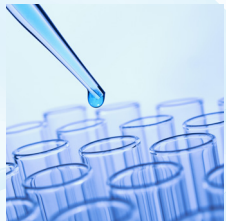
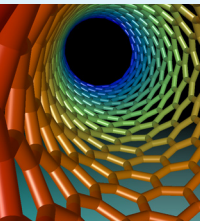
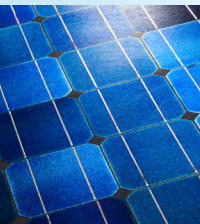


Upconversion of Lanthanide-containing glasses using DD-980L excitation TRFA-16

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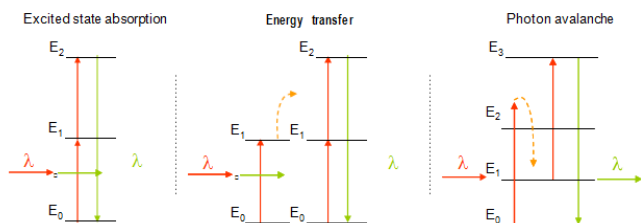


HORIBA's DeltaFlex system is perfect for photovoltaics and lanthanide-doped glass applications

The phenomenon of upconversion is an optical process that takes in lower energy (longer wavelength) photons and emits higher energy (shorter wavelength) photons. It relies on the presence of multiple long lived metastable states, which can be found in lanthanide materials. The use of the upconversion phenomenon encompasses bioimaging, where the longer wavelength excitation is advantageous, to photovoltaics, where it can be used to enhance collection efficiency. In this note emission from lanthanide containing glasses in the visible wavelength range is studied upon excitation in the near infrared (NIR) using a DeltaDiode laser (DD-980L) on a DeltaFlex system. The DeltaDiode sources with sub-nanosecond pulse widths are used in a new way to detect longer lifetimes such as microsecond to milliseconds, as found in upconverting materials such as photovoltaics and lanthanide-doped glasses.

The upconversion process

The upconversion process relies on the absorption of at least two sequential, spatially coincident, excitation photons. Principal mechanisms include excited state absorption (ESA), energy transfer upconversion (ETU) and photon avalanche (PA), which are shown in a very simplified form below.



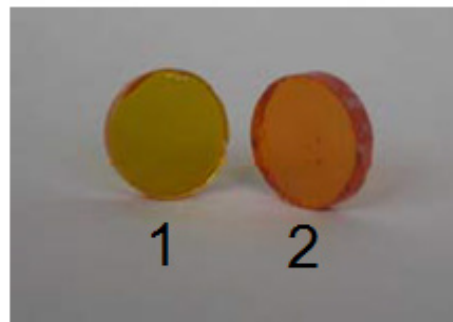
These mechanisms can act alone or in concert and there is also the possibility to have cooperative upconversion

(CUC), which is ETU like, but distinguished by second order electronic transitions, and energy migration upconversion (EMU), where long lived metastable states are not a prerequisite. There are many works in the literature reviewing this interesting phenomenon and hence only the briefest summary is given here.

Upconversion can be observed with great efficiency in the rare earth elements because of their long-lived excited states and the energy level structure of these materials which are favorable for a two-photon process.

Experimental

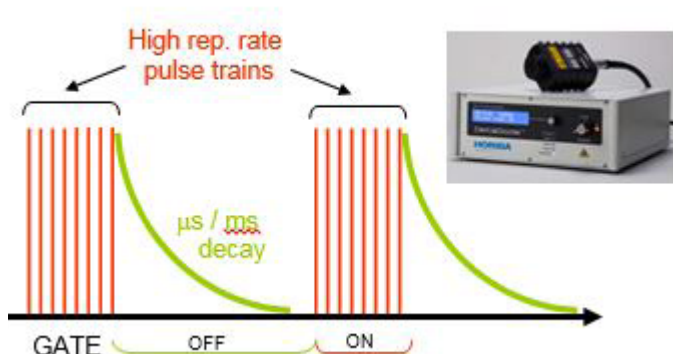
In this work we measure both the steady state fluorescence spectrum and the time-resolved emission from two erbium containing glasses of slightly differing matrix composition of silver, gallium and germanium sulphide.



