Extensive studies of Ultra Bright LEDs and Light Sources Based on Them

B.K.Lubsandorzhiev

Institute for Nuclear Research

Moscow Russia

University of Tuebingen

Tuebingen Germany

LEDs are everywhere

XXI century –
LEDs century

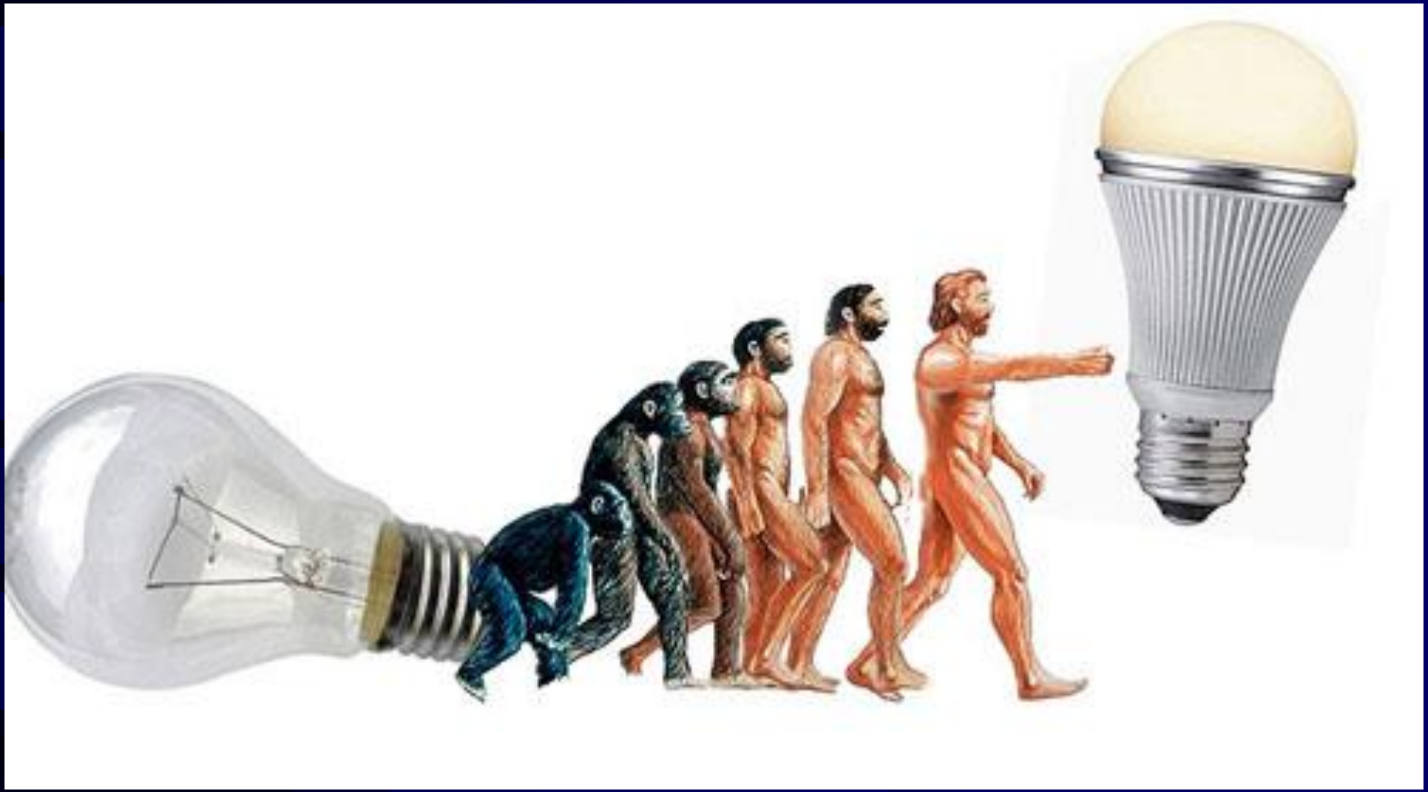
Giant LED bright displays

Street and Highway Lights

White LEDs car light

Gas station in Korolyov near Moscow

Bizzarre application



Henry Josef Round
1881 – 1966

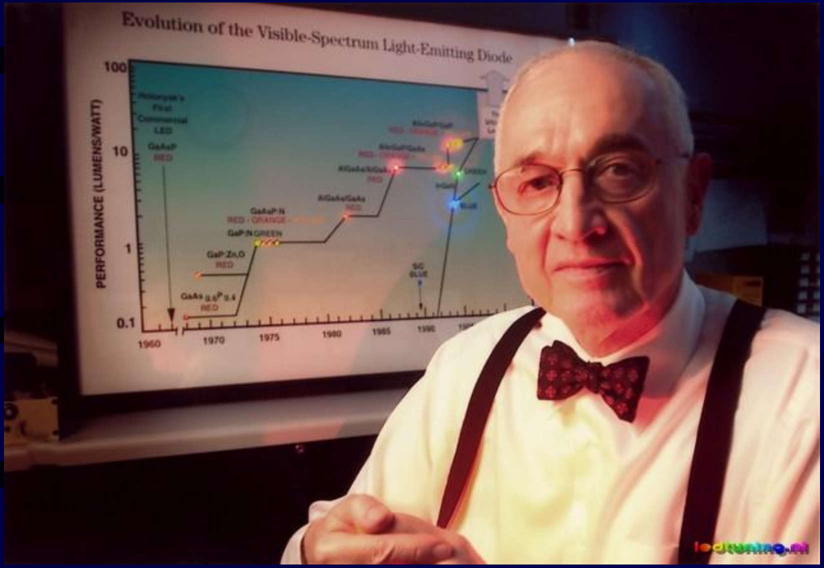
1907 - glow in carborund (SiC)

Oleg Vladimirovitch Losev (1903-1942)

"Losev's glow" or
"Losev's effect" – 1922-1923.
Green glow in SiC crystals

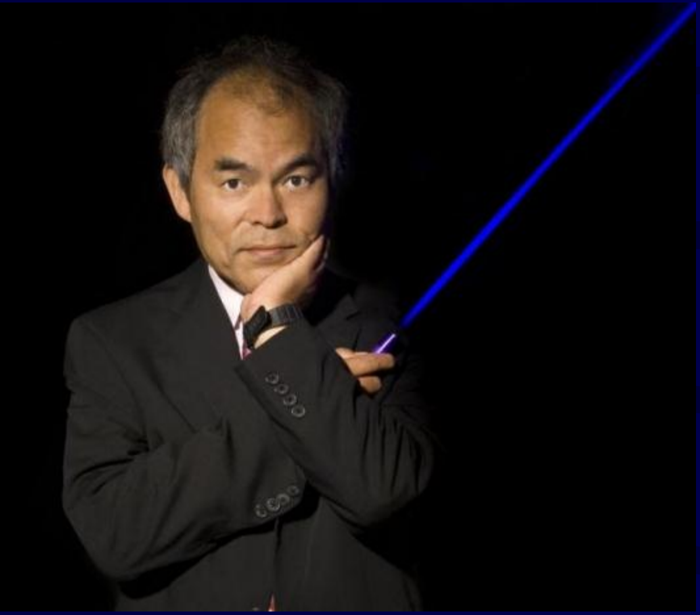
"…. green glow of SiC crystals at currents as low as 0.4 mA ……such glowing detector can be used as *fast light sources* "

