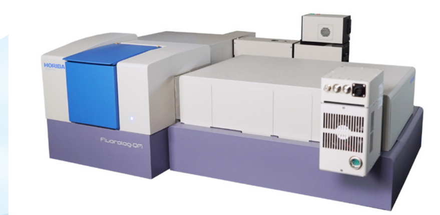
HORIBA

Fluorescence

Time-Resolved Electroluminescence with Fluorolog-QM



Technical Note

Fluorolog-QM
FL-2024-11-25

Introduction

Electroluminescence is a phenomenon of direct conversion of electrical energy into photons. The process involves a radiative recombination of holes and electrons injected into the material as a result of externally applied electrical bias. The most common electroluminescence materials are inorganic semiconductors, typically Group III and V elements, such as GaAs, as well as organic semiconductors (OLEDs). Applications of electroluminescence are numerous, most commonly the phenomenon is used in lighting and display devices. Electroluminescent materials are preferred for their low energy consumption, long life, and broad color emission range. Electroluminescence-based devices, such as light-emitting diodes (LEDs and OLEDs) are rapidly making their way into medical, industrial, and environmental applications.

With growing applications, there is an increasing demand for instrumentation capable of characterizing electroluminescent materials. Such characterization may involve measuring EL emission spectra and intensities as a function of applied DC voltage and current, as well as applying electrical pulses to measure the EL time response.

Typically, a basic photoluminescence spectrophotometer would require additional devices and components, such as an electrical power source, pulse generator, and time-resolved detection electronics to be able to perform EL measurements. In this Technical Note, we describe and illustrate the Fluorolog-QM ability to perform some of such measurements using its basic photoluminescence setup, without the need to employ any additional electrical devices.

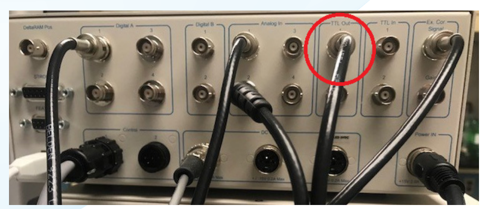
Materials and Methods

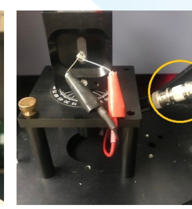
EL samples used in the tests were composed of a 495nm LED with different luminescent materials placed in front of it to demonstrate the instrument's operation in two different lifetime ranges.

Microsecond-Millisecond TREL with ASOC-10

The time-resolved EL (TREL) capabilities of the Fluorolog-QM are provided by advanced features of Felix FL software and the standard instrument interface (ASOC-10), which include output trigger pulses with software-controlled repetition rate and duration combined with a transient digitizer function of the 1 MHz interface board. This basic setup enables TREL decay measurements from microseconds to hundreds of milliseconds.

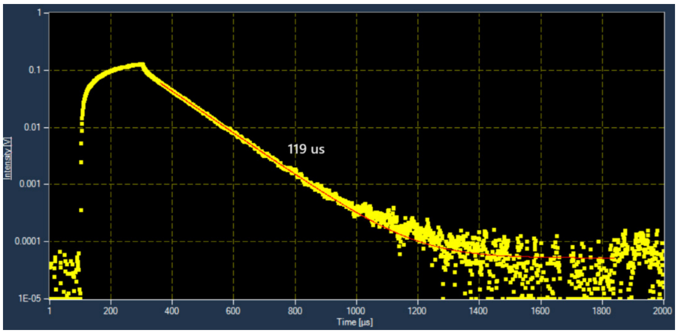
To configure the above setup, the following steps should be taken:





1. Connect one end of a BNC-BNC cable to TTL OUT 1 on the back panel of ASOC-10 interface and the other end to the sample input connector
2. Initialize the Phosphorescence (SSTD) hardware configuration in Felix FL
3. In the Setup select Phosphorescence Decay and Acquisition Settings.
4. Enter experimental parameters: emission wavelength, emission bandpass, start and end of the time range, electric pulse repetition rate (Lamp Frequency), number of electric pulses (Shots) and electric pulse width (Trigger Width, μs)

