Simulating short pulse scintillation light with a pulsed LED

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Abstract

Light emitting diodes (LEDs) were tested as a short pulsed light source, simulating the output for fast scintillators. These Scintillators usually have a pulse duration between the nanosecond and microsecond range. Commercial LEDs of wavelengths of 400-800nm are readily available, and offer a cheap solution for matching the wavelength and pulse duration of these scintillators. It was found that a pulse as short as 4 ns could be obtained at 405nm.

1 Introduction

Many diagnostics utilise scintillators, which emit pulses of optical light in response to incident radiation. These emissions have a pulse half width in the order of nanoseconds to microseconds. Detectors coupled to these scintillators, such as Micro Channel Plate Photo-Multiplying Tubes (MCP-PMTs), and Silicone Photo-Multipliers (SiPMs), should be hence characterised to verify their response is fast enough to detect such short pulses. This report explores a simple solution to simulate this type of scintillation light for controlled testing: LEDs. LEDs are easily available in different wavelengths. This report will explore the minimum pulse length that may be outputted from a 250Ω resistor protected LED, along with some modifications to further reduce the pulse length.

2 Resistor coupling

Standard consumer LEDs are usually operated with a safety resistor coupled in series with it. The voltage drop across this resistor limits the voltage across the LED, protecting it from damage. However, when driving short pulses, this resistor becomes a significant limiting factor in the brightness of the LED. The lower current flow over a shorter time means the low output is too low to detect.

In this regime the protection of the LED becomes less of a concern (time-scales are too small for the LED to overheat by driving at higher voltage), and the resistor may be replaced with a lower value one, or removed entirely. The greater current increases the light output. The effect of these modifications is explored.

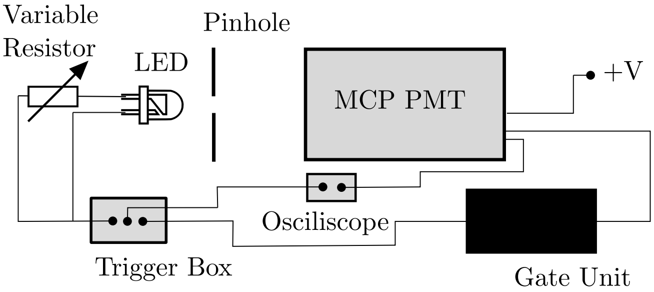


Figure 1: Setup for the LED characterisation test. The LED was pulsed with a driving pulse from a trigger box. This also triggered the PMT, and sent a driving pulse to the oscilloscope to be recorded. The LED light was funnelled through a pinhole to avoid scattered light from falling onto the PMT

3 Method

The output of the LED was measured with an MCP-PMT. This provided the temporal resolution required to characterise the LED. The LED itself was a 405 nm VAOL-5GUV0T4, with a standard resistance of 250 Ω, designed to be used with a TTL 5 V driving pulse. In addition to this, two modified LEDs were also tested, one with a 50 Ω resistor, and one without any resistor at all were also tested. The LED being tested was placed before the face of an MCP-PMT with a pin hole to limit scattered light (Fig. 1). The driver was a trigger box, which also sent the trigger pulse to begin the MCP-PMT acquisition. Both the driving pulse and the PMT acquisition were read out on an oscilloscope.

4 Results

The LEDs were found to perform very well for the purposes of simulating low pulse length. With the standard LED, a driving pulse of 15 ns was resolvable (Figure 4). Bellow this the light output was too weak for the trace to be detectable.

The modified resistors had a brighter light output, and so the minimum detectable pulse length was lower, with the 50 Ω LED showing a far stronger signal for the 15 ns driving pulse, and the resistor-less LED being able to resolve even a 4 ns driving pulse.