O.V. Losev 1923



Nick Holonyak

1962 – first LED



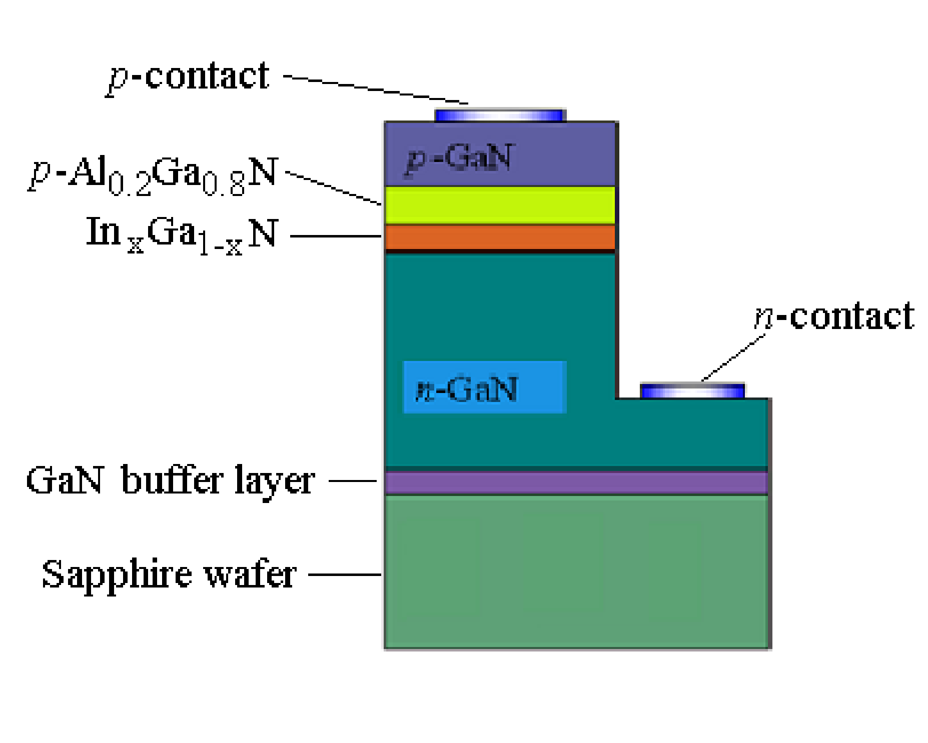
Shuji Nakamura

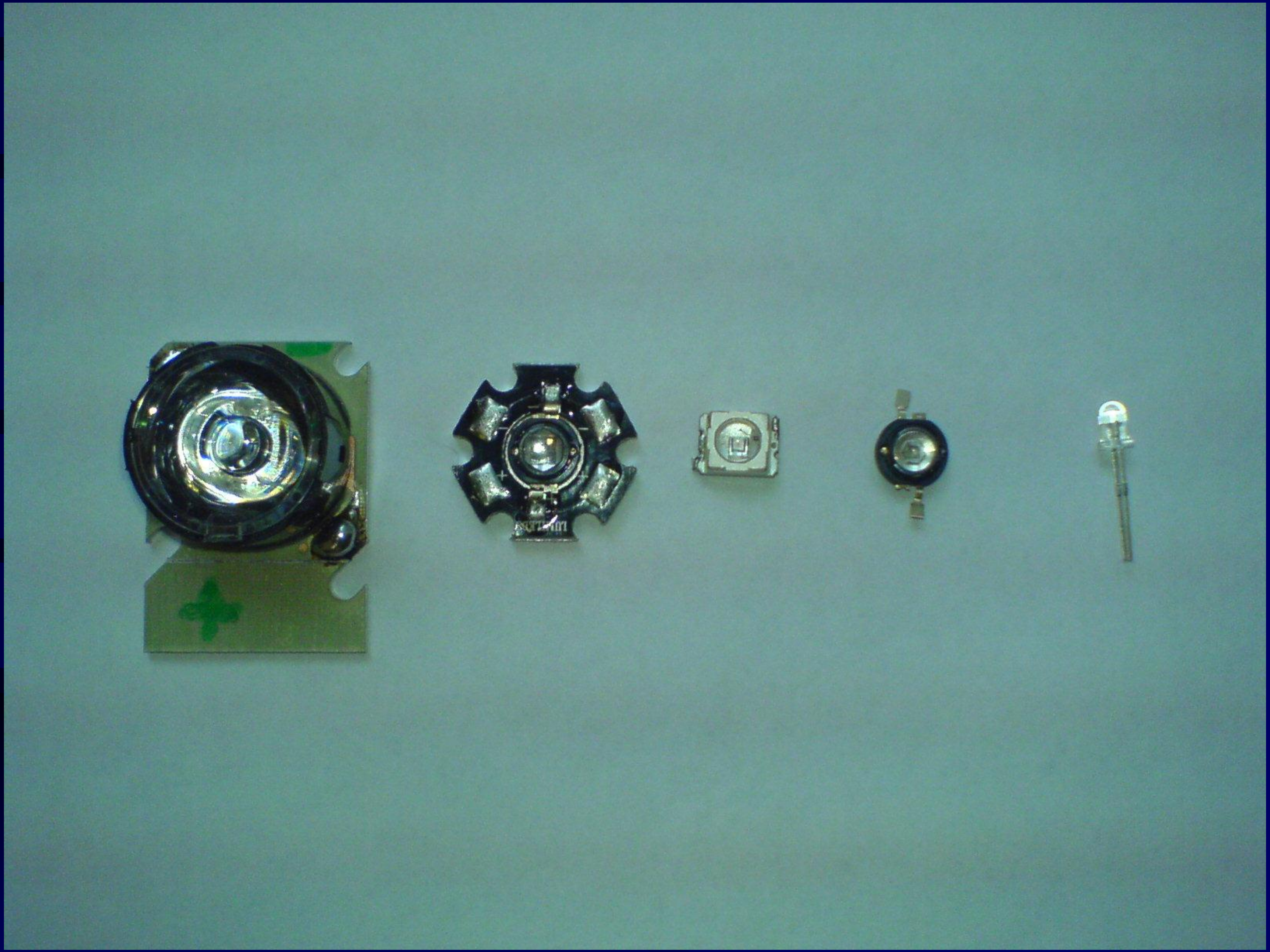
1993 - Ultra Bright Blue LED

Ultra Bright Blue LEDs

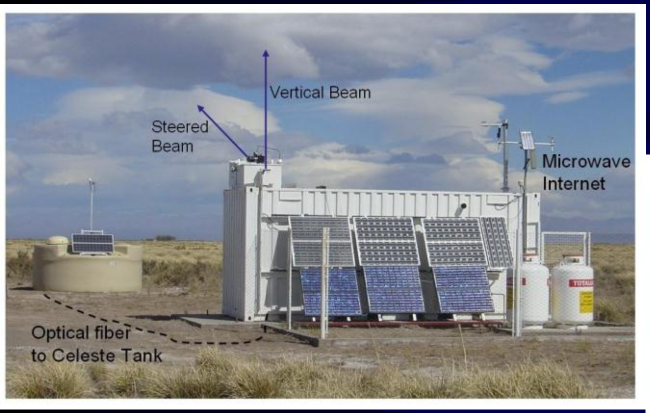
S.Nakamura NICHIA 1993

Single quantum well
InGaN/GaN structure





PAO experiment

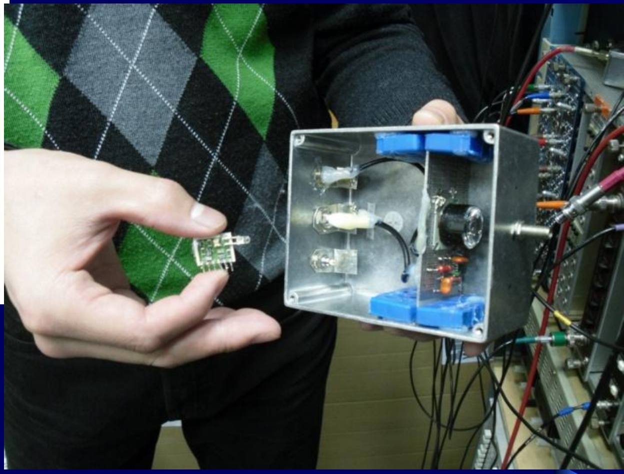


YAG, 3-rd harmonics
$\Delta t \sim 7$ ns, 10^{16}-10^{17} γ
λ_{max} = 355 nm

Baikal neutrino experiment

N_2 + Dye
$\Delta t < 1$ ns , 10^{13}-10^{14} γ
λ_{max} = 470 nm

Experiment GERDA



LEDs
$\Delta t \sim 0{,}5 \div 5$ ns, 10^{8}-$10^{12}\gamma$
λ_{max} = 450 nm

We need high light yield and fast emission kinetics

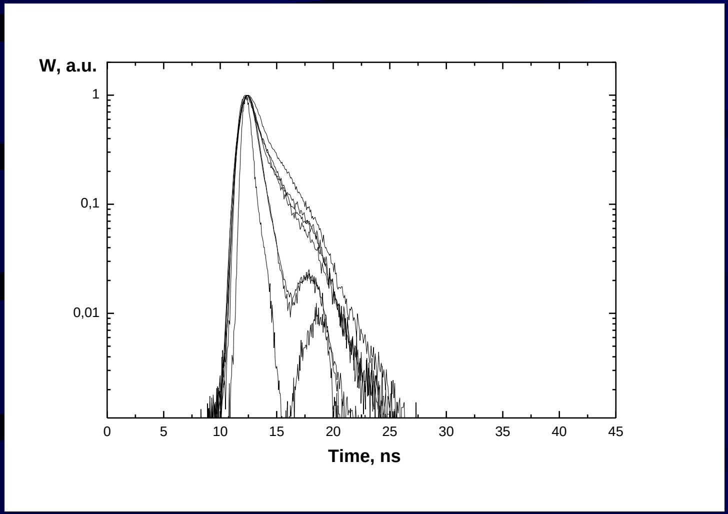
LEDs - Light emission kinetics at high light yield?

More than 5000 LEDs of various types from different suppliers and manufacturers have been studied

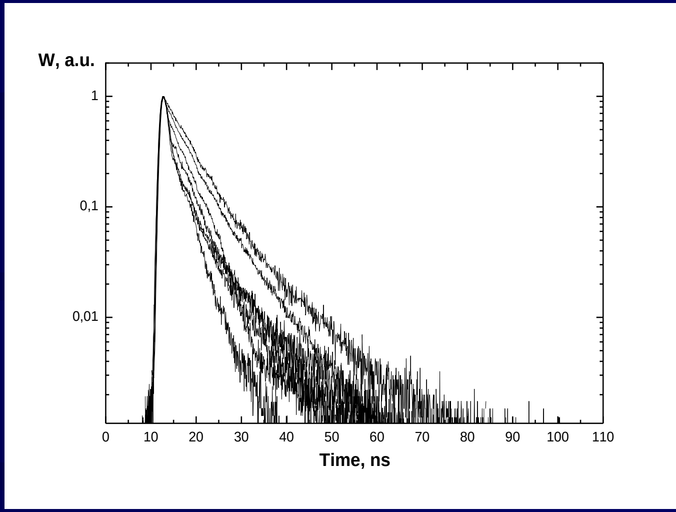
Light emission kinetics varies very much!

Even LEDs of one type can differ very much in their kinetics

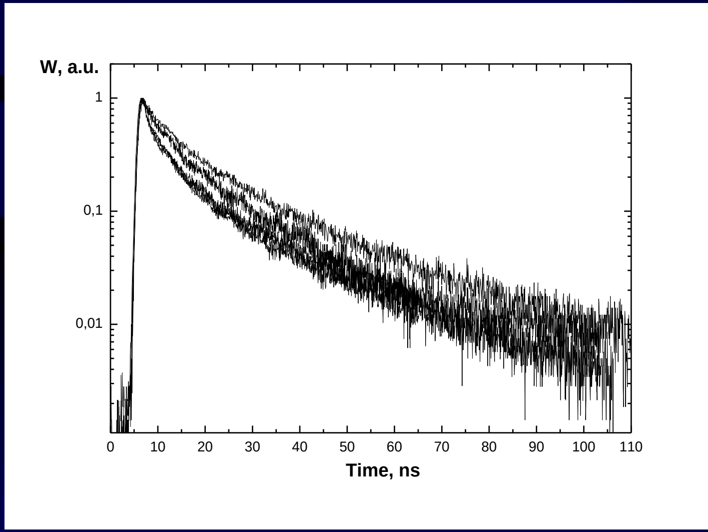
Ultra bright LEDs emission kinetics



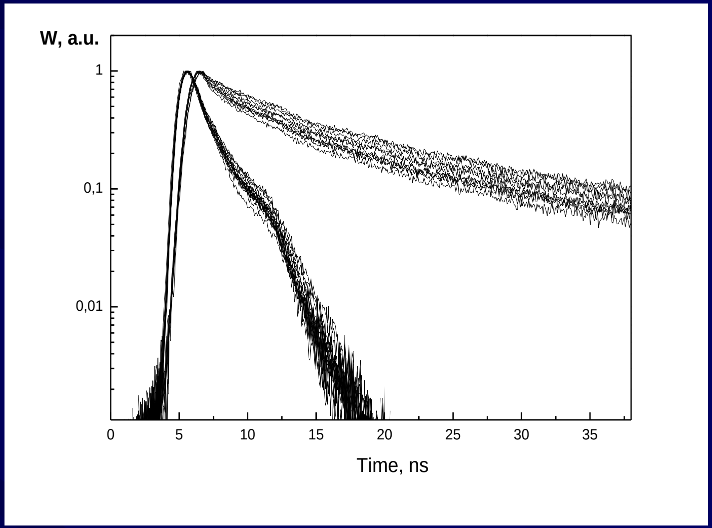
Fast LEDs(Nichia «old», G-nor, YolDal)



