An electrical ‘photon’ source

A word of explanation right at the start is required: the title of this document will not make sense to anyone familiar with even the basic principles in physics. In actual fact, we did not know what to call this device! It is intended to act as a pulse generator used to align photon-counting circuits, where photoelectron pulses are generated from photomultiplier tubes. Perhaps “random short pulse generator” would have been more accurate, but since you are reading this note, we must have caught your attention with the unusual title.

We describe here a pulse generator which provides fast, low amplitude, negative-going pulses generated by a fast photomultiplier tube (PMT). This generator is primarily aimed at testing detection circuits intended to be driven from PMTs. We use an ultrafast metal dynode tube manufactured by Hamamatsu as a signal source. When we though about constructing this, we though it may be useful to also include a high gain amplifier, constructed from ‘pill’ type microwave amplifiers (easily obtained from Mini-Circuits (http://www.minicircuits.com), e.g. ERA-XX (http://www.minicircuits.com/products/amplifiers_smt_gpw.shtml), but in fact, although drawn in the circuit diagram and although space for this amplifier is available, we found that in practice we hardly ever needed it.

The method used is extremely simple: an LED is used to illuminate the PMT photocathode through a small hole which acts as a rough pinhole to attenuate and distribute the LED light onto the photocathode. The LED current can be varied using a front-panel-mounted 10-turn potentiometer, as can the PMT gain, by varying its HT supply, again by using a a front-panel-mounted 10-turn potentiometer. Images of the completed unit are shown in Figure 1.

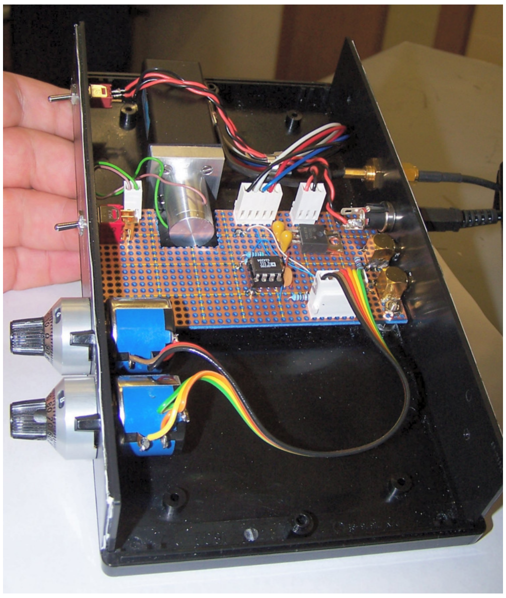

Figure 1: Internal and external views of the photon pulse generator.

The circuit of the unit is shown in Figure 2. The unit is powered from +15V; a regulator stabilizes the circuit’s dc power to +12V. This is used to drive a Hamamatsu PMT module (type H5783) which contains a reference-driven HT supply. The latter is controlled with a 10-turn potentiometer, limited to provide a maximum of 1000 V to the tube, though voltages above 900 V should be avoided. The PMT module’s reference output is also used to drive a simple current source, arranged to provide up to 1 mA through a red LED. The LED current can be monitored, using a high impedance load, at the rear of the unit, as can the PMT HT set voltage (SMB connectors). The LED can be short-circuited to simulate ‘dark’ counts from the PMT.

