

# Fluorescence excitation and lifetime measurements using GaN/InGaN micro-LED arrays

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## I. INTRODUCTION

The development of high-density, two-dimensional arrays of micrometer-sized InGaN/GaN light-emitting diodes (micro-LEDs) has produced devices with a considerable range of potential applications, from microdisplays [1] to compact and versatile sources for life-science applications. Such micro-LED devices have recently been demonstrated at wavelengths including green (540nm), blue (460nm) and UV (370nm) in 64x64 and 128x96 matrix-addressable arrays containing 10-20 micron-sized elements at up to 1200 dots per inch.

The importance of using elements of this size and density for time-resolved fluorescence spectroscopy is that they provide an ultra-compact and highly-parallel alternative to gas-discharge or laser induced fluorescence techniques [2]. With each element separately addressable, they have the potential to excite many thousands of individual fluorescent samples near-simultaneously. There is also a significant opportunity [3] to integrate such micro-LEDs into single 'lab on a chip' units with a combination of micro-lenses and PIN photodiodes, to produce portable micro-array screening devices. Here we report first results on the use of these devices to excite fluorescent samples.

## II. LED ARRAY PULSING

The micro-LEDs used were 64x64 arrays of 20- $\mu$ m-diameter micro-disk elements. They were fabricated on sapphire-substrate, MOCVD-grown InGaN/GaN wafers and were matrix-addressable via a contact grid. Details of the micro-LED fabrication process are given, for example, in ref. [4].

To test the fluorescence-excitation capability of these devices, several types of fluorescent dye were array-excited by a UV device and examined optically. For time-resolved demonstrations, single elements (at a time) of the different-wavelength arrays were pulsed using a driver circuit [5], with frequency variable from 200kHz to 10MHz, and individual pulse width of 2ns. A trace of the pulse output train is shown in Fig. 1. A fast photomultiplier tube was used to detect the optical pulses and the resultant signal was relayed to the 'start' channel of a time-to-amplitude converter (TAC) via a constant fraction discriminator. The 'stop' signal for the TAC was taken directly from the oscillator of the pulsed LED. The output of the TAC was then fed to a multi-channel analyser for data collection.

## III. DYE FLUORESCENCE

Dyes excited by the UV array included Dibac (470nm), Fluorescein (500nm), Rhodamine (570nm), Safranin (610nm)

and Nile Red (650nm) dyes, where the respective downconversion peak fluorescence wavelengths are given in brackets. A microscope image of UV micro-LED downconversion in Fluorescein, for example, is shown in Fig. 2, where the emission is at 500nm.

Fig. 3 shows, by way of example, the excitation pulse and time-resolved fluorescence decay curve of the mitochondria-staining dye Rhodamine 123 excited by the pulsed blue micro-LED. The best fit lifetime was found to be 5.53ns with a  $\chi^2$  fitting value of 1.439. This is a relatively high value compared to an ideal fit of unity, and is attributed to the background noise present in these initial measurements since each micro-LED element emits an average directed optical power of around 40nW at 4V.

## IV. CONCLUSIONS

In summary, we have shown the micro-LEDs are suitable sources for time-resolved fluorescence spectroscopy. Work is currently underway to increase the drive circuit power to pulse the elements at higher intensities, and on pulsed excitation using the green and UV devices. Progress will also be described on excitation of fluorescently-tagged DNA and on development of sub-nanosecond driving circuitry for exciting short-lifetime fluorophores.

## REFERENCES

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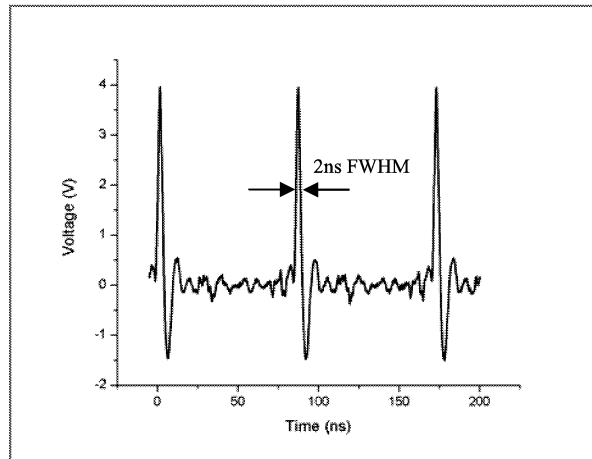


Fig. 1. 10MHz micro-LED driving pulse with 2ns pulse width

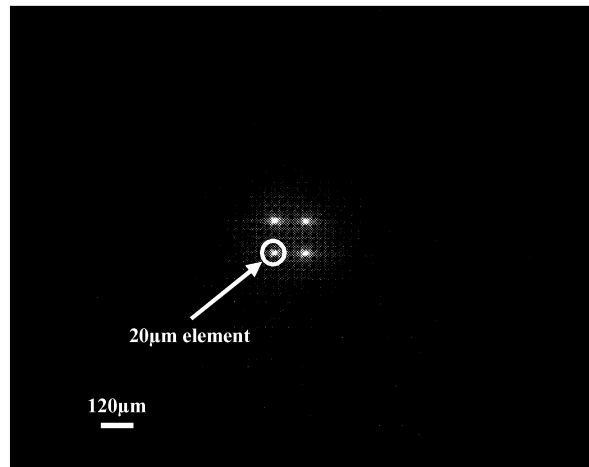


Fig. 2. UV micro-LED exciting Fluorescein dye and emitting at 500nm.

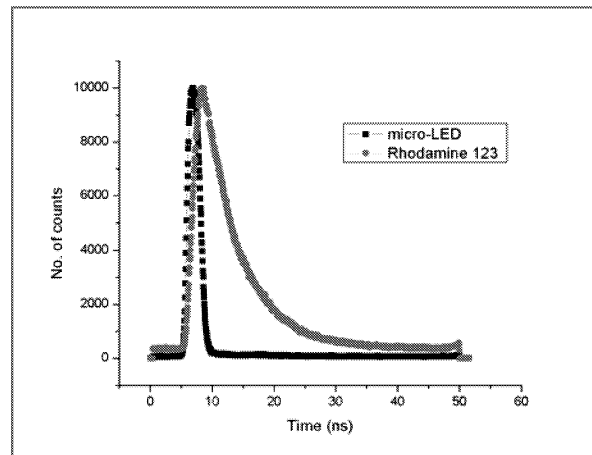


Fig. 3 Blue micro-LED pulse response and resultant fluorescent decay curve of Rhodamine 123.