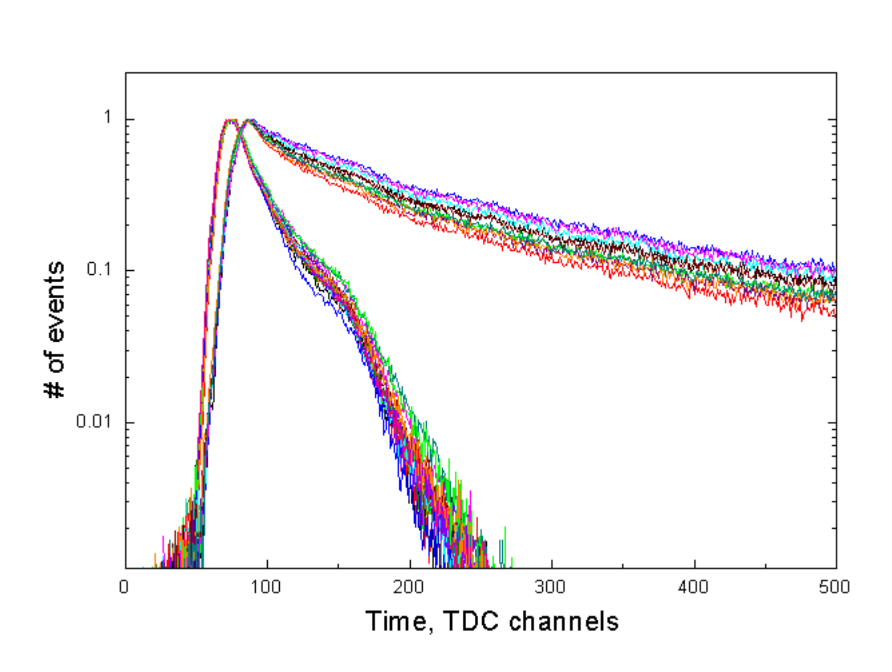
Intermediate LEDs

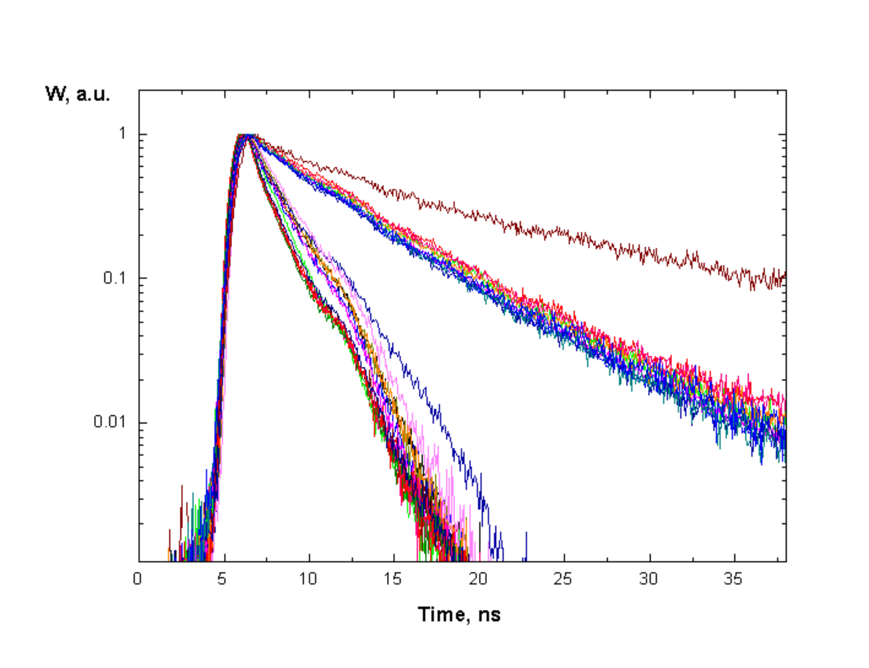


Slow LEDs



Nichia «old» and «new» LEDs



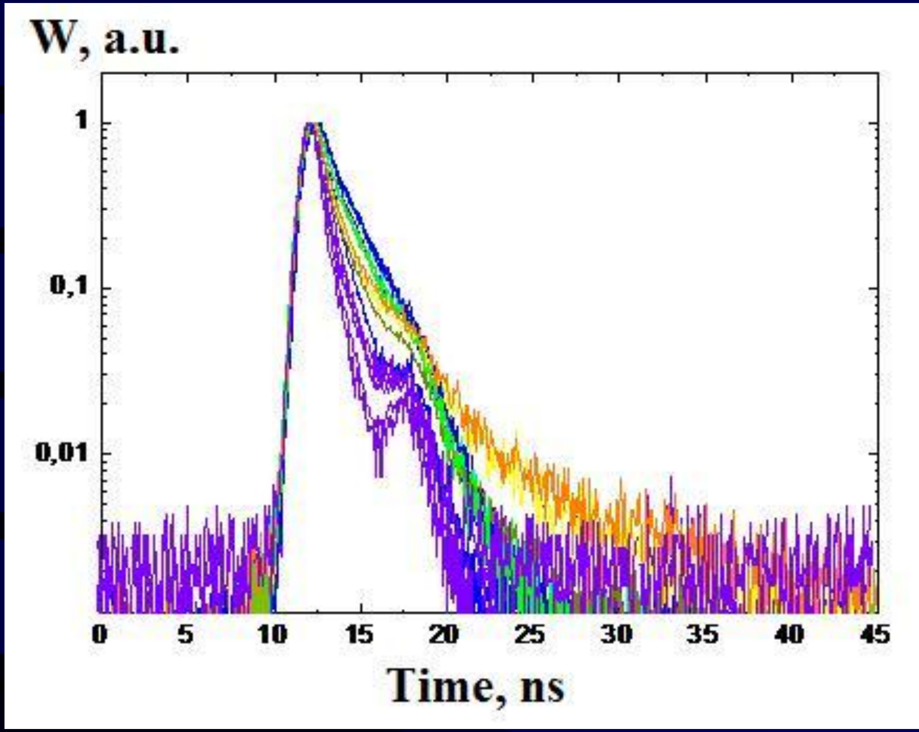


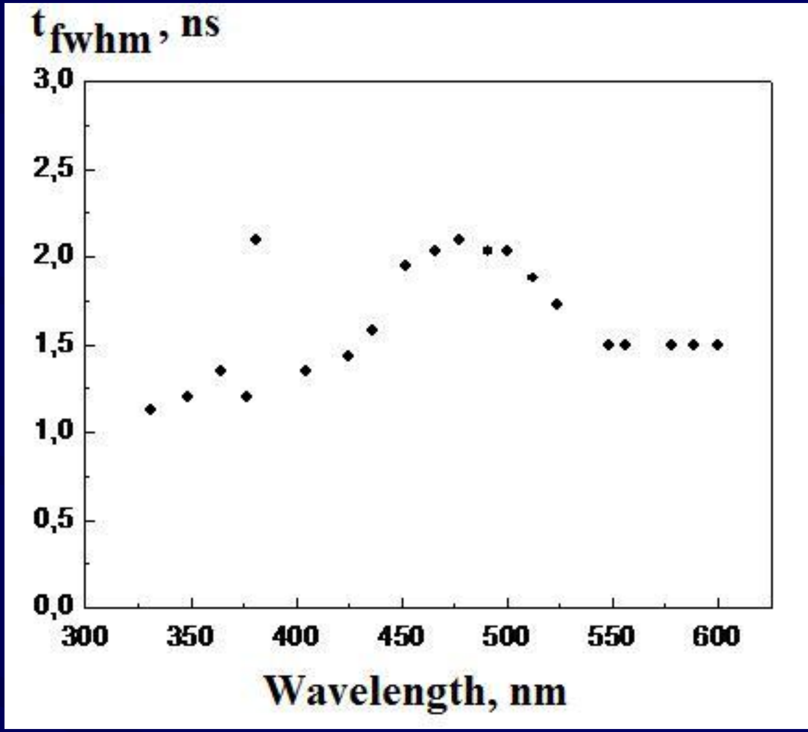
NSPB500S NICHIA CHEMICAL

KINGBRIGHT L7133NBC
slow L7113PBC

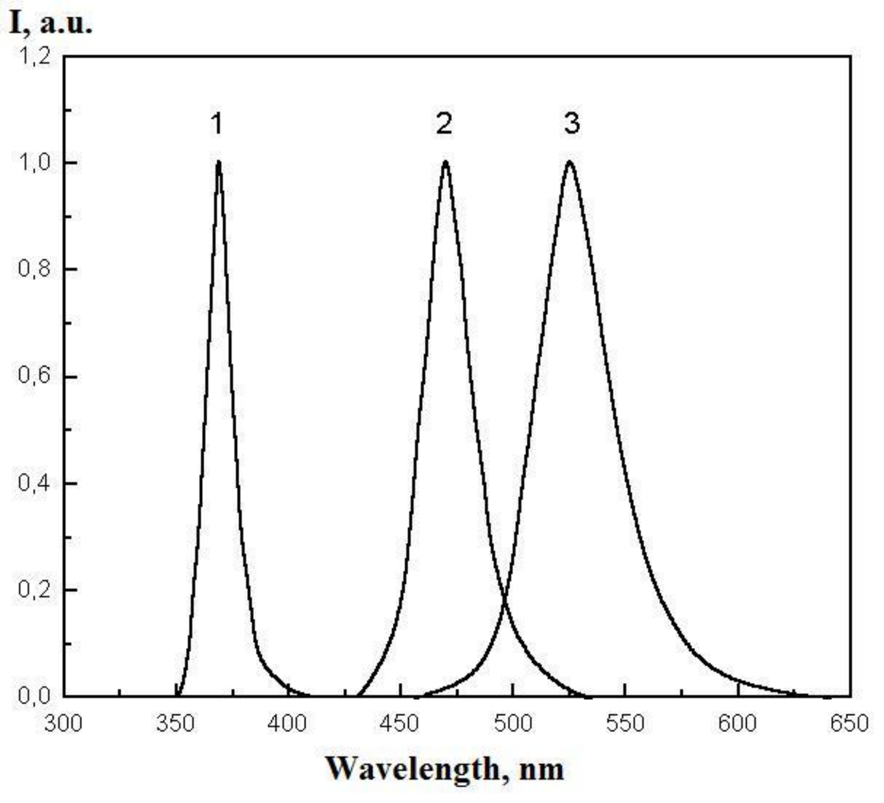
«old» - 1.8 ns width
«new» - 4ns width τ~10ns

«old» - 1.8 ns width
«old» - 4.5 ns width τ~16ns


W, a.u.
1
0,1
0,01
0
5
10
15
20
25
30
35
40
45
Time, ns


t_{fwhm}, ns
3,0
2,5
2,0
1,5
1,0
0,5
0,0
300
350
400
450
500
550
600
Wavelength, nm

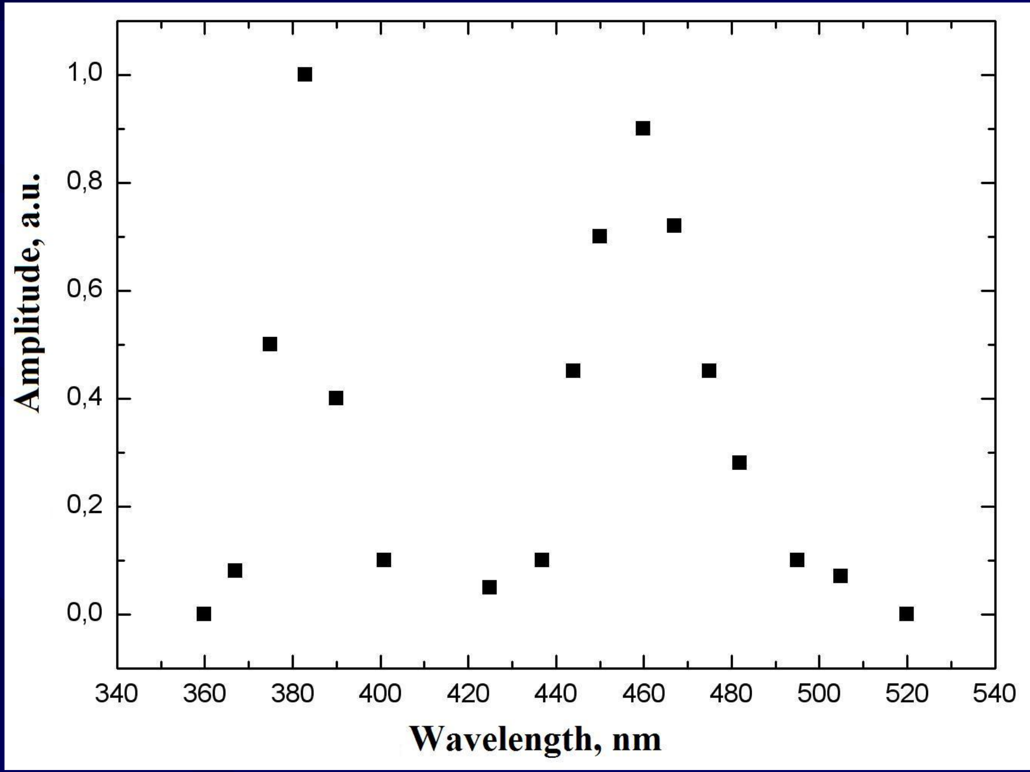
Emission spectrum at high current pulses



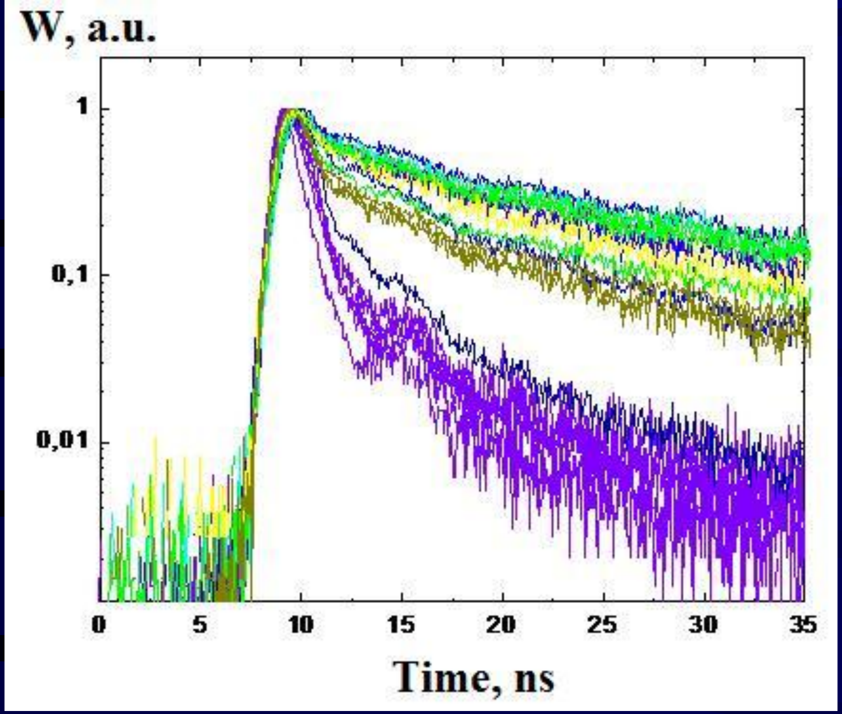
DC - mode

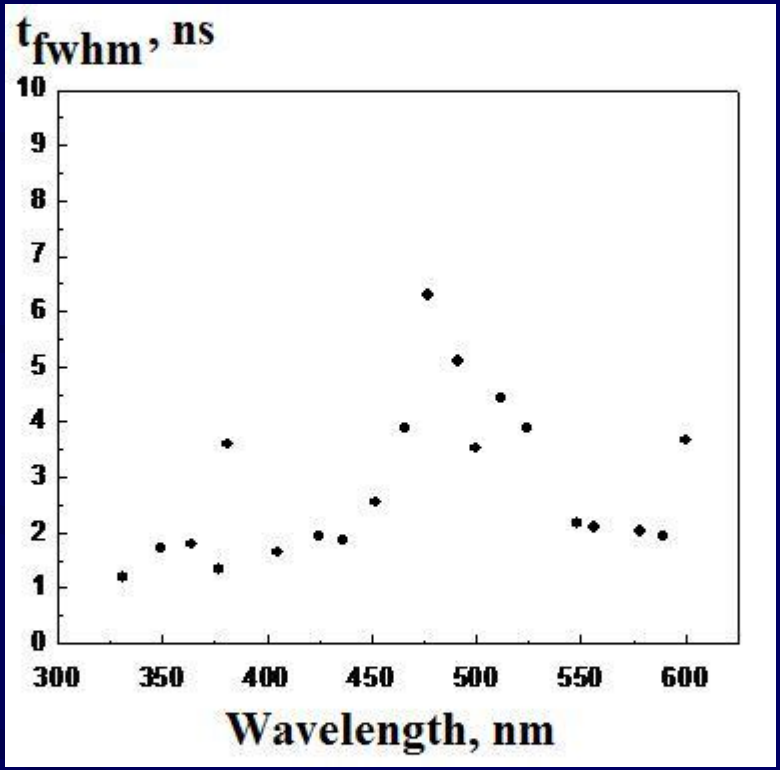
Pulsed mode

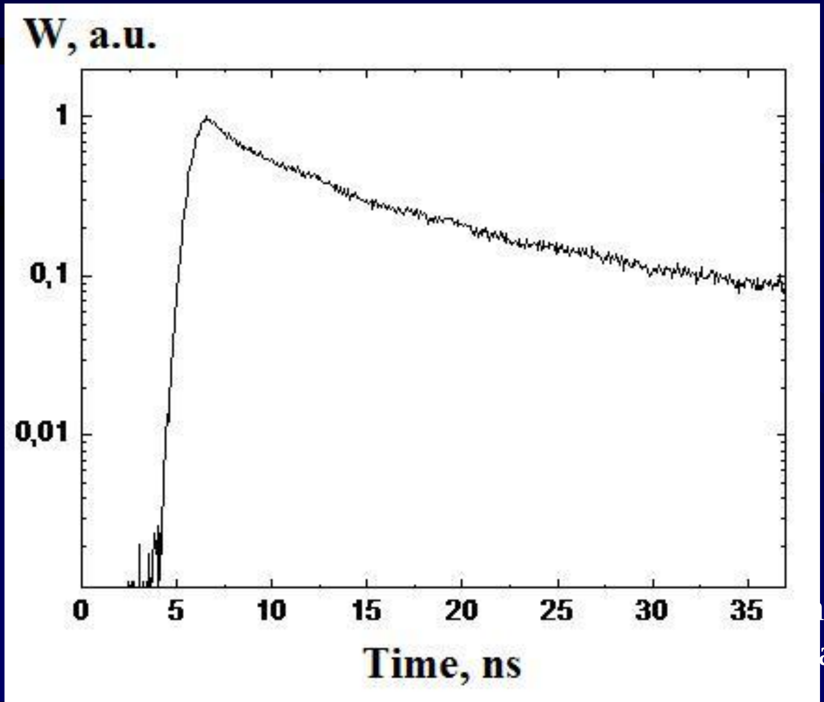
I > 2 A (1-2 ns)