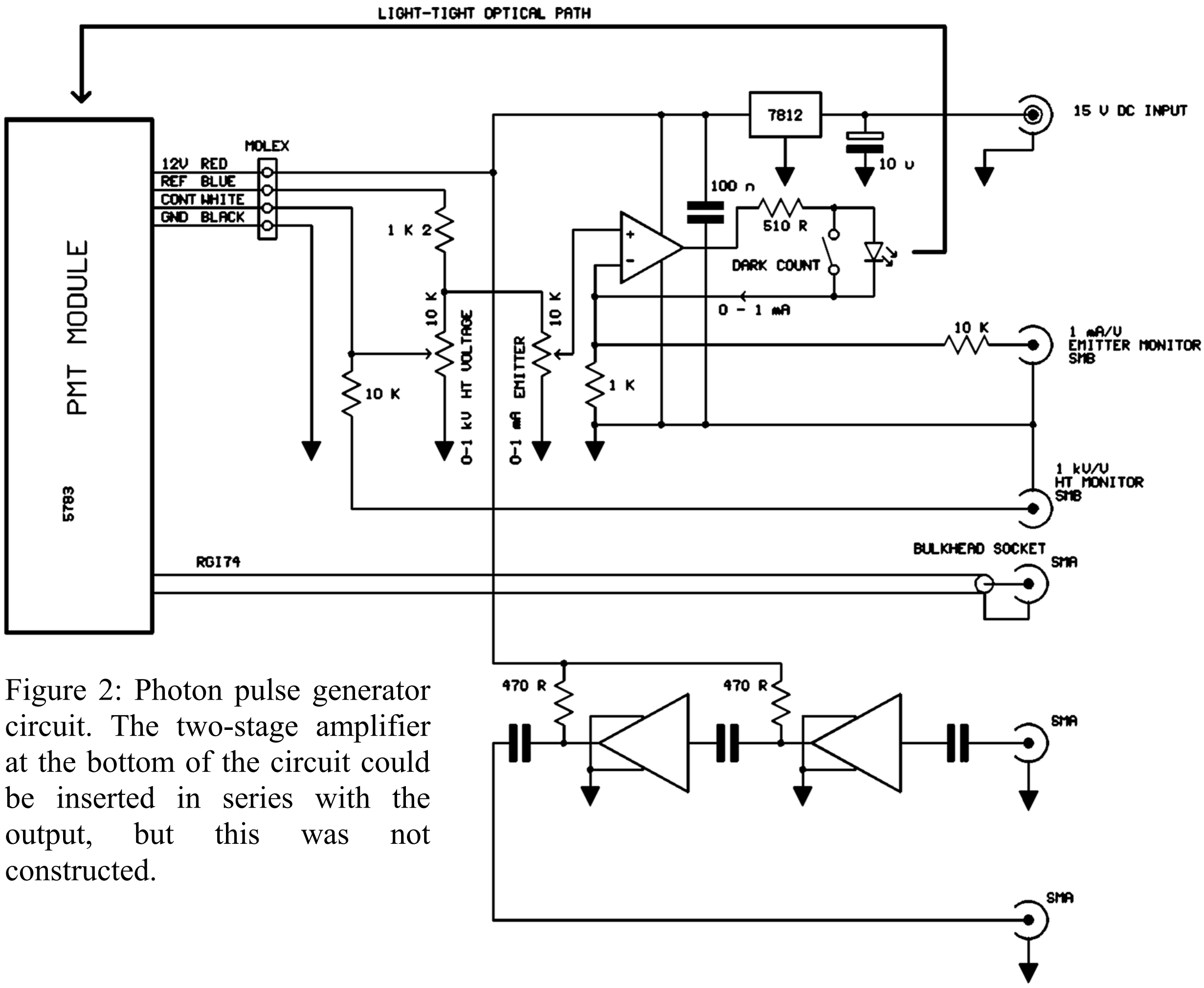

Figure 2: Photon pulse generator circuit. The two-stage amplifier at the bottom of the circuit could be inserted in series with the output, but this was not constructed.