5. Start the acquisition and record EL decay



EL decay of sample 1 resulting in a lifetime of 119 µs

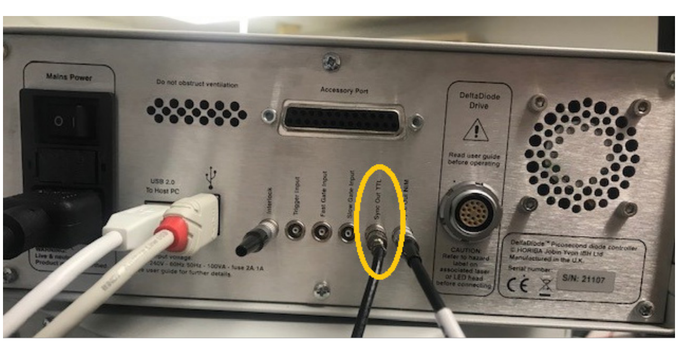
It should be noted that this type of EL decay measurement utilizes the principle of the Single-Shot Transient Digitizer (SSTD) technique, in which the original optical pulse has been replaced with an electrical pulse. By the nature of this technique, each electrical pulse generates a complete decay, therefore the acquisition is very rapid. The EL decay of sample 1 in Fig. 1 accumulated 500 single-pulse decays at a repetition rate of 500 Hz and the complete experiment lasted just 1 s.

TCSPC/MCS Based TREL

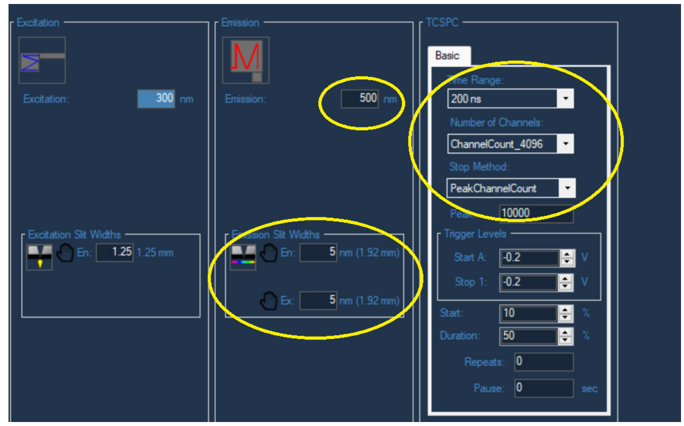
The Fluorolog-QM TREL capability can be further expanded to EL lifetimes ranging from a few nanoseconds to seconds with the HORIBA's TCSPC/MCS lifetime option comprising the DeltaHub electronics and DeltaDiode controller. The short EL lifetime range (ns – µs) is realized with the TCSPC function, while the longer range (µs – s) uses the MCS mode of the DeltaHub electronics.

To configure TCSPC-based TREL for short lifetimes, the following steps should be taken:

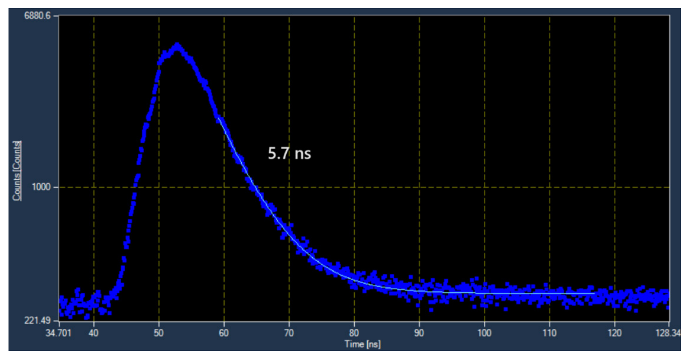
1. Set up the instrument and Felix FL for the standard TCSPC operation with the DeltaDiode selected as the source (a physical DeltaDiode is not required in the system).
2. Use a single-pin LEMO to BNC cable and connect the LEMO end to the Sync Out TTL output of the DeltaDiode controller. Attach the BNC end to the sample input connector