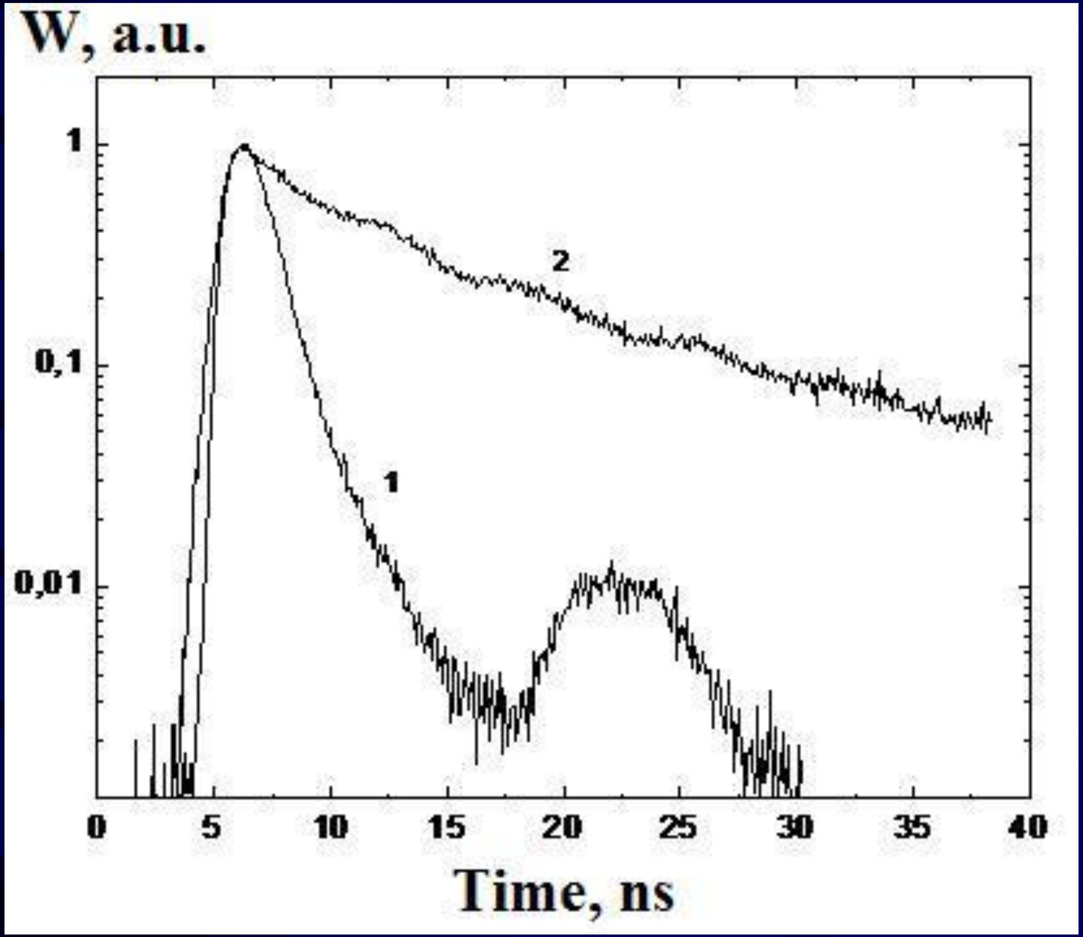


NSPB500S “new”



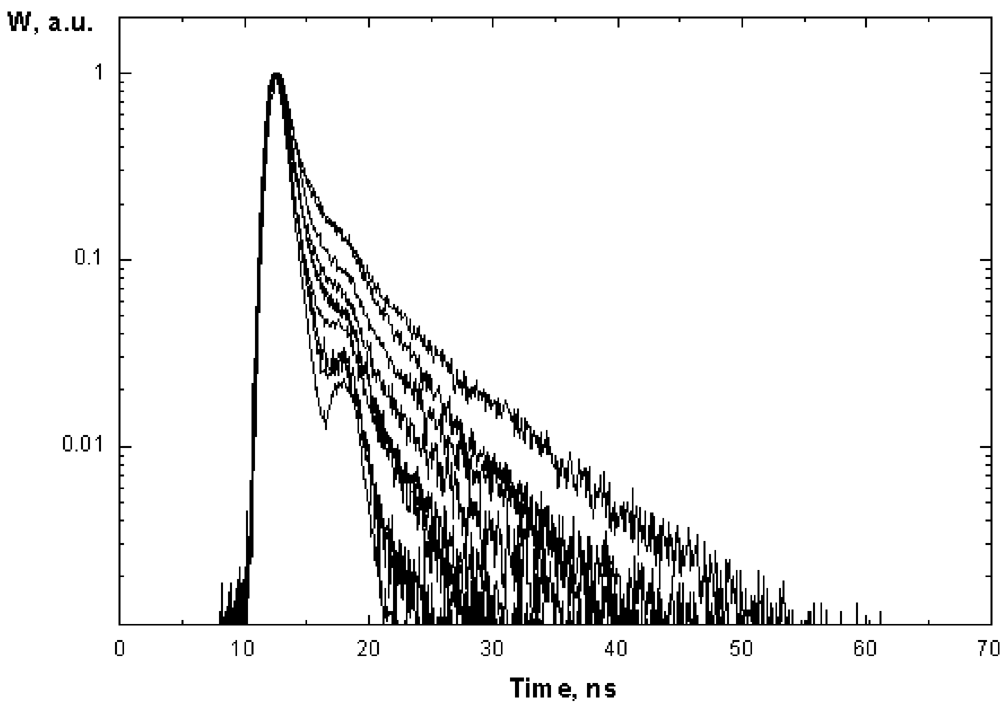






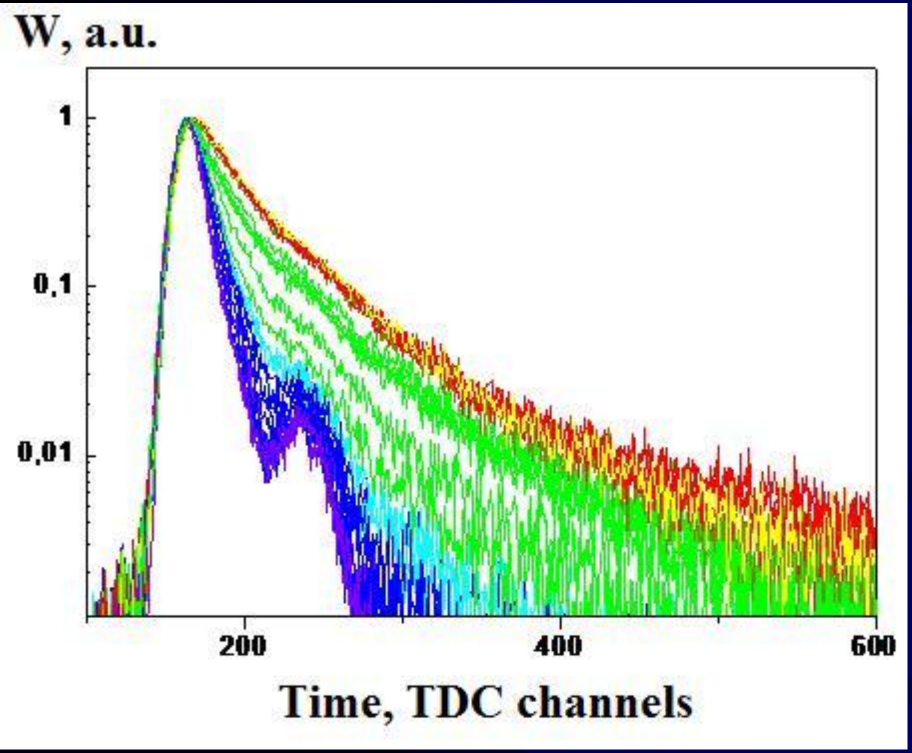
1 - 2,2 A (1-2 ns)
2 – 20 mA (1-2 ns)

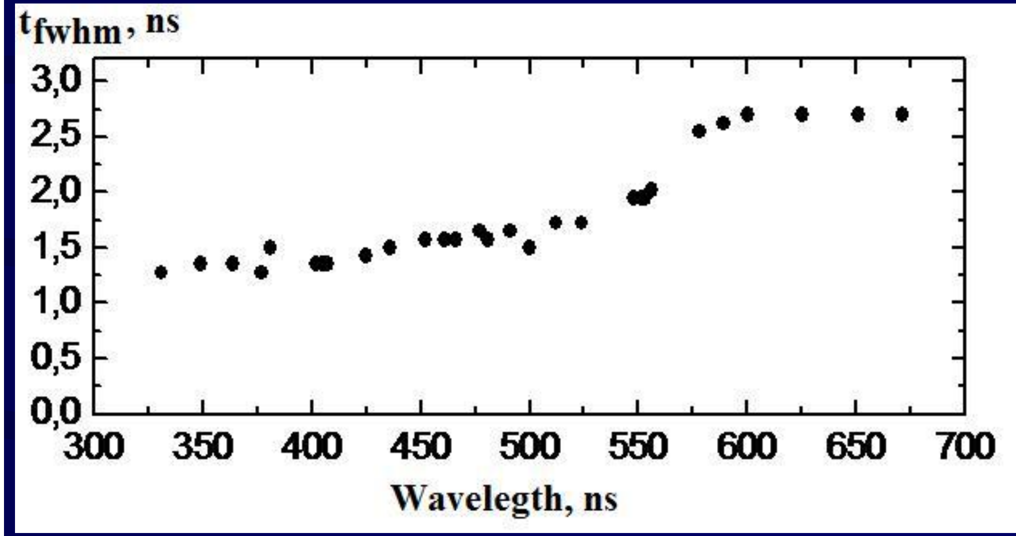
G-nor GNL3014BC



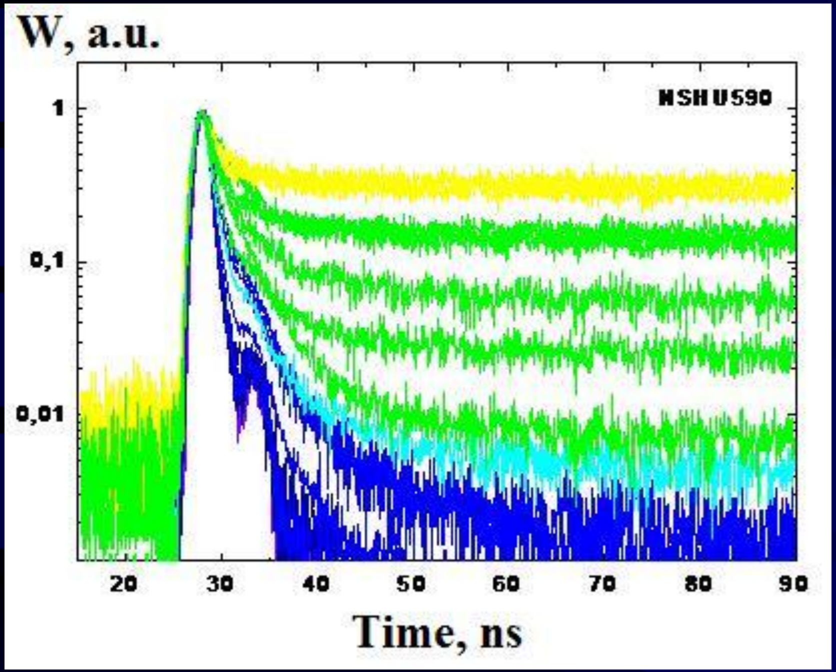
The fastest LED
0.6 ns width!
Without tail!

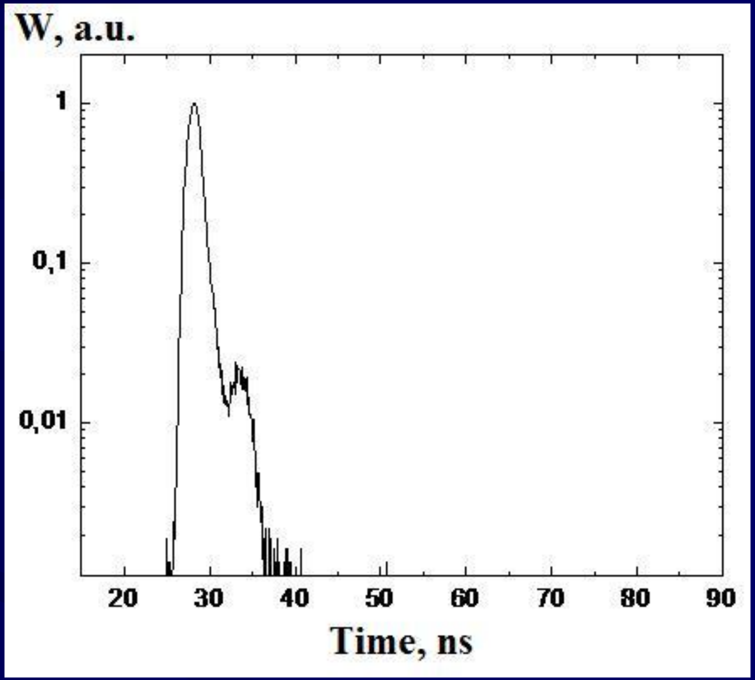
GNL-3014BC


W, a.u.
1
0,1
0,01
200
400
600
Time, TDC channels

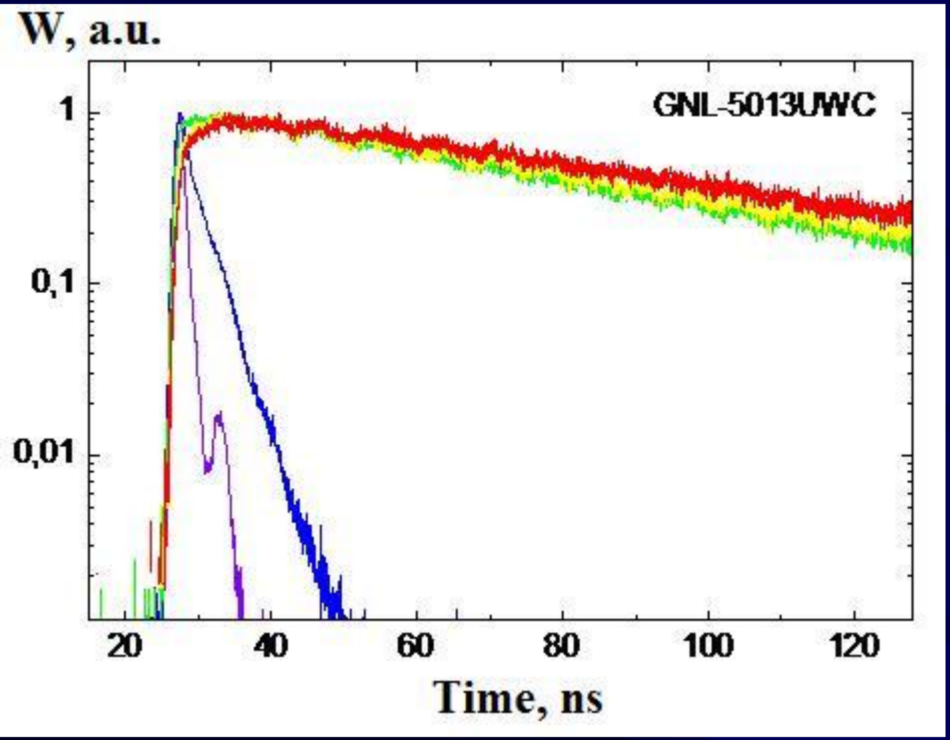

t_{fwhm}, ns
3,0
2,5
2,0
1,5
1,0
0,5
0,0
300
350
400
450
500
550
600
650
700
Wavelegth, ns