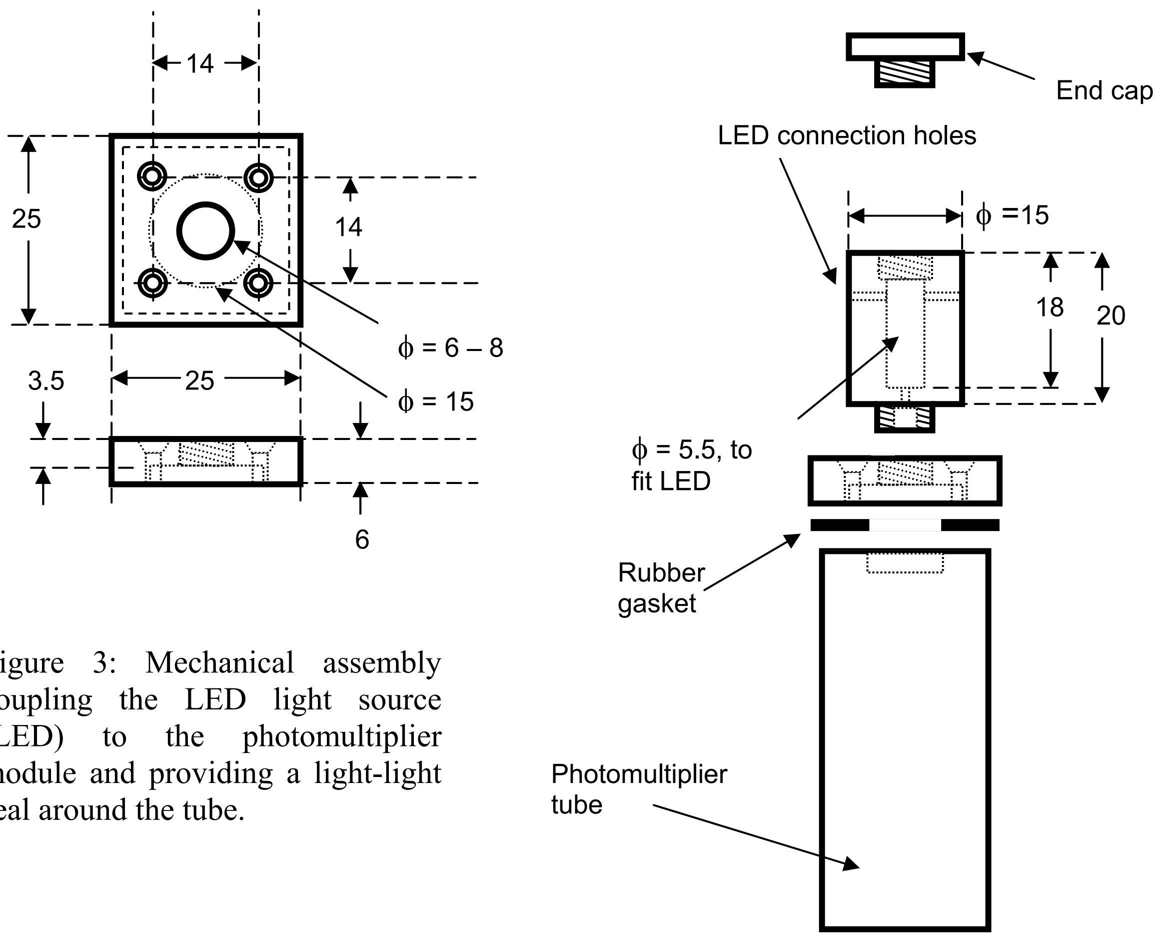

Figure 3: Mechanical assembly coupling the LED light source (LED) to the photomultiplier module and providing a light-light seal around the tube.

The photo-multiplier module is mounted on a 25 x 25 mm interface plate, which is also used to mount the assembly to the plastic case of the device. The LED assembly is screwed into this plate, as shown in Figure 3. The LED wires are taken out through small (~1 mm) holes on the sides of the LED assembly and finally an end-cap is inserted, ensuring that no stray light enters the system.

The circuit board, the LED-PMT combo, the potentiometers and the switches are housed in a thin plastic box, the internal layout of which is shown in Figure 4.

