Luminescence decay kinetics in fast scintillators

Luminescence decay studies are essential in order to get information on the structure and dynamics of molecular and nanosystems. Time-dependent properties of both excitation source and emission, generated from the object of studies, are analyzed in details in case of scintillators, transparent materials that generate short-time flashes of light when excited by ionizing radiation. In distinct objects, called fast scintillators, these flashes are fading in nanoseconds, which is extremely fast.

In the simplest cases, the luminescence decay curves are described by a sum of discrete exponentials. Time dependence of the luminescence intensity $I(t)$ could be written as:

$$I(t) = \sum_i I_0^{(i)} \exp\left(-t/t_0^{(i)}\right),$$

with $I_0^{(1)}, I_0^{(2)}, \ldots$ and $t_0^{(1)}, t_0^{(2)}, \ldots$ as decay parameters.

In general, an integral should be applied:

$$I(t) = \int_0^\infty H(k) \exp(-kt)\, \mathrm{d}k, \quad I(0) = 1.$$

$H(k)$ is the inverse Laplace transform of $I(t)$.

More on this: http://web.tecnico.ulisboa.pt/berberan/data/98.pdf

During measurements, a rapid impulse of X-ray radiation is being generated to irradiate the scintillator, which emits light. The time dependence of its intensity is being measured as the output signal (Fig. 1).

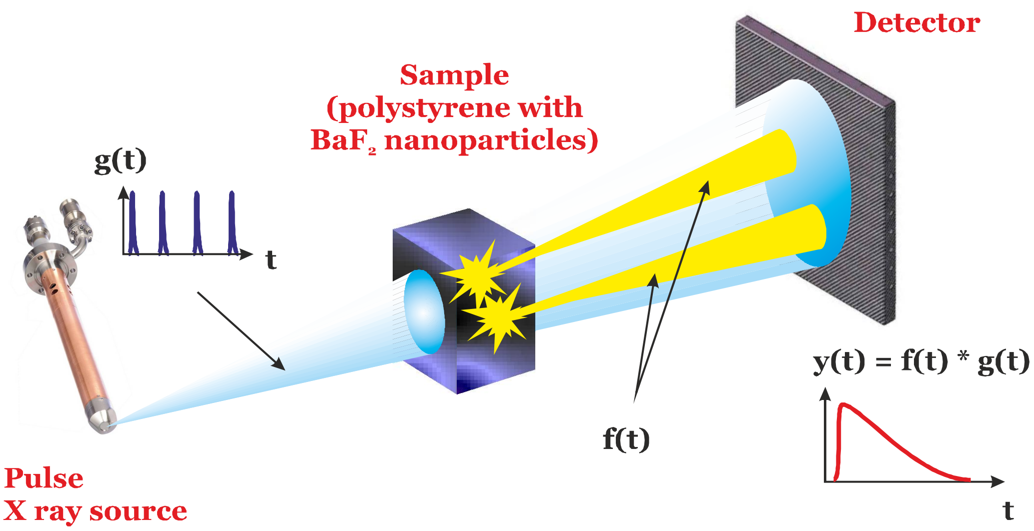

Fig. 1 – Measurements of decay kinetics in polystyrene:BaF_2 composite

In a typical scintillator (Fig. 2a), where decay times are relatively long while the excitation impulse is nearly delta-like, $I(t)$ might be applied to describe the output, which could be interpreted as “pure” decay kinetics in the scintillator.

In case of fast scintillators like BaF_2 (Fig. 2b), luminescence decay is of the same scale as the excitation impulse. Therefore, the output signal is composed of both decay and impulse.

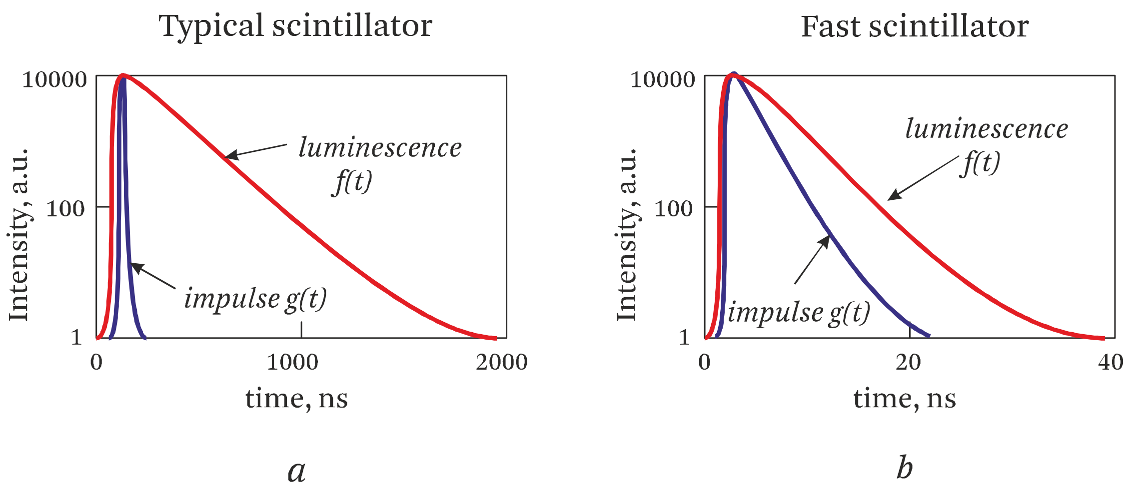

Fig. 2 – Decay curves of impulse and emitted luminescence in scintillators

In order to exclude excitation one has to evaluate convolution equation:

$$y(t) = f(t) * g(t),$$

where '*'-sign means convolution:

$$y(t) = \int_0^t f(\tau) g(t-\tau) d\tau .$$

Here $y(t)$ is the output (measured) signal, $g(t)$ - excitation impulse, $f(t) \equiv I(t)$ - unknown function of luminescence decay kinetics.

The objective of this assignment is to obtain the $f(t) \equiv I(t)$ curve and calculate decay parameters, given the data frame that includes 3 columns: time *t*, output *y* and excitation impulse *g*, measured for polystyrene:BaF_2 composite.

More about this material here: http://dx.doi.org/10.1063/1.4892112

Based on the results from these studies, it is reasonable to use the simplest model with only one exponent:

$$f(t) = I_0 \exp(-t/t_0).$$

Therefore, the only decay parameter to be calculated is decay kinetic constant t_0.