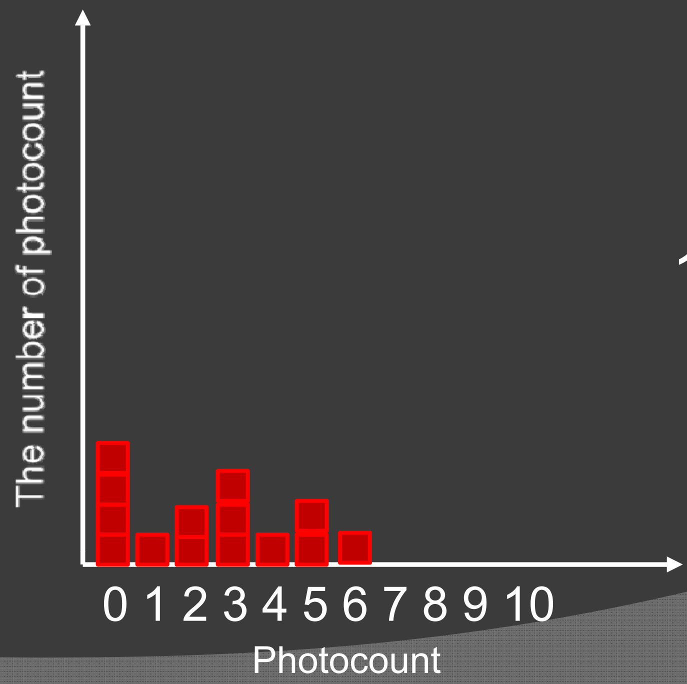
$$T \gg \tau_c$$

$$\left\langle (\Delta n)^2 \right\rangle = \langle n \rangle$$

Measurement time : T

Redline: pulse





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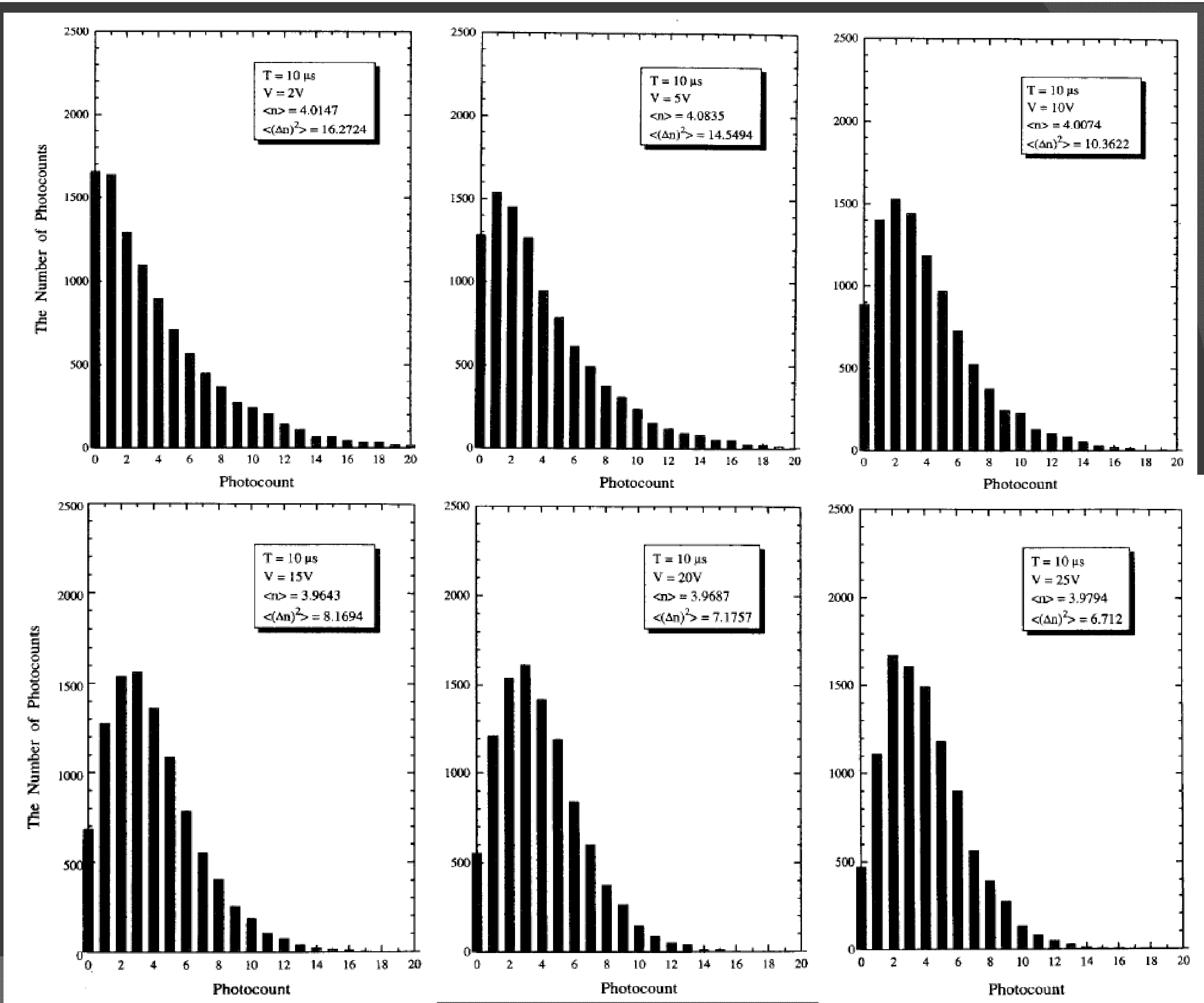
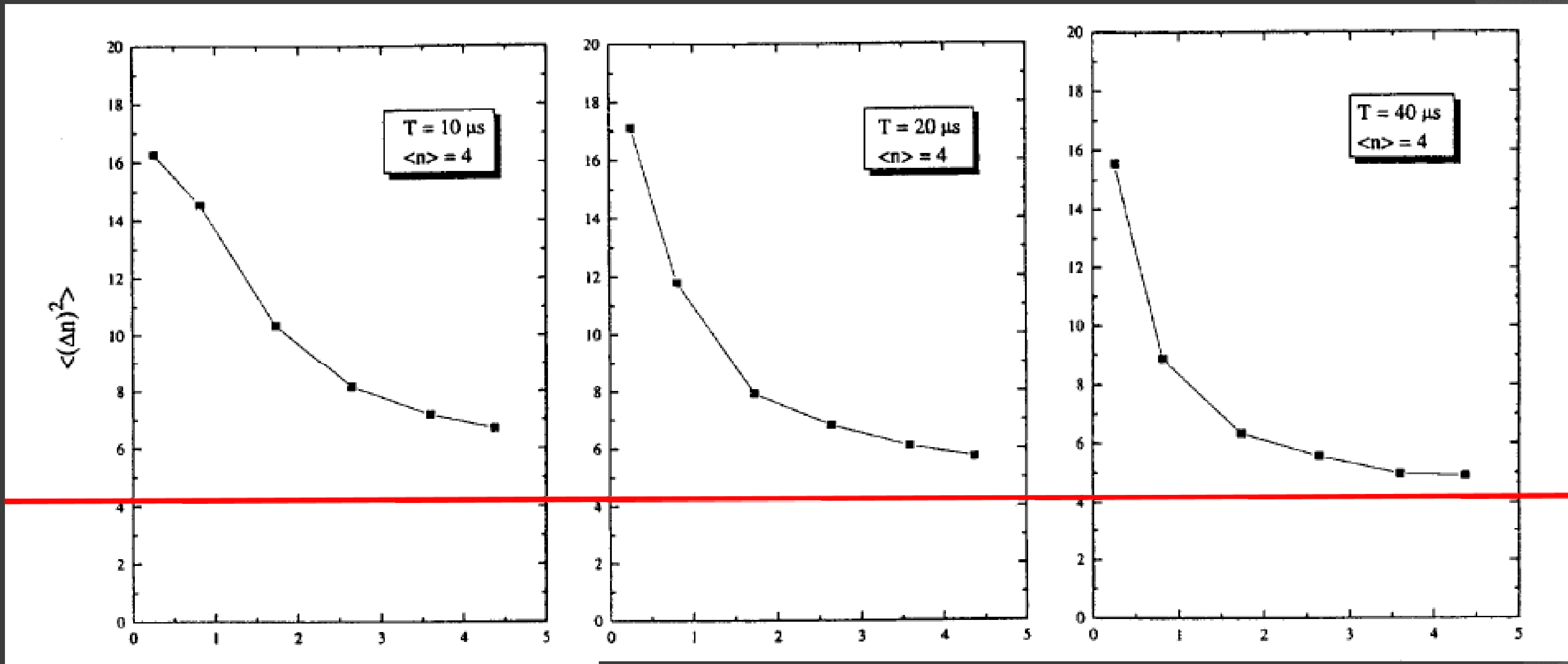