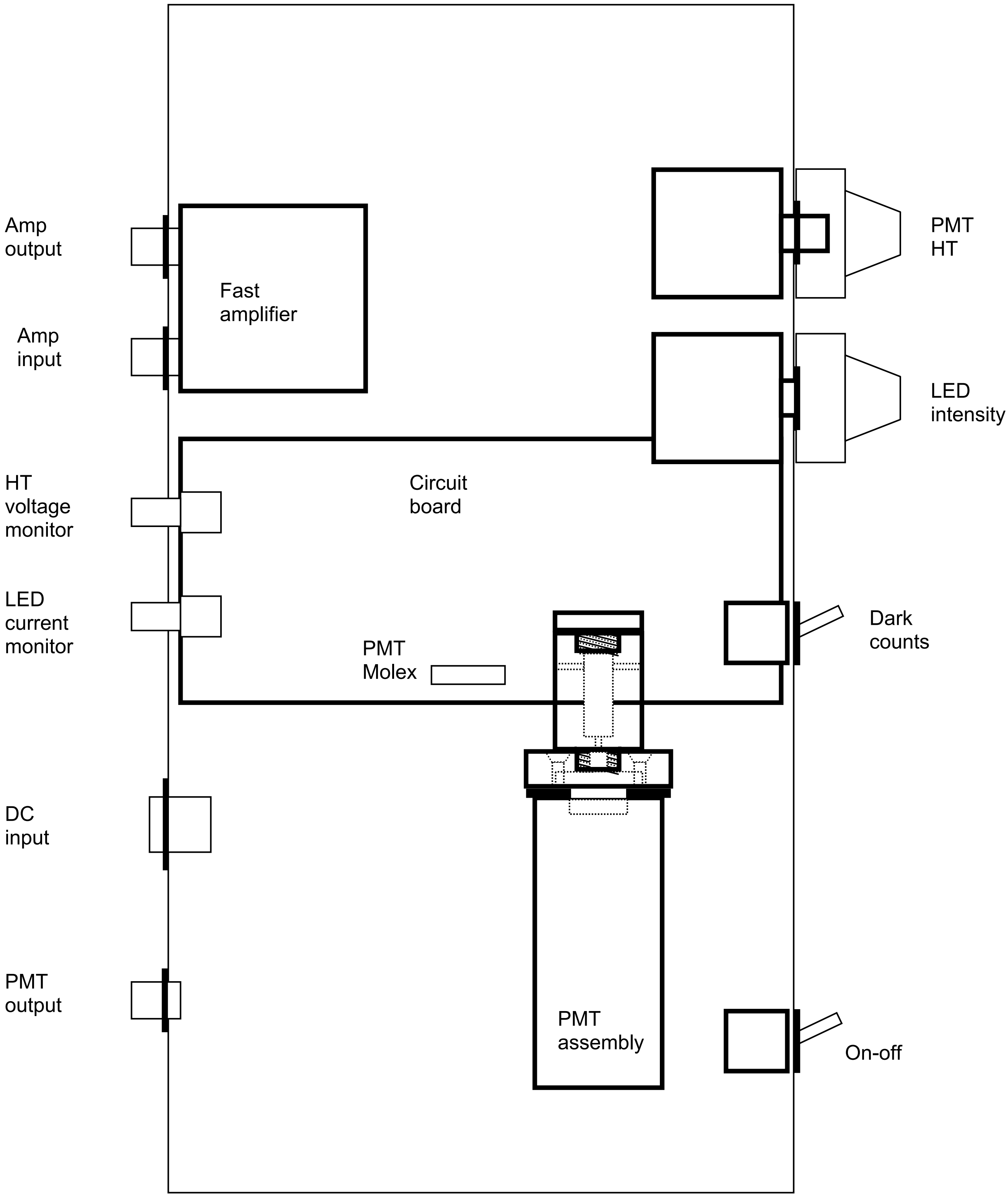

Figure 4: Internal layout of the photon pulse generator. The area reserved for future placement of the fast amplifier is also shown (top left).

For completeness, the mechanical dimensions of the PMT module are presented in Figure 5, as supplied by Hamamatsu. Its RG174 cable is terminated with a bulkead SMA soxket socket, which is mounted on the rear panel. The rear connections of the unit can be seen in Figure 6, which also shows a small wall-plug power used to power the unit.