The peak signal from the PMT increases as the resistance was dropped to 50 Ω and 0 Ω for the same pules length (Fig. 2). As the driving pulse length is shortened,

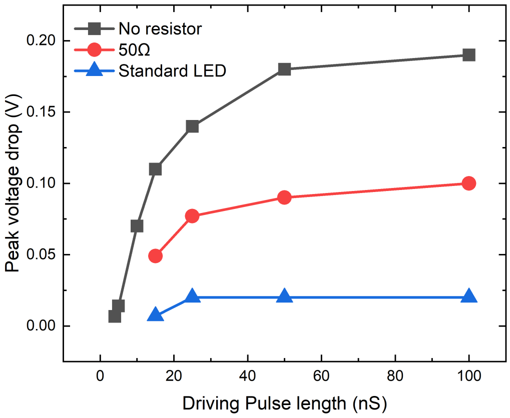


Figure 2: PMT trace peak voltage for the different LEDs at different driving pulses

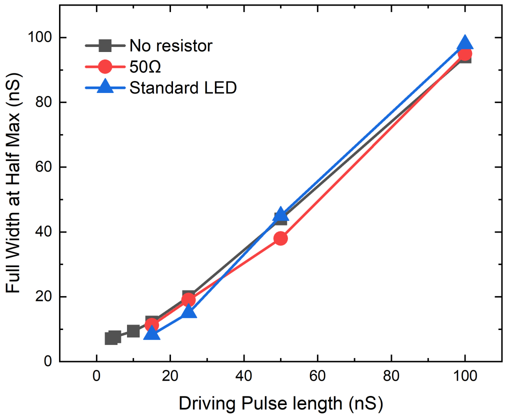


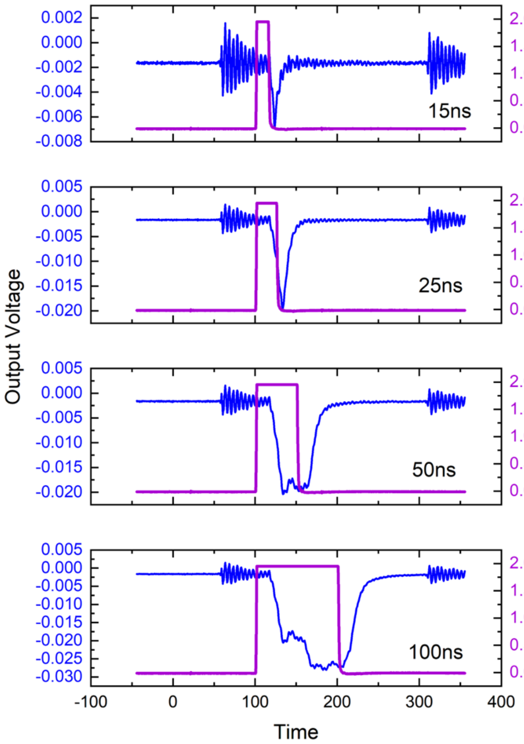
Figure 3: PMT trace FWHM for the different LEDs at different driving pulses

the peak voltage for all three LEDs drops off sharply.

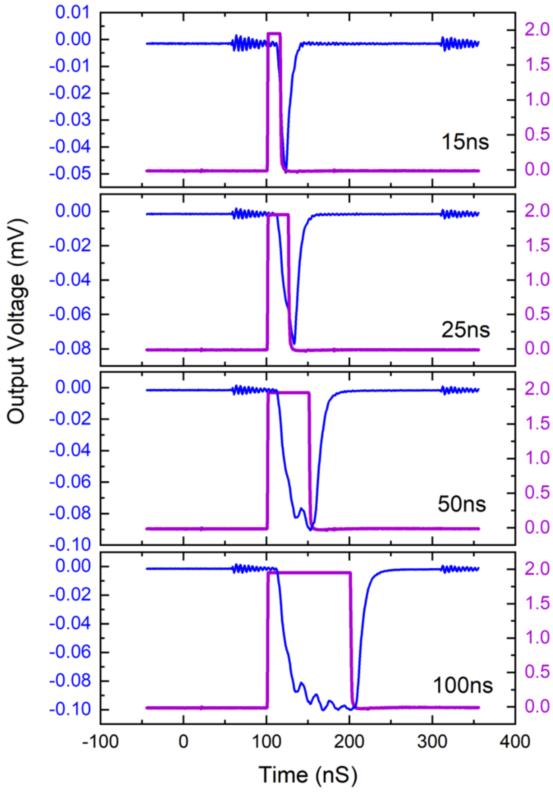
The Full Width at Half Maximum (FWHM) of the PMT traces were observer to correspond roughly to the driving pulse lengths for higher pulses, but start to fade off for shorter pulses (Fig. 3).

