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LED calibration system of the lake Baikal neutrino telescope NT-200+

B.K. Lubsandorzhiev, P.G. Pokhil, R.V. Poleshuk, B.A. Shaibonov, R.V. Vasiliev, Y.E. Vyatchin.
Institute for Nuclear Research RAS, pr-t 60-letiya Oktyabrya 7a, Moscow 117312,
Presenter: Y.E. Vyatchin. (lubsand@pcbai10.inr.ruhep.ru), rus-vyatchin-Y-abs1-OG27-oral

We present a description of a system developed for calibration of NT-200+ neutrino telescope which started operate at the lake Baikal last spring. The system based on nanosecond LED light sources. Some characteristics of the system are described.

1. Introduction

The lake Baikal neutrino telescope NT-200 has been operating since April 1998 [1]. Presently an upgrade of NT-200 neutrino telescope is underway [2]. The upgrade is aimed at an increasing the effective volume of the experiment for high energy neutrinos to the scale of more than 10^7 tons. The upgrade is implemented by adding three sparsely instrumented distant outer strings to the existing NT-200 telescope, fig.1 (left). Each outer string is arranged at 100 m apart from the core of NT-200 which is remained untouched. To synchronize the outer strings with NT-200 we have developed LED calibration system.

2. LED calibration system

The LED calibration system consists of four deep underwater nanosecond light sources fixed at each outer string of NT-200+ and one of peripheral strings of NT-200 above optical modules of strings (blue circles in fig.1). All light sources are triggered simultaneously from one electronic unit arranged in deep underwater module and fixed at one outer string at distance of ~1 km. In fig.1 (left) this module is depicted by red circle. Each light source module is connected with triggering module by 1.2 km long coaxial cable. The time jitter of triggering pulses after passing of 1.2 km long coaxial cables are less than 75 ps, see fig.1 (right bottom). Right upper part of the fig.1 shows the jitter measuring principle. All optical modules of outer strings are illuminated by light sources via plastic optical fibers of equal length. As for a peripheral string of NT-200 its optical modules are illuminated directly through water.

Deep underwater light sources modules (Light Beacons) have been developed especially for the lake Baikal neutrino experiments [3]. They are based on a matrix of ultra bright blue InGaN/GaN LEDs and an avalanche transistor driver. The electrical scheme of the driver is shown in fig.2 (left). The driver exploits avalanche breakdown of two consecutive avalanche transistors (FMMT415 produced by ZETEX) discharging small capacitor (27 pF). Five LEDs (NSPB500S produced by NICHIA CHEMICAL LTD) are switched in parallel into the transistors emitter circuit with a tail canceling RL filter. In fig.2 (right) the light emission kinetics of an individual LED from the matrix and of the whole matrix measured by fast PMT (XP2020) are shown. To measure light pulses shape of individual LED all other LEDs of the matrix were masked. One can see from the figure that the light pulses shapes of LEDs are very similar. The light pulse shape of the whole matrix is practically the same as for an individual LED. The light pulse width of an individual LED and of the whole matrix is 2.5 ns (fwhm). Better results were reached with a matrix incorporating a separate driver for each LED: light pulse width of 1.8 ns with higher light yield but for simplicity we chose the system presented here [6].

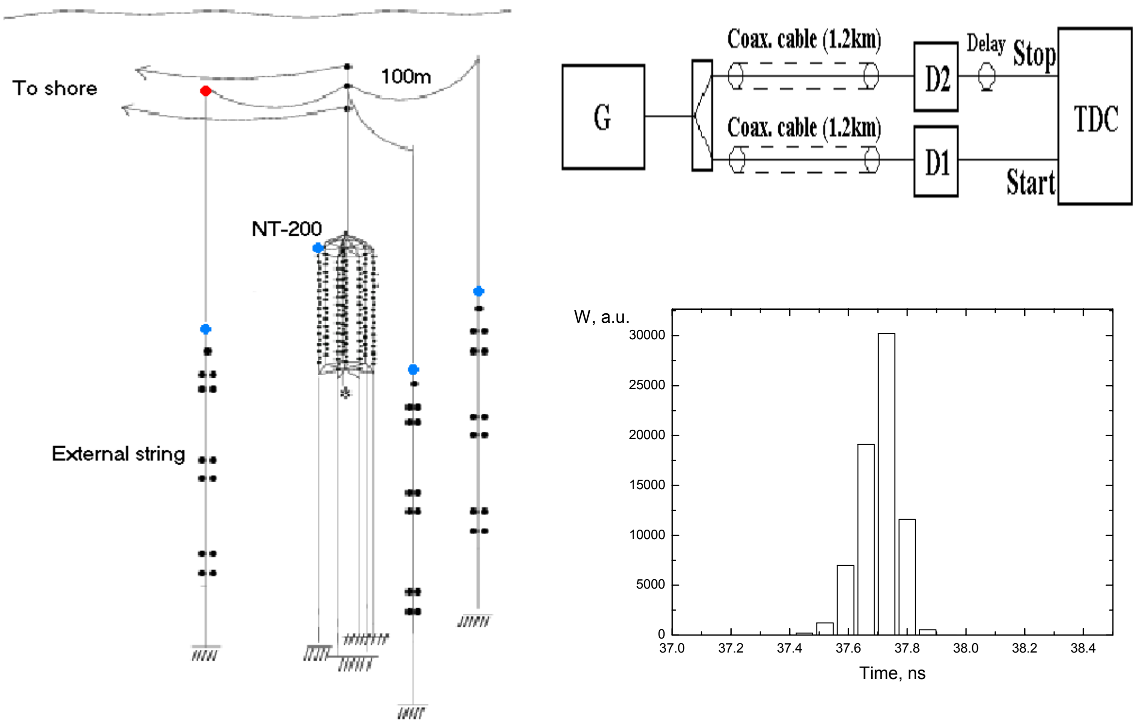

Figure 1. Left: Neutrino Telescope NT-200+. Blue circles – deep underwater light sources; red circle – module generating triggering pulses. Right: triggering signals jitter after 1.2 km cables (bottom) and its measuring principle (up).