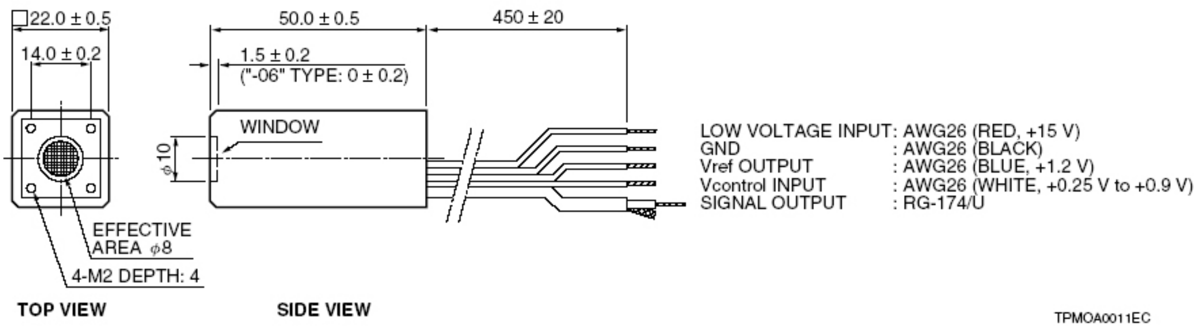

Figure 5: Details of the photomultiplier assembly

Figure 6: The rear panel of the photon pulse generator

So what do we get from this pulse generator? Single photoelectron pulses of course! Figure 7 below shows typical single-shot-acquired and repetitive trigger outputs. A 1 GHz bandwidth oscilloscope was used to acquire the signals, though its bandwidth could be restricted down to 20 MHz (≈16 ns risetime), and the resulting pulses, single shot acquisition, are shown in Figure 8. The dark count rate is typically less than 200 counts per second.

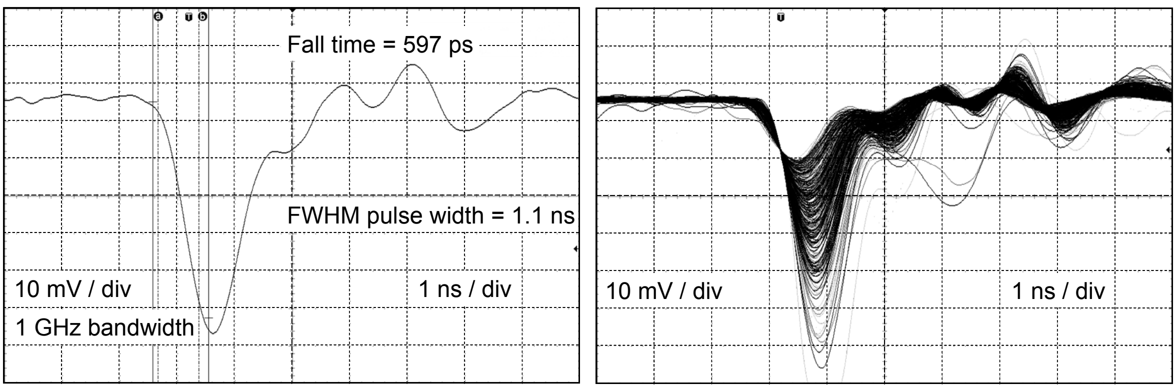

Figure 7: The fastest signal pulses that could be obtained from the photon generator

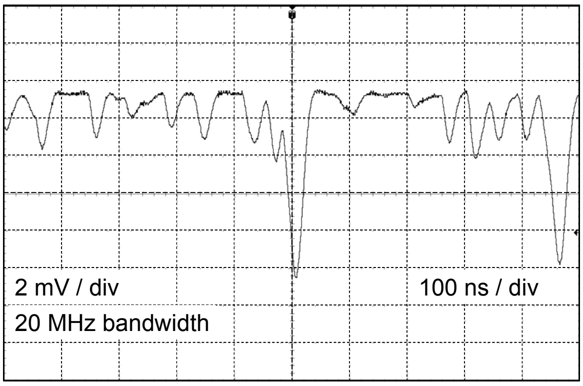

Figure 8: Reducing the detection bandwidth: This single-shot acquisition was obtained by using a relatively high illumination light level provided by the LED + pinhole.

