R&D of new, fast scintillators is a very topical problem due to the demanding new applications in the medical, security and scientific fields. Fast scintillators emitting in VUV spectral region can be coupled with position-sensitive detectors filled with photo-sensitive gases or with other VUV-sensitive detectors and used in special imaging techniques. Wide band-gap fluorides are the best single crystal host for this purpose, and the Nd$^{3+}$ ion provides fast 5d–4f emission around 180–190 nm in the host lattices like LaF$_3$, LiYF$_4$, LuLiF$_4$, BaY$_2$F$_8$ and others, while the oxide hosts are not suitable for this purpose due to the overlap of the lowest lying 5d levels with the 4f ones [1]. Due to low energy yield of single Nd$^{3+}$-doped crystals the codoping with other rare earth (RE) ions, namely Er$^{3+}$ or Tm$^{3+}$, has been recently studied as a tool to improve energy transfer from the host to Nd$^{3+}$ emission centers and to consequently increase the light yield [2,3].

The aim of this paper is to study doubly (Nd$^{3+}$, Gd$^{3+}$) doped LuLiF$_4$ single crystals. This host was chosen due to the elevated density of 6.17 g.cm$^{-3}$ and easy crystal growth enabled by its congruent melting [4]. The Nd$^{3+}$ and (Nd$^{3+}$, Gd$^{3+}$) doped LuLiF$_4$ and GdLiF$_4$ samples were prepared in Tokuyama Co. by micro-pulling-down technique [5] in the form of rods a few cm long with a diameter of about 2 mm from which the polished plates 2x8x1 mm in size were prepared for the experiments. Their absorption and emission spectra were measured, and observed peaks in the VUV-UV-visible region were ascribed to the 5d-4f and 4f-4f optical transitions of the doped RE ions. Concentration dependences of emission spectra and decays will be discussed. Decay kinetics of 4f-4f transitions of Gd$^{3+}$ and energy transfer between Nd$^{3+}$ and Gd$^{3+}$ energy levels was also investigated.

The dependence of photoluminescence and radioluminescence intensity of the doubly doped samples are presented in Fig. 1 and 2. The most intense PL and RL are observed for Nd 1% Gd 4% sample. There is an overlap of Nd$^{3+}$ emission and Gd$^{3+}$ absorption band around 185 nm. It is obvious that the increasing concentration of Gd$^{3+}$ reduces the Nd$^{3+}$ luminescence due to energy transfer from Nd$^{3+}$ to Gd$^{3+}$ centers. At the same time, the highest scintillation efficiency of Nd1%
Gd4% sample points to the improved energy transfer to the 5d state of Nd$^{3+}$, which is due to Gd presence in the sample.

PL decay was measured for several exc/em combinations: under the direct excitation of Nd$^{3+}$ the fast 5d–4f emission usually shows a single exponential decay and a decay time around 19 ns (Fig. 3). When the same emission is excited via the host band edge at 120 nm Fig. 4, the decay shows a rising part with the rise time of about 7 ns and decay time of 20 ns.

The rise time presence points to fast energy transfer from the host to Nd$^{3+}$ centers. The energy transfer from the host is accelerated with increasing Gd concentration as the rise time is getting shorter. (0.4 ns for LuLiF$_4$:Nd 4%,Gd 10%). We studied also the characteristics of the dominant luminescent transition $^{6}P_x$–$^{8}S_{7/2}$ of the Gd$^{3+}$ at about 310–312 nm to monitor eventual concentration quenching phenomena in the Gd sublattice. The maximum efficiency of the Nd$^{3+}$ luminescence in the VUV region ($\lambda_{\text{exc}} = 185$ nm) is achieved for samples with Nd 1% concentration and Gd concentration between 1% and 4%. The highest concentration of Gd leads to energy transfer away from the Nd$^{3+}$ centers, and an increase of Nd content causes additional concentration quenching as well. Monitoring the decay characteristics of the dominant Gd$^{3+}$ emission line at 312 nm, a limited radiation trapping effect was observed with increasing Gd concentration which is evidenced by somewhat increasing Gd$^{3+}$ decay time.

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