5 Conclusion

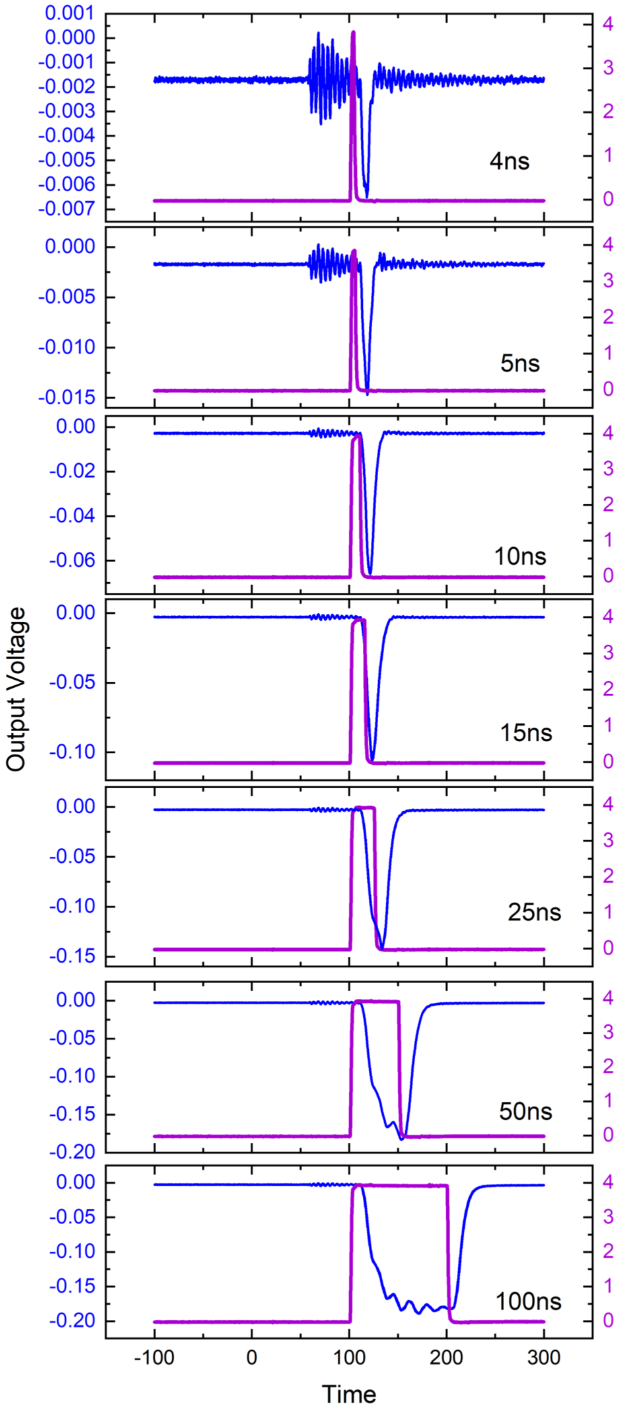
The LEDs were found to be suitable for the purpose of simulating short pulse scintillation light. A standard 'off the shelf' LED was found to be able to resolve up to a 15 ns pulse, and with some modification, namely removal of the safety resistor, was able to resolve up to 4 ns.



(A)250 Ω LED



(B) 50Ω LED



(C) Resistor-less LED

Figure 4: Driving pulses (purple) and PMT traces (blue) of the three LEDs as indicated. The ringing-like noise at the beginning and end of the trace is due to gate switching noise. The trace appears a short time after the driving pulse by a constant amount due to differences in cable delays.