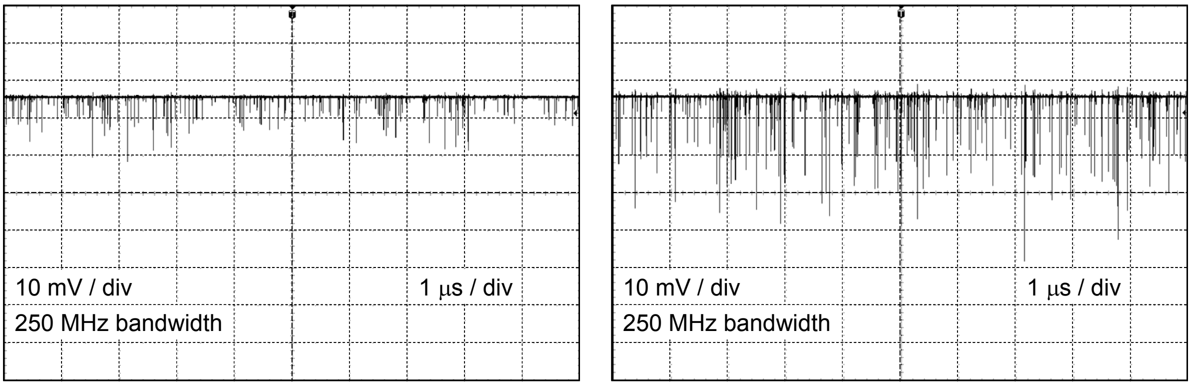

Figure 9: These data were obtained at a typical (mid-range) illumination level at lower (~800 V) PMT HT voltage (left panel) and higher (~870 V) PMT HT voltage (right panel).

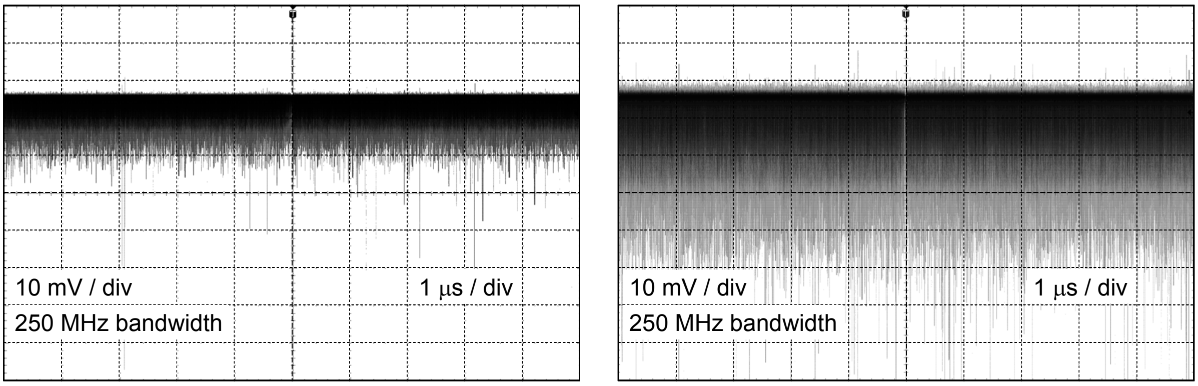

Figure 10: These data are obtained as in Figure 9, but over a longer measurement period….these traces may convince your students that light really is made up form photons!

This device has been found useful when testing ultra-fast comparators or constant-fraction discriminator circuits It was constructed in January 2006 by RG Newman at the Gray Institute, when the Institute was based in Northwood, Middlesex.

The note was written by B. Vojnovic and IDC Tullis in March 2006. The note was updated in June 2011.

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