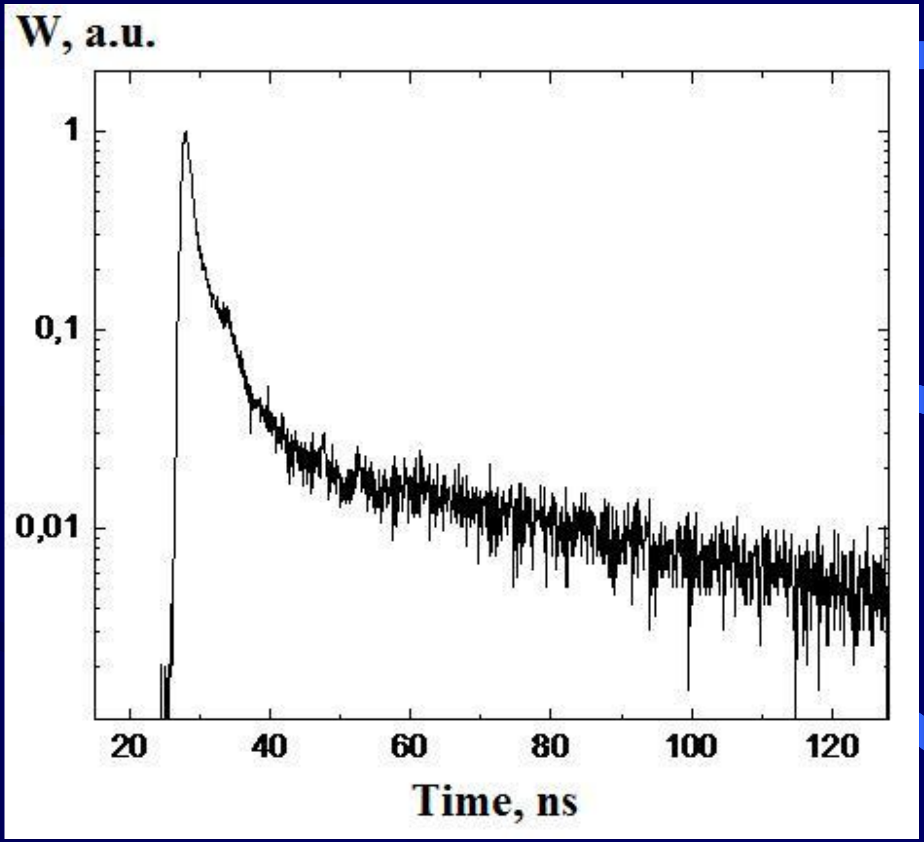
UV LED NSHU590





White LED GNL-5013UWC



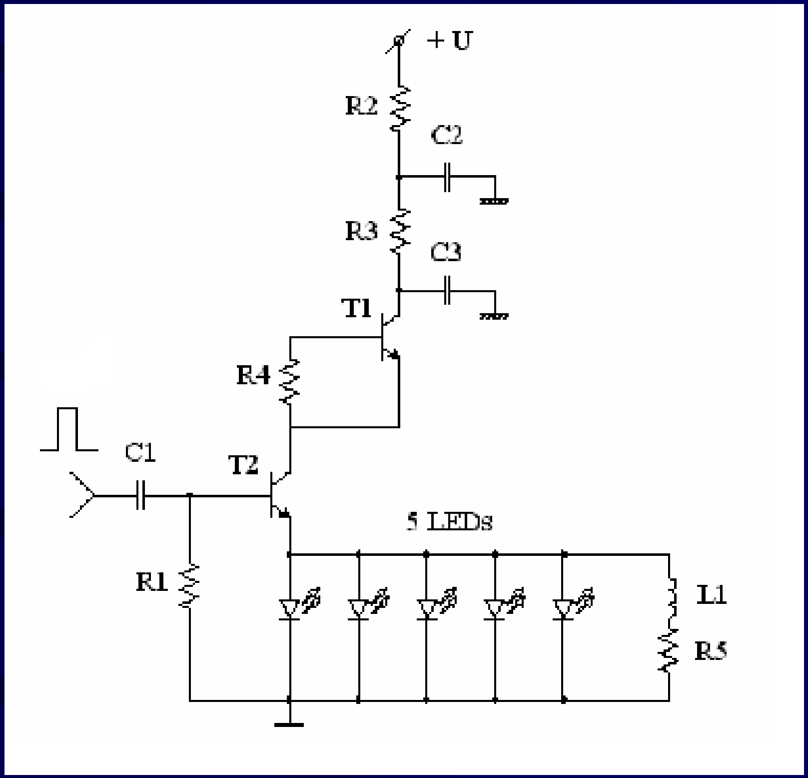


LED DRIVERS
for astroparticle physics experiments

- Drivers with single LEDs provide 1 ns width (FWHM) light pulses with up to 10^9 photons per pulse.
- How to increase light yield keeping emission kinetics fast?

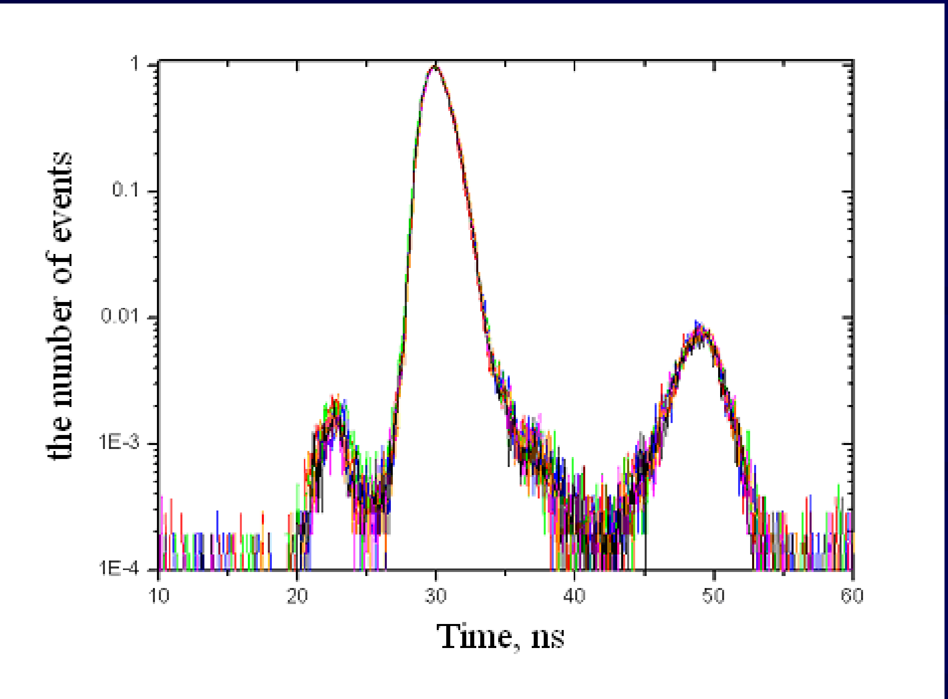
- To assemble LEDs in a matrix.
- Problems: Light emission kinetics of the whole matrix?
- LEDs in the matrix should be selected thoroughly.
- They should be identical in their emission kinetics and intensity
- If several drivers - they should electronically tuned

LED Matrix. One driver for a Matrix of LEDs

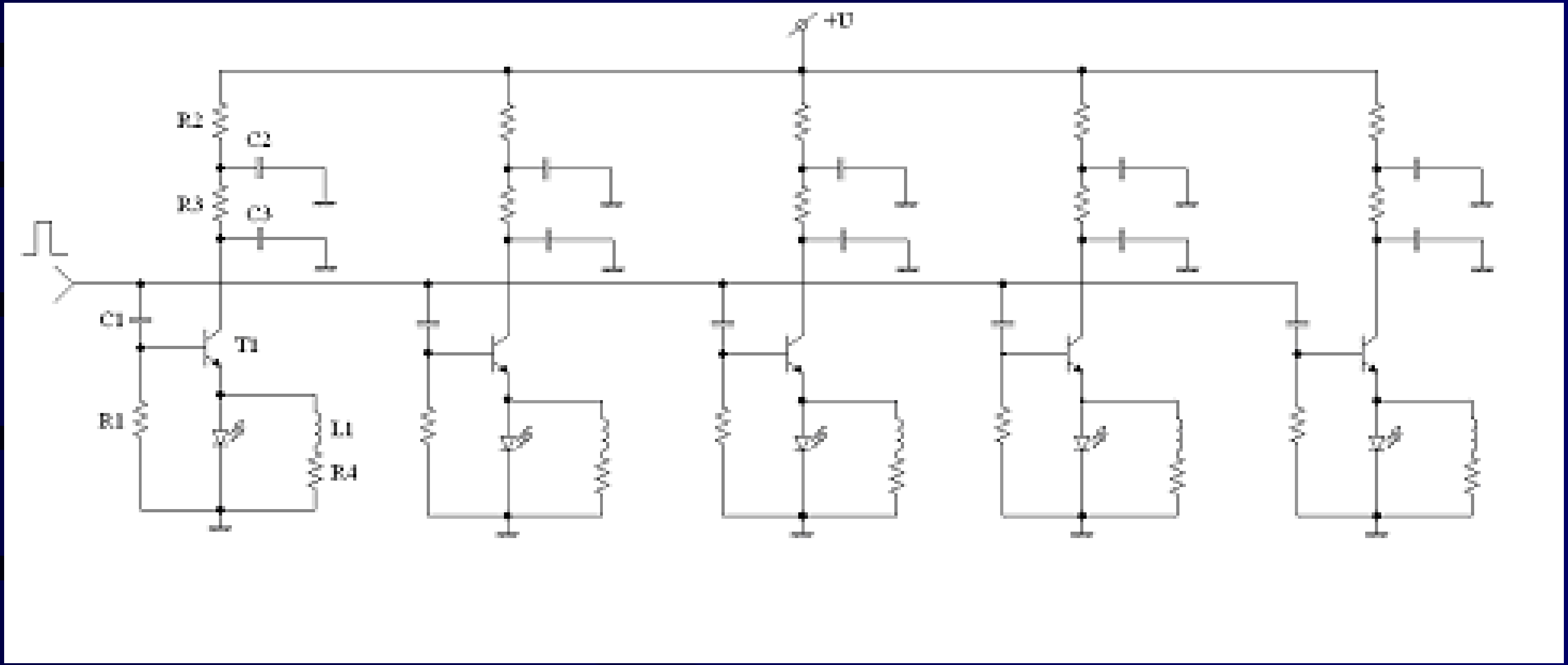


Nearly identical (in emission kinetics, spectrum and light intensity) LEDs are selected for the matrix. The light pulses of individual LEDs coincide with each other with an accuracy of ≤50 ps.