T = 10 μs
V = 2V
<n> = 4.0147
<(Δn)²> = 16.2724
T = 10 μs
V = 5V
<n> = 4.0835
<(Δn)²> = 14.5494
T = 10 μs
V = 10V
<n> = 4.0074
<(Δn)²> = 10.3622
T = 10 μs
V = 15V
<n> = 3.9643
<(Δn)²> = 8.1694
T = 10 μs
V = 20V
<n> = 3.9687
<(Δn)²> = 7.1757
T = 10 μs
V = 25V
<n> = 3.9794
<(Δn)²> = 6.712
The Number of Photocounts
Photocount
0
500
1000
1500
2000
2500
0
2
4
6
8
10
12
14
16
18
20

Variance of $\langle(\Delta n)^2\rangle$ by the velocity *v*



v (rotating speed) (m/s)

Input Voltage(V)	frequency (s^{-1})	$\omega(=2\pi f)$ (s^{-1})	$v(=r\omega)$ (m/s)
2	1.026	6.45	0.26
5	3.226	20.27	0.81
10	6.873	43.18	1.73
15	10.526	66.14	2.65
20	14.286	89.76	3.59
25	17.391	109.27	4.37

$$\tau_c = \frac{\sigma(=9\mu m)}{v} \qquad \left\langle (\Delta n)^2 \right\rangle = \langle n \rangle + \frac{\tau_c \langle n \rangle^2}{T}$$

	Input Voltage	σ/v에 의해 계산된 τ_c	광전자 분포에 의해 측정된 τ_c
T=50 µs	2V	34.62 µs	31.4 µs
T=30 µs	5V	11.11 µs	11.4 µs
	10V	5.202 µs	5.38 µs
T=20 µs	15V	3.396 µs	3.67 µs
	20V	2.507 µs	2.92 µs
	25V	2.059 µs	2.48 µs