There is a plethora of ultra bright blue LEDs in the market. Unfortunately not so many types of the LEDs demonstrate fast light emission kinetics. It was shown in [4] the "old" NICHIA LEDs are among the fastest LEDs. Extensive studies of the LEDs timing and light yield characteristics with the avalanche transistors drivers have been carried out in our group. The studies shows that the light yields of light sources based on such LEDs are about 10^9 photons per pulse with 1-2 ns pulse width. The long term stability is very high. The light yield and pulse width don't deteriorate even after 10^{10} of total pulses running through LEDs at current pules of 2 A. As for temperature stability the light yield changes by 7% in temperature range of $–3^0÷+45^0$C [5]. Although in case of neutrino experiments at the lake Baikal the temperature at the depth of ~1km is very stable. In table 1 we gathered data on some fastest ultra bright blue LEDs measured by us up to now. There are good alternatives to the "old" NICHIA and KINGBRIGHT LEDs: LDBK13633L6, YM-BV5S15N and GNL3014BC produced by LIGITEK, YolDal and G-nor companies correspondingly. The last one is very promising. To compare data of the "new" NICHIA and KINGBRIGHT LEDs are listed in the table too.

Deep underwater light source module, fig.3 left, consists of a standard NT-200 electronic crate including the matrix of LEDs with their driver, fast discriminator for triggering pulses, power supply and pressure housing to withstand high pressure at the depth of ~1 km. The matrix of LEDs and the driver are encapsulated into metallic screen to avoid cross-talks. In fig.3 right one can see one of the light source modules already fixed at NT-200+ cable and ready for final deployment. A bundle of plastic fibers attached to the light source module are clearly seen.

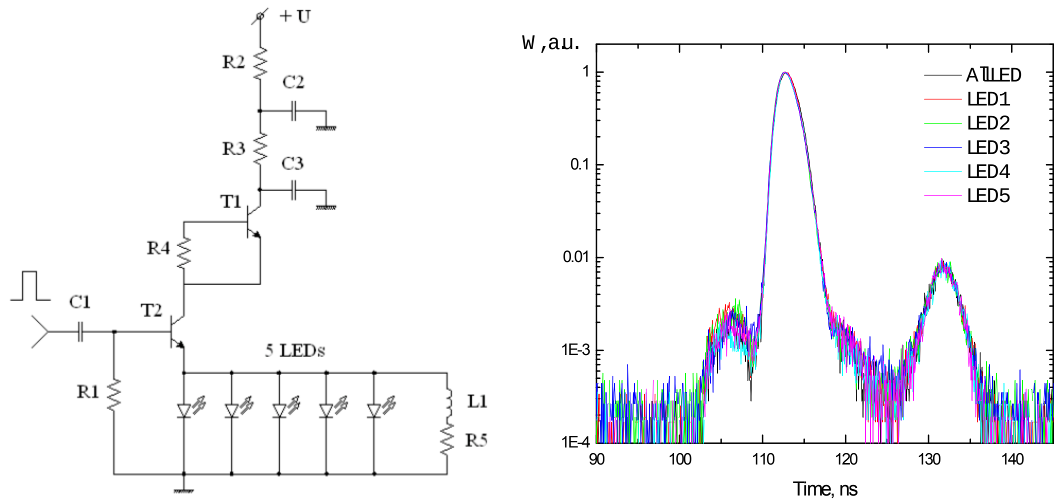

Figure 2. Left: Electrical scheme of LED driver. T1 and T2 – FMMT415; LEDs – NSPB500S; C3 – 27 pF. Right: Light pulses shapes of individual LEDs of the matrix and of the whole matrix.

Table 1.

LED Type	Light pulse width, ns	Light yield, a.u
NSPB500S (old)	1.8	1
L7113NBC (old)	2.0	0,5
NSPB500S (new)	4.5	2
L7113PBC (new)	4.5	1.4
BLBB43V1	2.1	1.3
LDBK13633L6	2.1	1.5
YM-BV5S15N	2.0	2.1
GNL3014BC	1.6	2.0
LBH3000	2.4	2.2

3. Conclusions

A system to calibrate distant outer strings of the lake Baikal neutrino experiment has been developed. A nanosecond time precision for outer strings synchronization with the central part of the array is reachable. There are possibilities to improve performances of the system: to increase light yield up to 10^{10} photons per pulse or higher to get faster light emission kinetics.

Figure 3. Left: Light source, electronics and pressure housing. Right: Light source module fixed at underwater cable ready for deployment. One can see optical fibers attached to the light source module. To avoid stray light the module is blackened.

4. Acknowledgements

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