# **Study of the energy resolution and non-proportional light response of the CsI:Tl scintillator based on digital spectrometry**

# **Abstract**

Presented research considers a problem of improvement of the energy resolution and other spectrometry parameters of alkali halides scintillation materials using analysis of a scintillation light pulse shapes. Experimental research on light response of CsI:Tl and other crystals that was performed in the last 30 years, have shown that spectrometry parameters of this crystal are strongly influenced by existence of so called slow scintillation components. The parameters could be improved by  
the increase of peaking time during light detection procedure.

In this study author analysed and discussed the non-proportionality, number of photoelectrons and energy resolution (with their contributions to intrinsic, statistical and noise resolution) as  
a function of light pulse time response. The study was performed using three methods.

In the first one a classic analogue spectrometry equipment was used to check the CsI:Tl light response as a dependence of thallium doping, temperature, excitation energy, and integration time. The CsI:Tl crystals with thallium concentrations of 0.0012wt%–0.13wt% were tested in temperature range from 30C to -70C and X-ray and gamma-ray radiation sources with energies from 17 keV to 835 keV. The data was processed with peaking time from 4 s to 20 s. The second method registered the averaged light pulses directly from the photomultiplier. The 500 µs raw pulses from the region of full energy peaks were chosen by analogue NIM modules, but the pulses averaging and saving were made with oscilloscope. The third technique was based on acquisition of raw single scintillation signals using a high class digital oscilloscope and off-line analysis of collected data. In this case, raw pulses were registered with the base time equal 150 µs.

The analysis carried out in the thesis showed a change in the shapes of light pulses with temperature. It has been shown that cooling the crystals from 30C to -70C results in scintillation decay times prolongation. A significant improvement of the non-proportional light response of the CsI:Tl scintillator was observed with the increase of the integration time, even up to 500 µs, which suggested the possibility of energy resolution improvement at the same integration times. However, precise measurements of the energy resolution, possible with single scintillation pulses, with  
an integration time range up to 150 µs and for a wide range of gamma quanta energies showed opposite observation. After the initial improvement in the energy resolution for the integration time reaching about 34 µs (the limit of integration with the analogue method), there was a significant deterioration of the energy resolution despite the improvement of non-proportionality (energy resolution corrected for the electronic noise contribution and the statistical contribution of  
the photoelectron number). The possibility of spectrometry parameters improvement with the integration time prolongation was correlated with the analysis of the total light pulse described by three exponential components of CsI:Tl reaching 30 µs at room temperature (total number of photons for each component). In turn, it was assumed that the prolongation of the light pulse integration time above the value of third component decay time, to the area of so-called afterglow, may deteriorate the energy resolution.

It has been shown that the best energy resolution values are achieved when the integration time of a single light pulse is dynamically adjusted to the energy deposited in the crystal. As the shape of the light pulse depends on the radiation energy absorbed in the scintillator. Similarly, the optimal values of other spectrometry parameters seem to improve, when the constant integration time values will be replace with dynamic values determined by the height and duration time of scintillation pulses.