One dirver – LED matrix

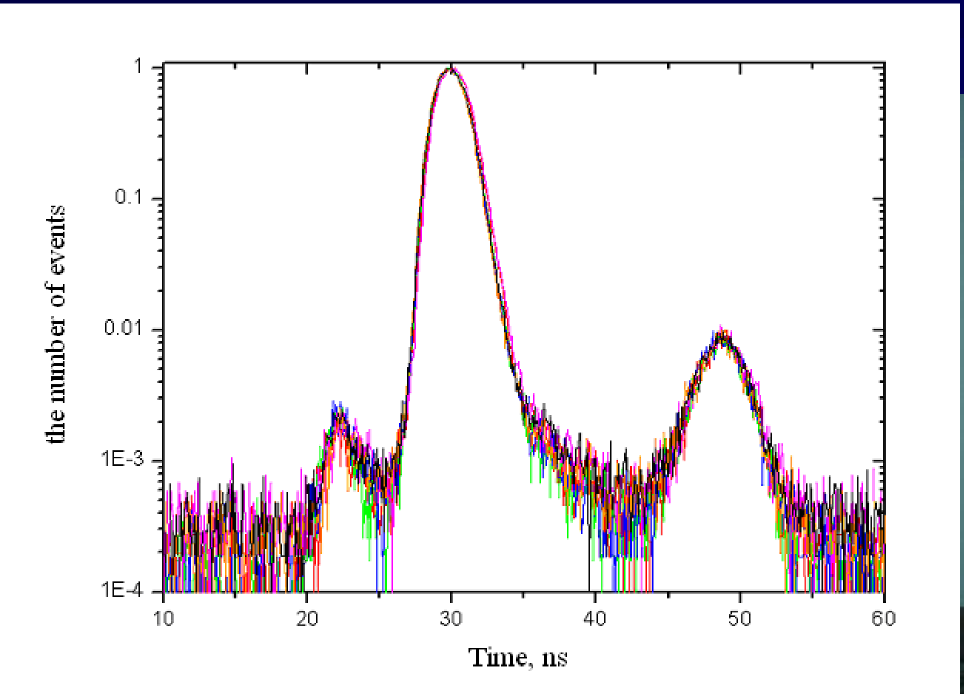


Matrix of LED drivers

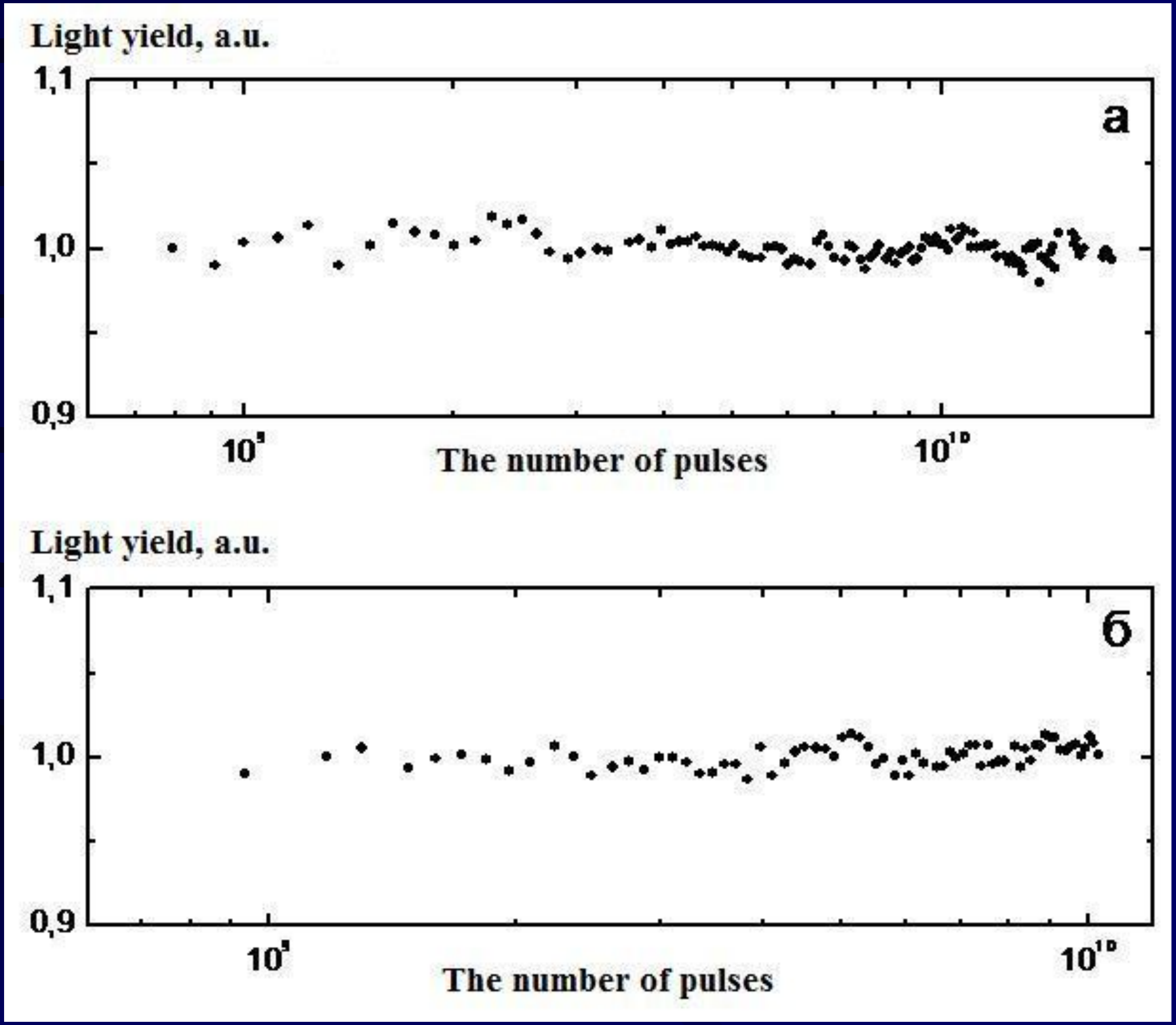


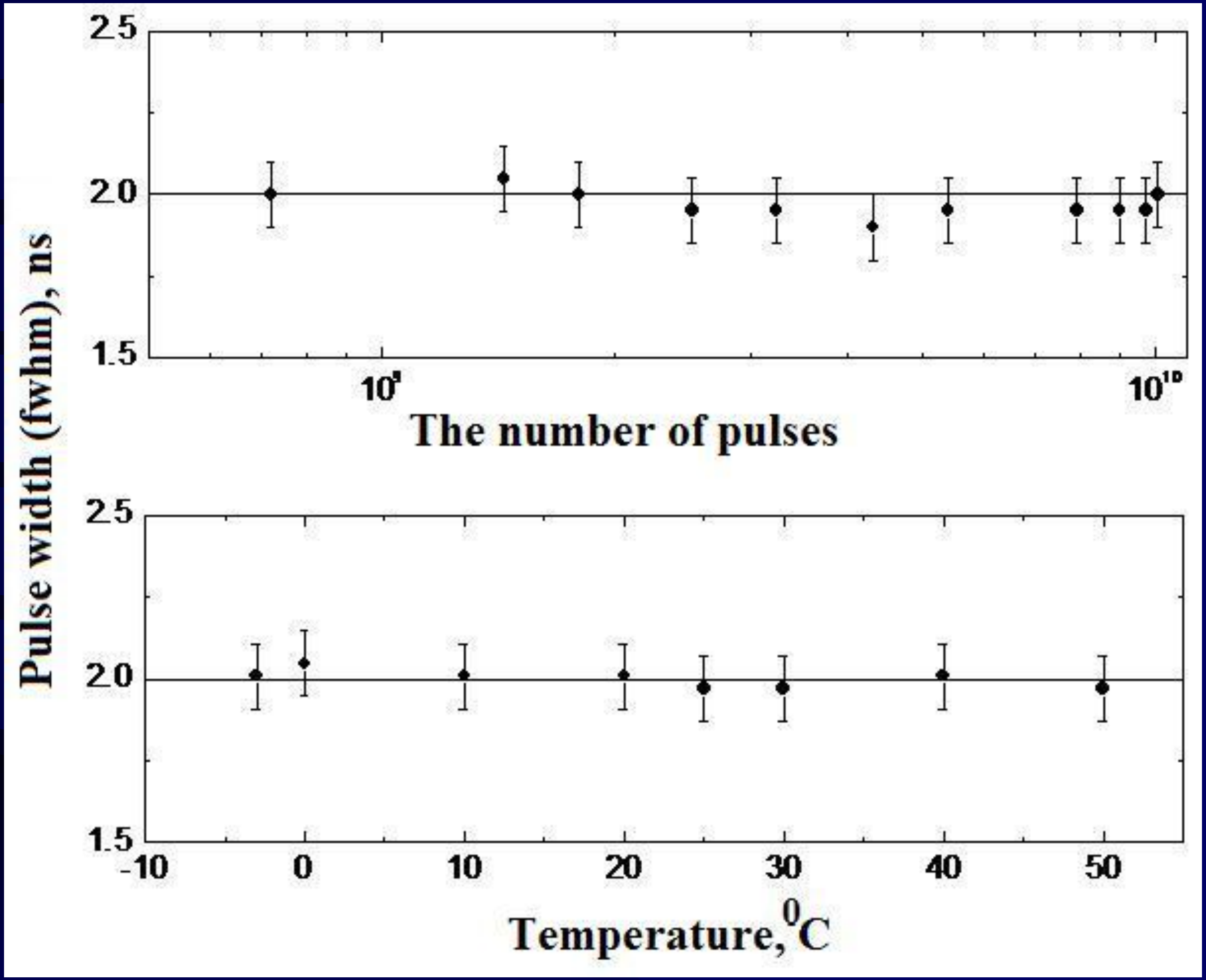
Each LED of the matrix has its own driver based on avalanche transistor. LEDs and their drivers are thoroughly tuned to be identical in timing and intensity. The light pulses of individual drivers coincide with each other with an accuracy of ≤50 ps.

One LED – one driver; matrix of LED drivers

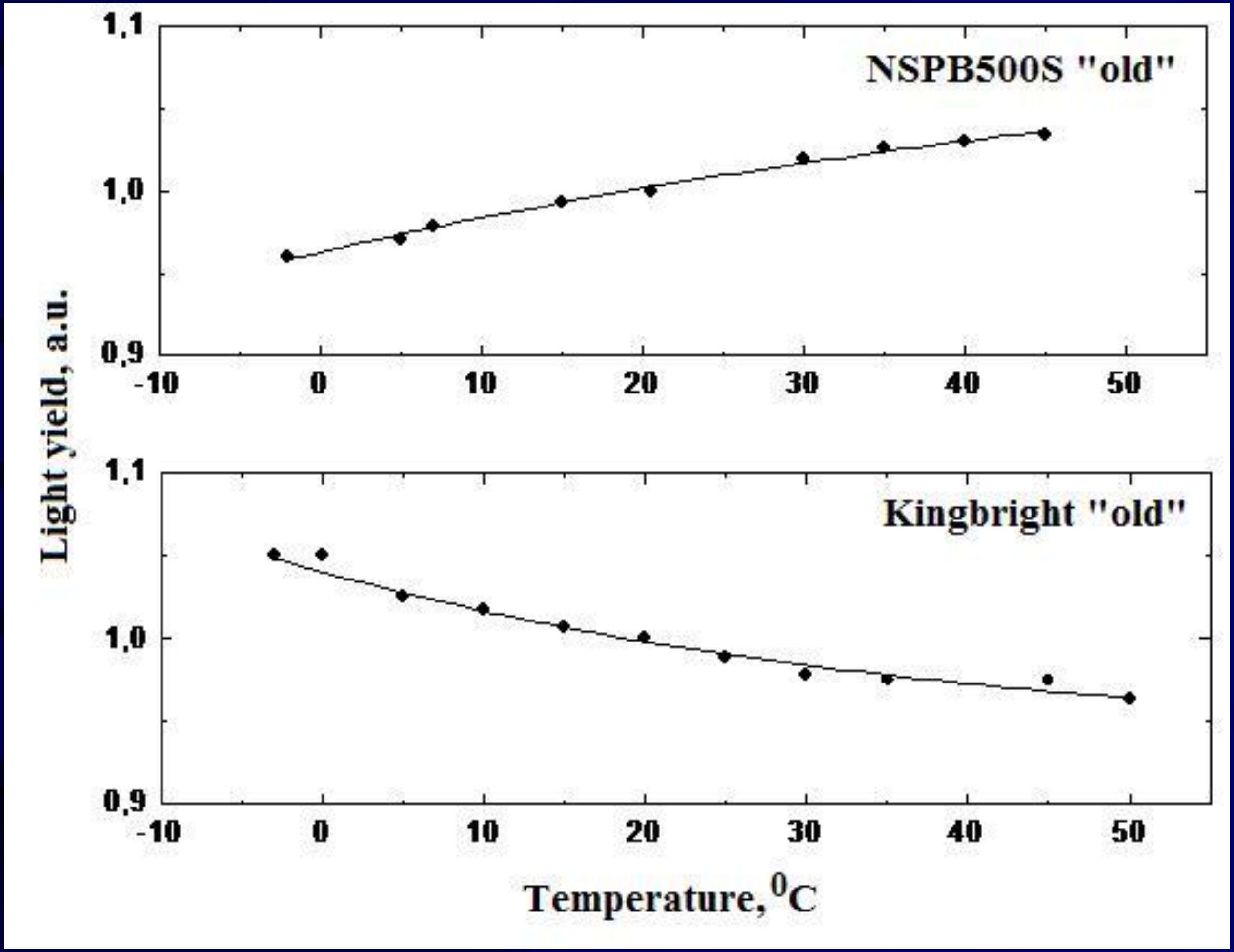


LED stability and life time



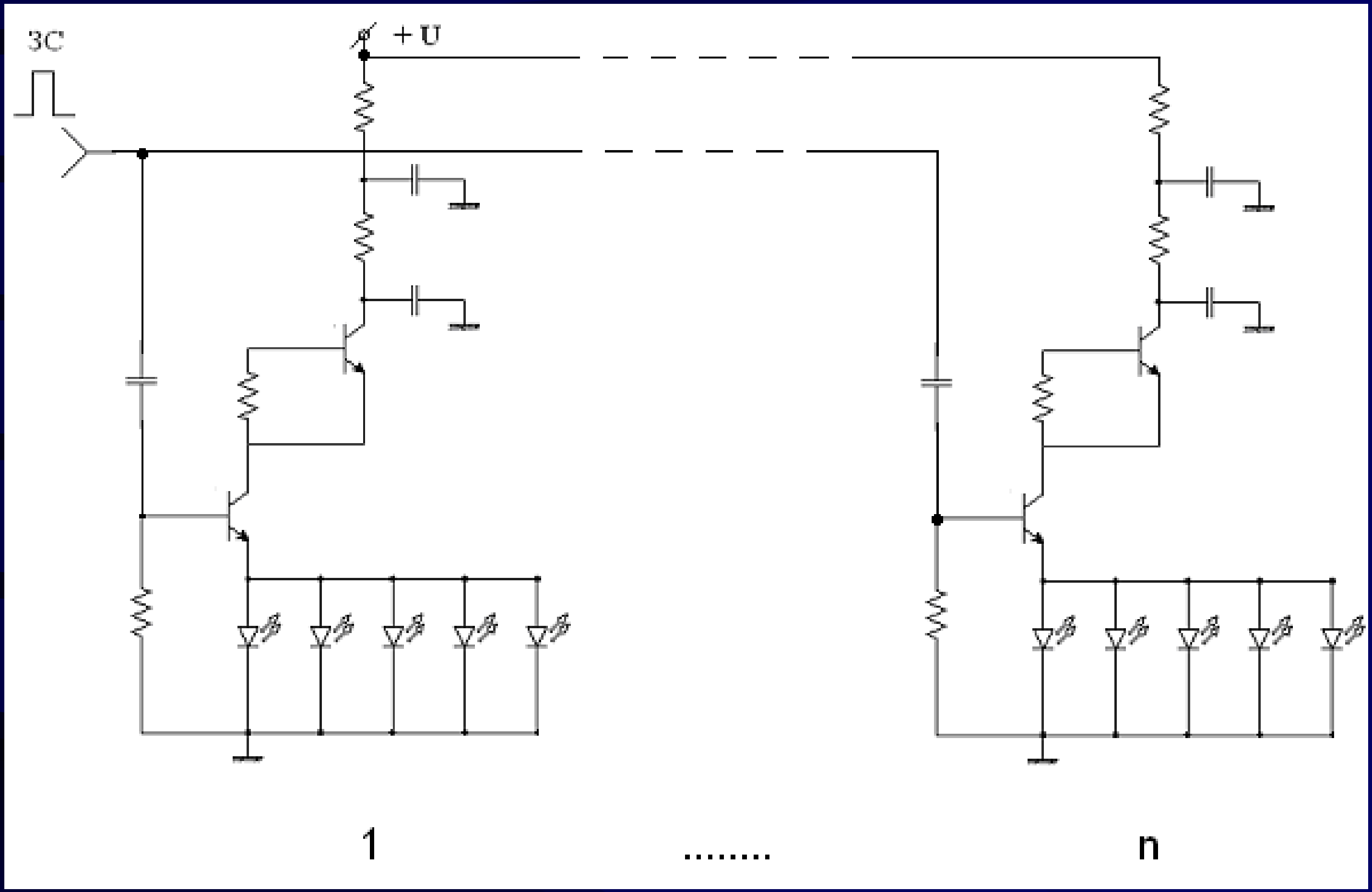

2.5
2.0
1.5
10^9
10^10
The number of pulses
Pulse width (fwhm), ns
2.5
2.0
1.5
-10
0
10
20
30
40
50
Temperature, 0C