3. Initialize the TCSPC/DeltaDiode hardware configuration
4. In Setup select Decay and Acquisition Settings.
5. Enter experimental parameters: emission wavelength, emission bandpass, time range (valid range for this mode is between 100 ns and 100 µs), channel count and stop method



6. Start the acquisition and record the EL decay



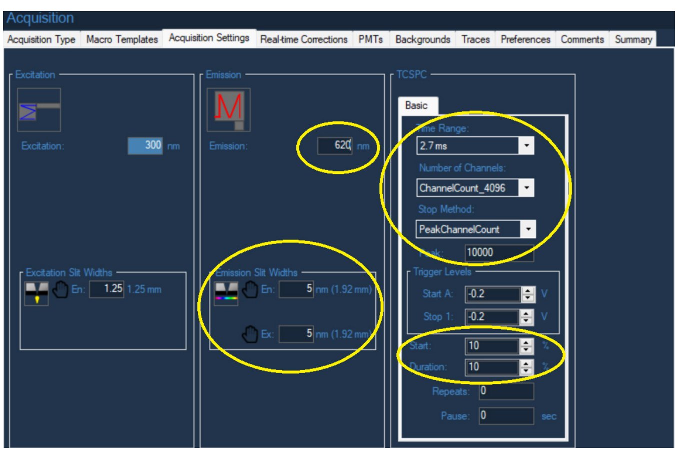
TCSPC EL decay of sample2 resulting in a lifetimes of 5.7 ns

In this method, the EL signal is generated by a short TTL pulse with a fixed duration of about 10-15 ns. The nature of the measurement does not allow for easy determination of the instrument response function (IRF). Because of that, with no reconvolution capability due to the lack of IRF, the 'tail fit' method has been used for the decay data analysis, which limits the shortest measurable lifetime to a few ns (Figure 2). For sub-nanosecond EL lifetimes, an IRF function would have to be determined. Potentially, this can be done by using an EL sample with a very short luminescent response to an electrical pulse.

To configure MCS-based TREL for longer lifetimes, the following steps should be taken:

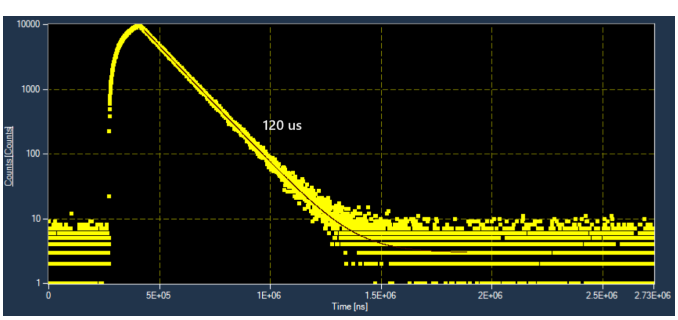
1. Set up the instrument and Felix FL for the standard TCSPC operation with the SpectraLED selected as the source (actual SpectraLED is not required in the system).
2. Use a 4-pin LEMO to BNC cable and connect the LEMO end to the SpectraLED output of the DeltaHub. Attach the BNC end to the sample input connector

3. Initialize the TCSPC/SpectraLED hardware configuration
4. In Setup select Decay and Acquisition Settings.
5. Enter experimental parameters, such as an emission wavelength, emission bandpass, time range (valid range for this mode is between 340 µs and 11 s), channel count, stop method, pulse start (% of the time range), and pulse duration (% of the time range)



MCS EL decay of sample1 resulting in a lifetime of 120 µs

6. • Start the acquisition and record the EL decay



The main advantage of MCS-EL over SSTD-EL is the ability to extend EL lifetime range to seconds. Due to photon counting statistics limitation on the photon count rate, the acquisition with the MCS usually takes more time than with the SSTD setup. It took about 30 s to acquire the EL decay in Figure 3, while only 1 s for the same sample using the SSTD method, with both methods returning virtually the same lifetime.

