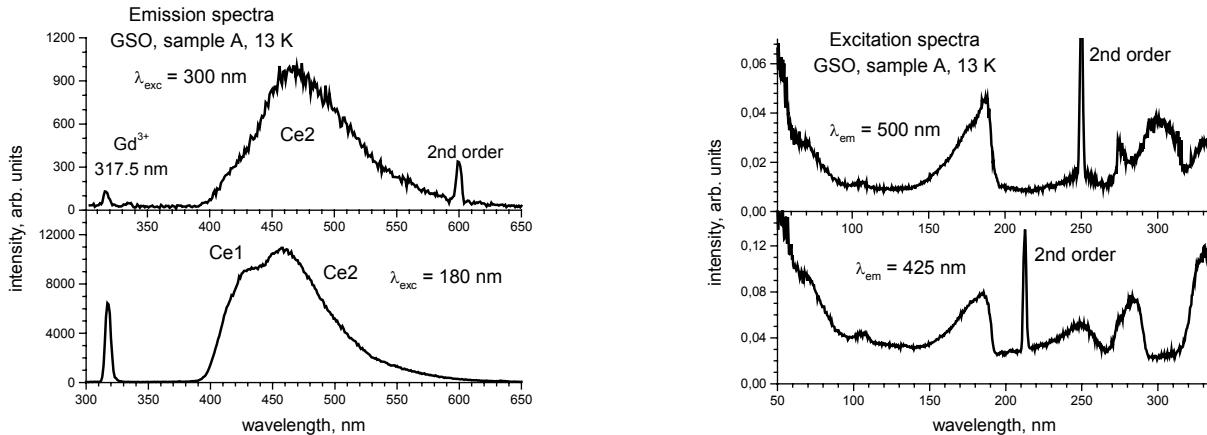


# VUV studies of energy transfer processes in GSO:Ce

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Cerium activated gadolinium oxyorthosilicate ( $\text{Gd}_2\text{SiO}_5:\text{Ce}$ , GSO:Ce) is a well known commercial scintillator material discovered more than two decades ago [1]. The scintillation properties of this material have been studied and described in a number of subsequent papers (see e.g. [2,3]). Also the mechanism of scintillation light production in GSO has been studied extensively [4]. Interestingly, however, we note that almost all of the previous spectroscopic studies of GSO involved no VUV excitation wavelengths as these are not readily available. Nevertheless there are clearly energy transfer processes involving excitons, traps, and uncontrolled defects producing effects such as slow components, room temperature afterglow and so-called “host” emissions that can be studied using VUV range of excitation wavelengths. In this report we present preliminary results of VUV studies of the pixel samples of GSO ( $2\text{x}2\text{x}8\text{ mm}$ ), performed at the Superlumi station of Hasylab at DESY and aiming at revealing and characterizing the various host-to-ion (indirect) energy transfer channels that are active in GSO. In particular it is interesting to reveal and clarify the role of Gd and Ce ions in two different crystallographic sites that are typical of the oxyorthosilicate host lattice.



*Figure 1: Uncorrected integrated emission spectra (resolution 5.4 nm, step 1 nm) of Ce-doped GSO crystal at 13 K. The excitation wavelengths were selected to demonstrate various features observed in the spectra, as indicated in figure.*

*Figure 2: Corrected (sodium salicylate standard) integrated excitation spectra (resolution 0.32 nm) of Ce-doped GSO crystal at 13 K. The emission wavelengths were selected to maximize contribution from Ce1 site (lower panel) and Ce2 site (upper panel).*

In Fig. 1 we show the “integrated” emission spectra of GSO:Ce under 300 nm (upper panel) and 180 nm (lower panel) excitation wavelengths. The “integrated” spectra, unlike “time-gated” spectra, to be shown later, have been measured with the signal accumulated during the time between the consecutive synchrotron pulses (192 ns). The 300 nm excitation was selected to enhance the contribution of the Ce ions in the second site (Ce2). The deep VUV excitation at 80 nm, mimicking X-ray or gamma excitations, produces the spectrum (not shown) very similar to the spectrum obtained under the 180 nm excitation (bandgap peak, excitonic contributions) although there are some differences (less Gd emission at 317.5 nm, slightly more contribution of Ce1 at 425 nm).