Glass samples (1 & 2) used in this upconversion study

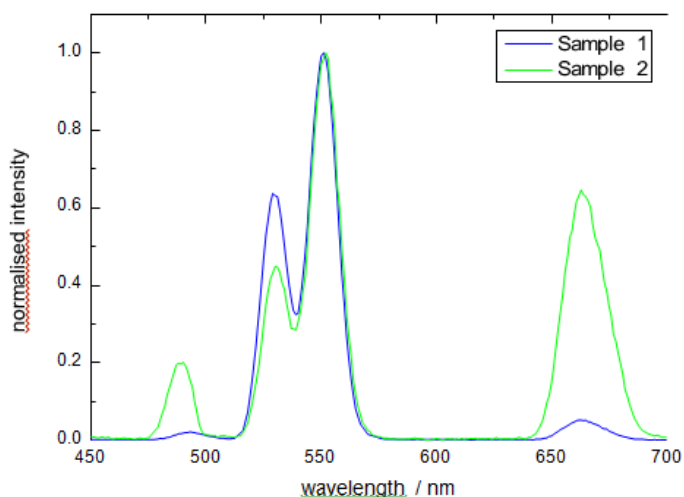
The measurements were made using a DeltaFlex lifetime system in front face geometry and with a DeltaDiode laser (DD-980L) as the excitation source. Since the time scale for the decay process can be in the order of μs to ms the laser is operated in "burst mode". This involves gating of the highest repetition rate of the laser and is performed automatically by the control software with an additional

connection between the “trig out” on the *DeltaHub* and “fast gate” input on the *DeltaDiode* controller. Because of the time scale, to the sample, the pulse train appears like a single high intensity pulse and data can be simply analyzed using a tail fit. i.e. fitting without the need for reconvolution from the point the pulse train is gated off (see below).



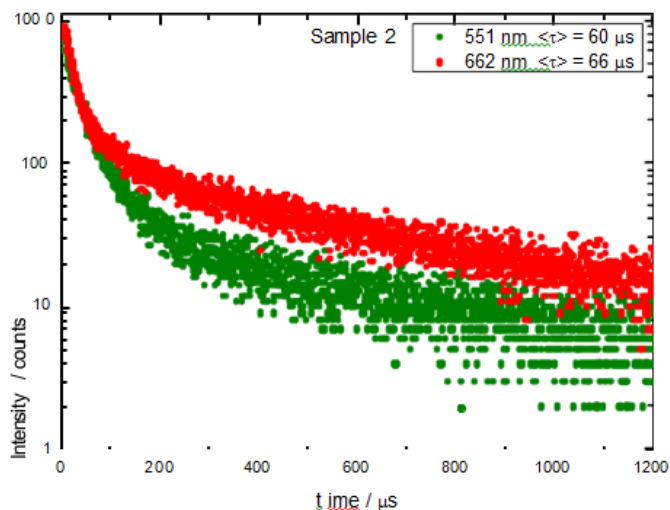
Results

The steady state spectra (below) show the influence of the host matrix. There is a clear difference in the bands at 488 nm and 662 nm. These data were recorded using the *DeltaFlex* in steady-state mode with the DD-980L.



Lifetime measurements of the luminescence emission at 551 nm and 662 nm were performed and the decays found to be multiexponential. However, similar lifetime values were obtained with both samples, with average lifetimes of 65 μs and 60 μs returned for Samples 1 and 2 respectively at 551 nm. Example decays, in this case obtained for Sample 2 are shown below.

When fitting to a bi-exponential decay model a longer-lived ($\sim 330 \mu\text{s}$) decay component was found for both samples, while the dominant component was much shorter-lived (37 μs and 22 μs for Sample 1 and 2 respectively). This is indicative that the upconversion processes involved in both samples are similar, but the matrix influences their relative contributions.



Conclusion

The results obtained show that by making use of the *DeltaFlex* system with *DeltaDiode* laser excitation (DD-980L) in the near infrared it is possible to obtain both spectral and lifetime upconversion measurements. The DD-980L was operated in “burst” mode, automatically controlled by software, to obtain lifetimes on the microsecond timescale.