Light yield temperature dependence



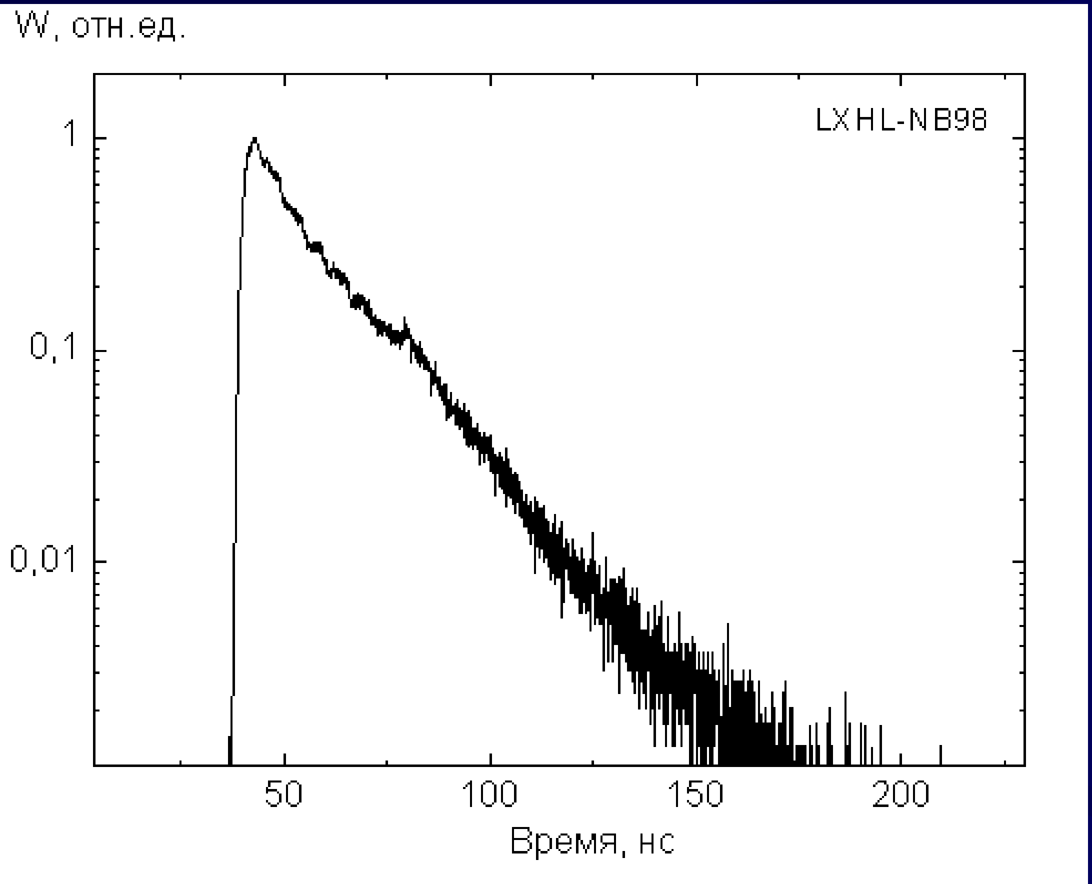
Temperature coeff. - 0.14%/C in the range of -3 ÷ 50 ^{0}C

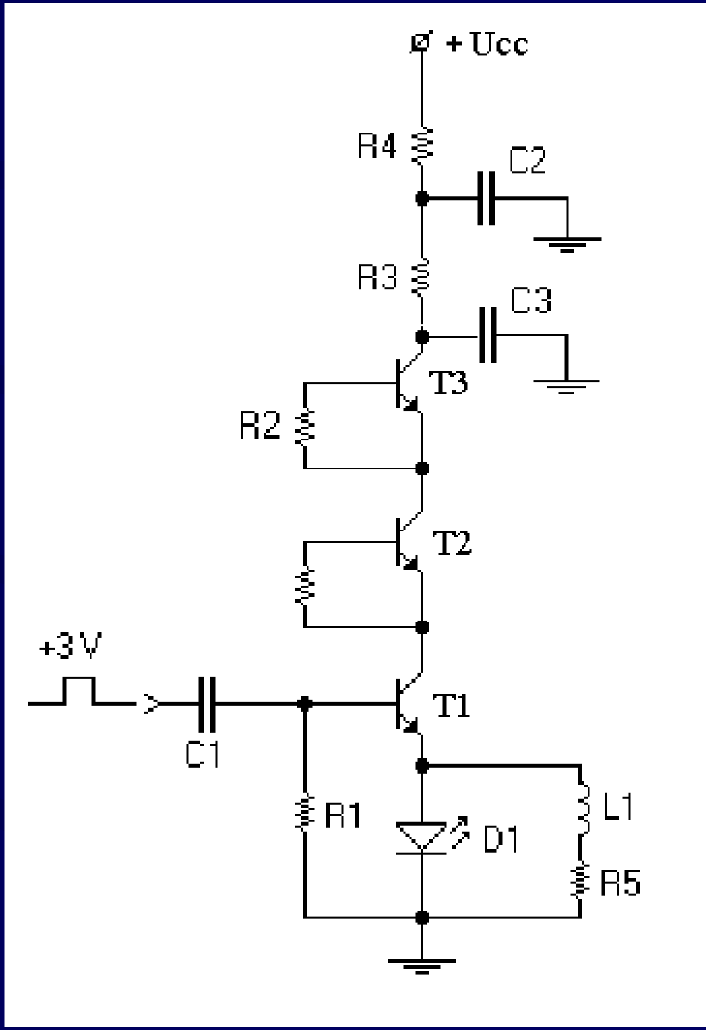
Cluster of n matrixes of ultra bright blue LEDs



light pulses with $\geq 10^{11}$ photons per pulse with 1-2 ns width

High power LEDs

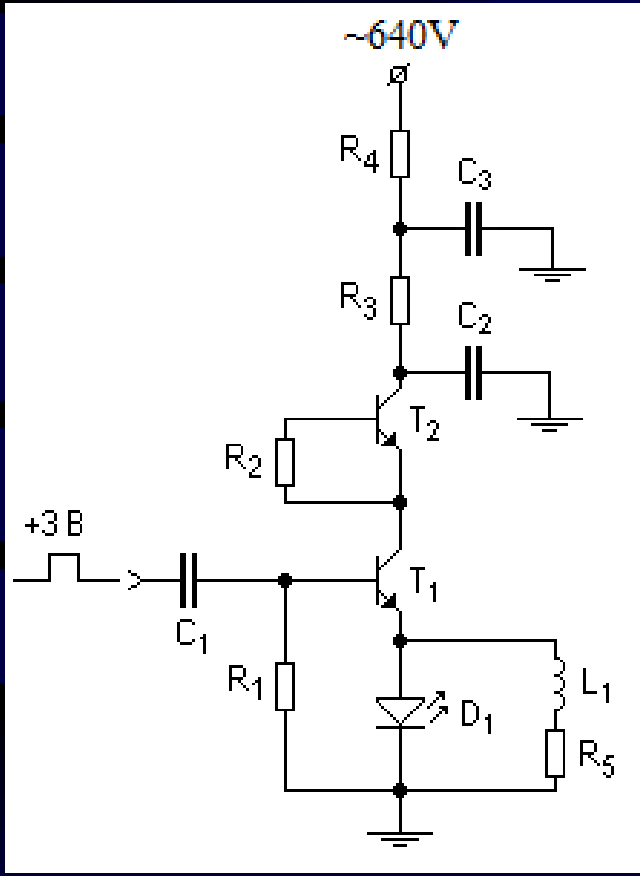


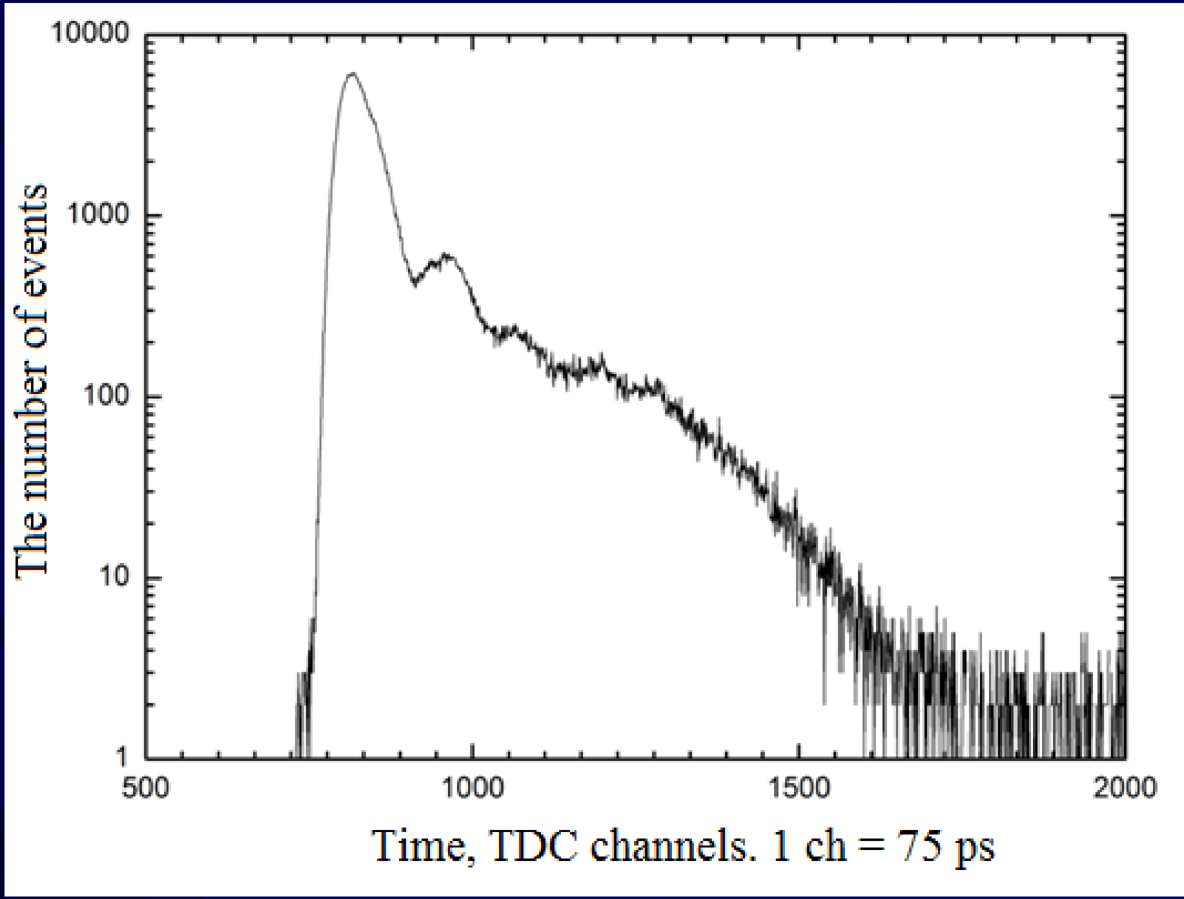


LUMILED LXHL-NB98

10^{11} -10^{12} photons/pulse~6 ns width (fwhm)