Steady-State EL

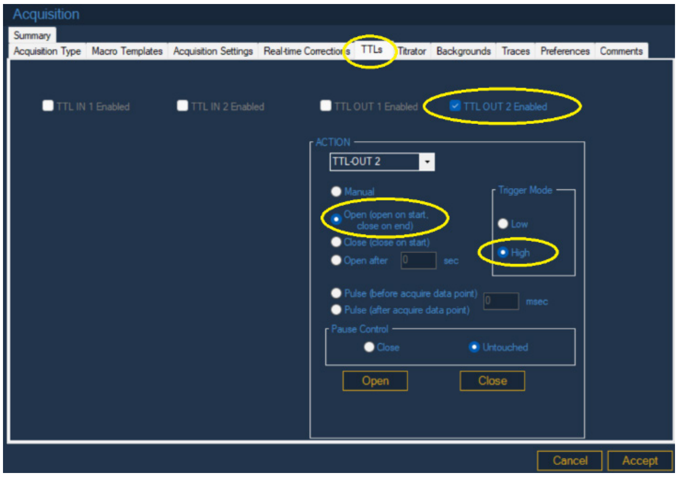
Advanced steady-state EL measurements usually require a dedicated power source with variable voltage and current outputs. The Fluorolog-QM can be configured and interfaced with such devices. However, the Fluorolog-QM standard interface and Felix FL have a TTL functionality that can be set up to output a constant voltage, which will enable the instrument to induce electroluminescence for spectral steady state acquisition. This feature will allow the user to perform basic emission characterization of EL samples.

To configure Steady-State EL, the following steps should be taken:

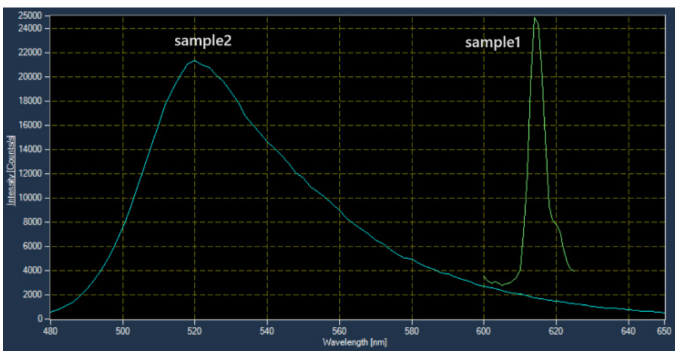
1. Set up the instrument and Felix FL for the standard steady-state operation
2. Use a BNC-to-BNC cable and connect one end to the TTL Out2 output on the ASOC-10 interface

3. Attach the other BNC end to the sample
4. Open hardware configuration for Steady State. Hover the mouse over TTL-OUT 2 section, right click and check Active

5. Save the hardware configuration with a new name and initialize the instrument
6. Click on Setup and select Emission Scan
7. Click on Acquisition Settings and enter scan parameters, such as excitation wavelength, emission range, bandpass, integration and step size
8. Click on TTLs tab and check the following boxes: TTL OUT2 Enabled, Open (open on start, close on end) and Trigger Mode High.



9. Save the acquisition and click Accept
10. Click on Acquire to start EL spectrum acquisition



EL-induced steady state emission spectra of sample1 and sample2

Conclusion

The highly modular and multi-functional Fluorolog-QM is capable of measuring electroluminescence lifetimes without adding any 3rd party components, such as a pulse or an arbitrary function generator. The basic system can measure lifetimes from a few microseconds to hundreds of milliseconds utilizing its standard interface and Felix FL software capabilities of generating electrical pulses. By adding the DeltaHub/DeltaDiode option the range of lifetimes increases from a few nanoseconds to seconds. The instrument also offers a basic functionality to measure steady-state electroluminescence spectra without any external power sources.

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