In Fig. 2 we present the “integrated” excitation spectra of GSO:Ce. The emission monochromator was set at 425 nm and 500 nm to maximize contributions from the Ce1 and Ce2 sites, respectively. While the VUV response of both centers is good (indicating that both centers are good recombination centers for free e-h pairs) there are clearly differences in the near UV, presumably because of the UV shift of the Ce1 site  $f-d$  absorption band. Clearly, the 300 nm excitation wavelength is the best choice to maximize the contribution of the Ce2 site and, at the same time, minimize the contribution of the Ce1 site. Note the group of sharp

lines in the Ce2 spectrum at 270 to 280 nm. These lines, most likely due to transitions to the  $^6I$  term of the Gd $^{3+}$  ion, are conspicuously absent in the “integrated” spectrum of the Ce1 site.

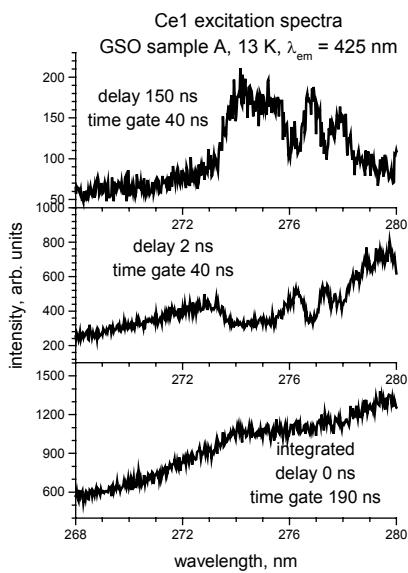


Figure 3: Uncorrected, high resolution “integrated” and “time-gated” excitation spectra of the Ce1 emission from GSO:Ce. The delay and time gate values are indicated in the figure. The resolution was 0.32 nm and step 0.03 nm. Temperature was 13 K.

In Fig. 3 we present three excitation spectra of the Ce1 emission in GSO:Ce. The “time gated” spectra were measured within a 40 ns time window triggered by a synchrotron pulse with almost no delay, 2 ns (to minimize scattered synchrotron light) or 150 ns delay to record fast and slow components, respectively.

The fine features observed in the spectra shown in Fig. 3 take a form of sharp lines or “dents” at about 274.2, 275.3, 276.8 and 277.8 nm. Clearly, all these features can be associated with the Gd $f-f$  transitions starting at  $^8S_{7/2}$  and terminating at various levels of the  $^6I$  term of the Gd $^{3+}$  ion [5,6]. The similar observations were reported before in the case of (Lu,Gd)AP [7]. The appearance of the Gd-related features in the excitation spectra of Ce-emission in

(Lu,Gd)AP:Ce (lines and dents) have been explained by assuming that energy absorbed by Gd $^{3+}$  ions is transferred, with some delay, to Ce $^{3+}$  ions [7]. For excitation wavelengths, for which direct Ce $^{3+}$  excitation is efficient (270 to 280 nm), Gd $^{3+}$  ions compete with Ce $^{3+}$  ions changing the distribution of intensity between slower and faster components in the time profiles of the Ce $^{3+}$  emission. In the short (40 ns) time window this process effectively lowers the intensity of the Ce $^{3+}$  emission (hence “dents” in the “time gated” spectrum). Since almost no “dents” are observed in the “integrated” spectrum we conclude that delay introduced by Gd $^{3+}$  ions should be between 40 and 150 ns and that efficiency of the Gd-Ce transfer must be very high.

It is interesting to note that in (Lu,Gd)AP:Ce, known to feature only one site populated by Ce ions, there are two lines that have been associated with the  $^6I$  term, at 277.8 nm and at 275 nm. Clearly, the set of four lines, identified in GSO, must be related to two different sites identified in GSO and other orthosilicates. Gd ions in both sites despite differences, take part in processes of energy transfer in GSO activated by Ce $^{3+}$  ions.

We have also measured a number of time profiles of Ce emissions in GSO. The Ce1 emission time profiles differ significantly under direct Gd excitation into one of the  $^6I$  Gd $^{3+}$  features (274.2 nm) and directly into the excitation band of Ce $^{3+}$  (283 nm) despite relatively small change in excitation wavelength. This observations prove that under selective excitation into Gd features, reported in this communication, energy is transferred from the Gd sublattice to Ce ions in GSO.

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