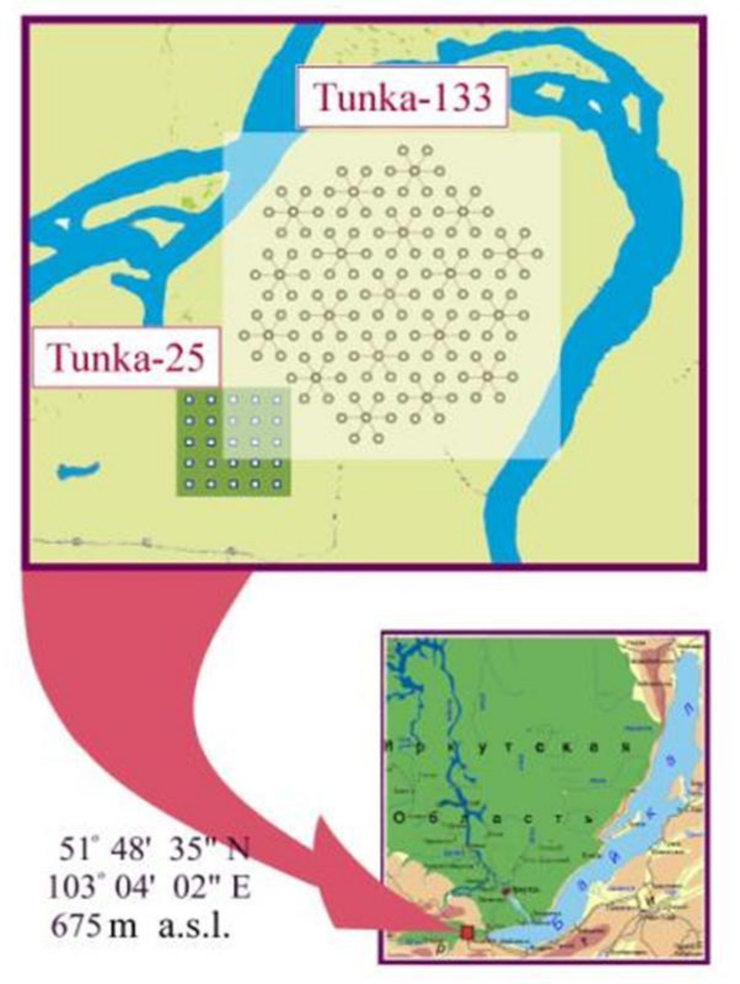
Cree XR7900 high power LED



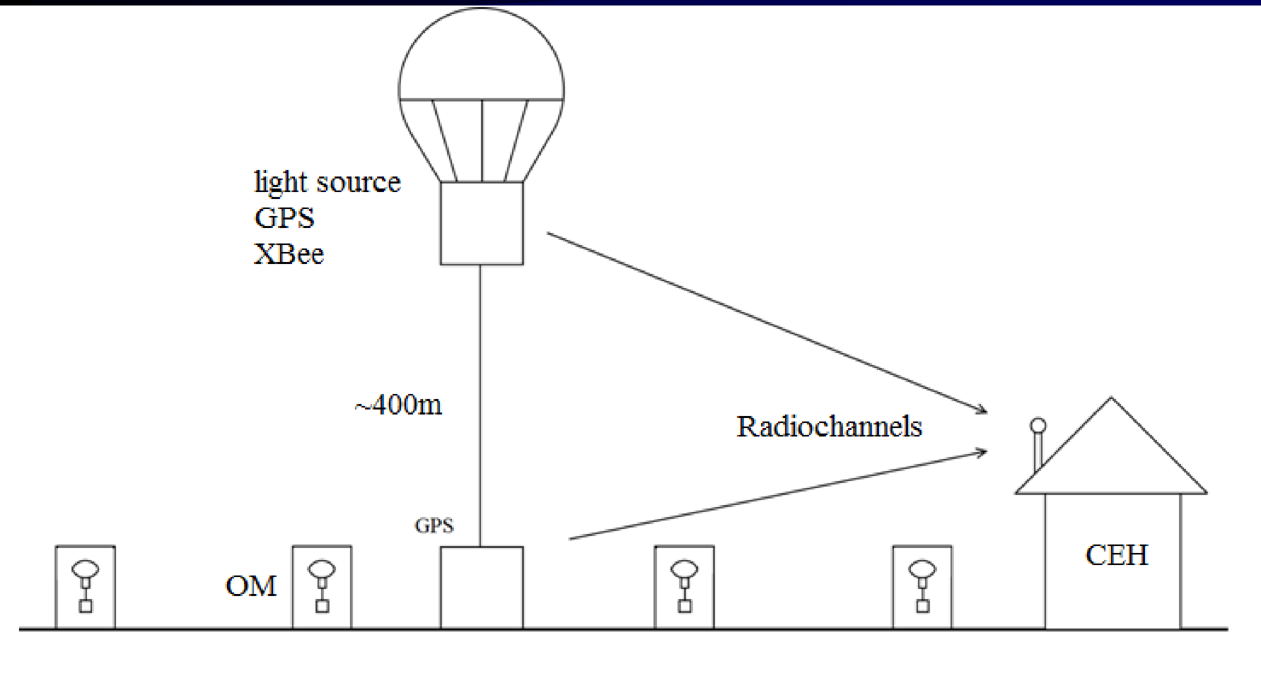


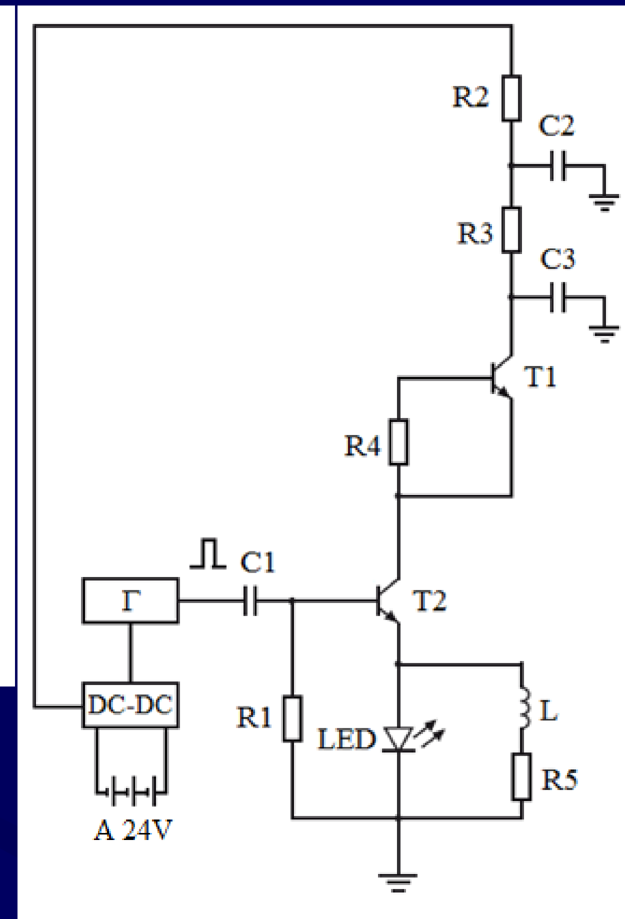
Royal Blue 10^{12} photons /pulse ~3 ns (FWHM)

TUNKA-133 1 km^2 EAS Cherenkov Array



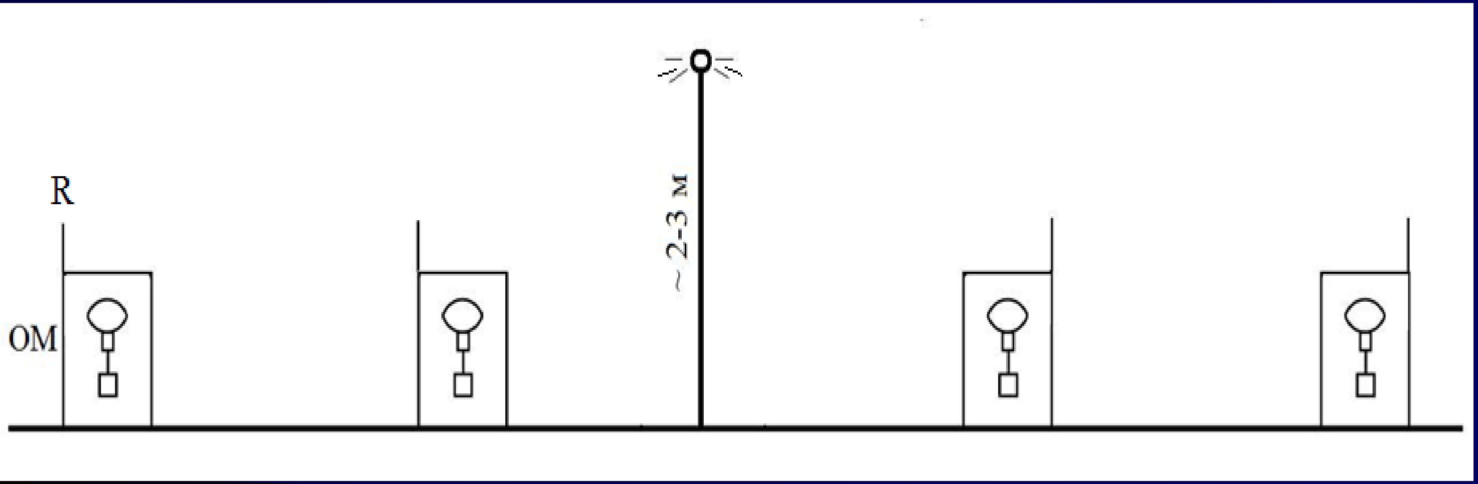
Balloon or pilotless helicopter or quadrocopter

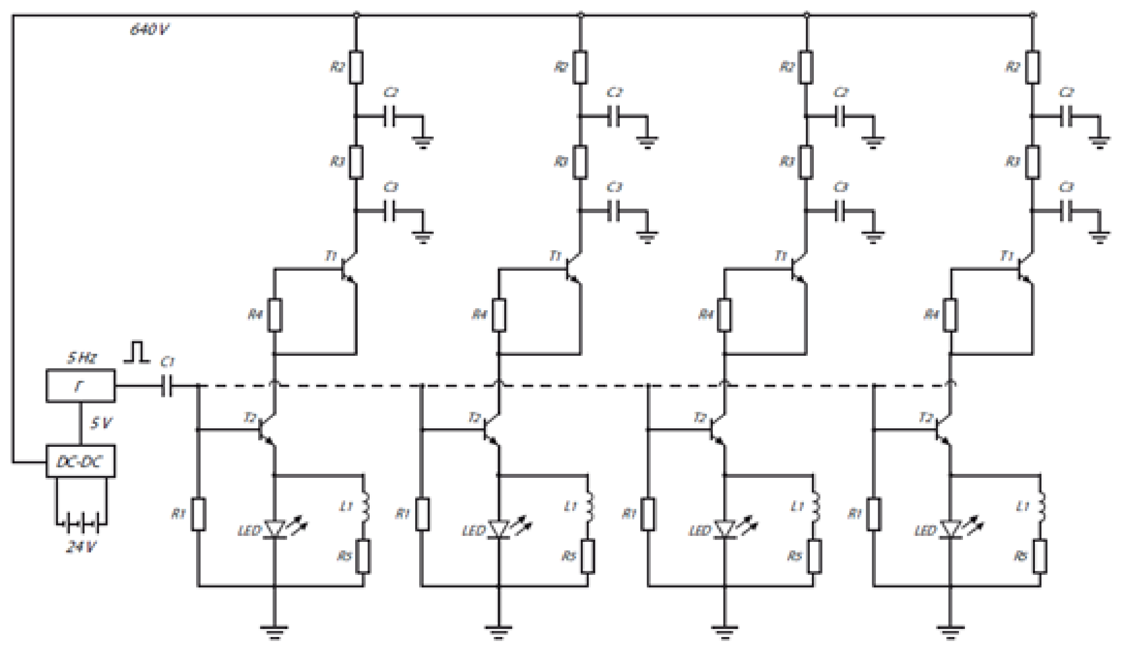




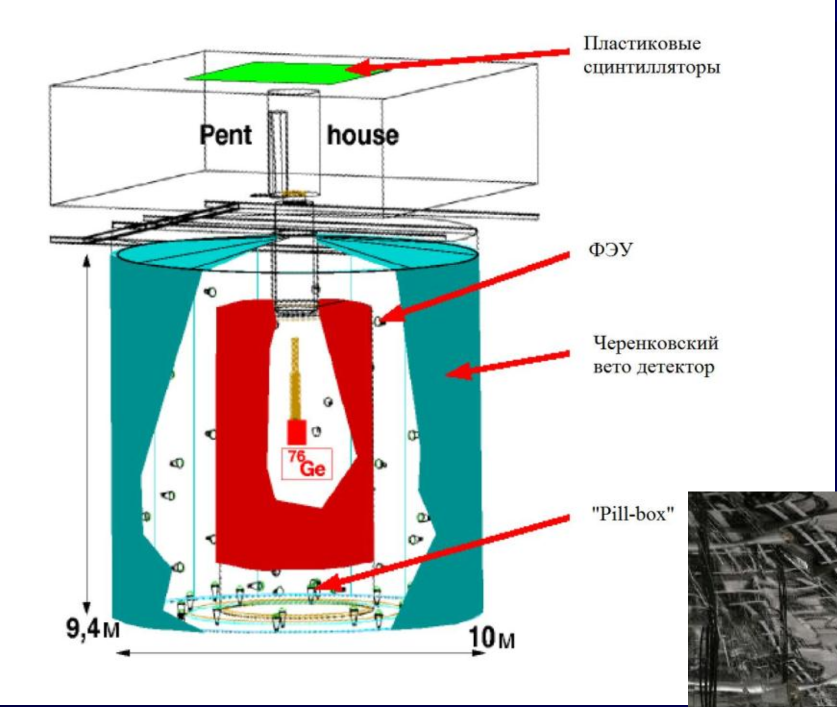
One high power LED to illuminate the whole array!

Pole + reflectors





GERDA



Пластиковые
сцинтилляторы
Pent house
ФЭУ
Черенковский
вето детектор
76Ge
"Pill-box"
9,4м
10м

1950-60s ELECTRONICS ----- NUCLEAR ELECTRONICS

1990-…… PHOTONICS ----- NUCLEAR PHOTONICS!

Photon sources (light sources in calibration systems – lasers, LEDs, scintillators)
Variety of DC or pulsed sources with : 0-10^{16} photons per pulse with 1ps – 10 ns width covering very wide spectrum.

Photon propagation and photon producing media (scintillators, light guides and optical fibres, photon radiators etc) λabs, λscatt

Photon detectors: different types and sizes (1mm – 0,5 m)

Electronics: preamps, amps, drivers, power supplies etc.

CONCLUSION

- Ultra bright blue LEDs give excellent opportunities to design powerful, fast light sources for calibration systems of astroparticle physics experiments based on Cherenkov and scintillation techniques
- Using matrixes of ultra bright blue LEDs it's possible to have light sources with 1-2 ns width (FWHM) and intensity of up to 10^{10} photons per pulse and even more, and with a cluster of matrixes - 10^{11} photons per pulse.

- New ultra high power blue LEDs allow to have light sources intensity of $\geq 10^{12}$ photons per pulse with a single LED but their emission kinetics relatively slow - ~3-6 ns (FWHM).
- Powerful light sources based on ultra bright blue LEDs have very high long-term stability abd very long life time.
- They are powerful, fast, stable, reliable, cheap and very simple in operation.
- They are in many respects very good competitor to laser systems.