# A combined NIR filter and trigger sensor for use with a supercontinuum laser

## 1. Introduction

In recent years, the availability of pulsed supercontinuum lasers has opened up novel applications in optical imaging and spectroscopy (see e.g. http://en.wikipedia.org/wiki/Supercontinuum). These devices are used in our laboratory as excitation sources for fluorescence lifetime imaging instruments which we have developed. We use a variety of devices produced by Fianium (http://www.fianium.com/) which produce ~6 ps pulses at repetition rates of 40 and 80 MHz. One drawback of such lasers is that they produce considerable energy in the near infra red portion of the optical spectrum, above the commonly used upper fluorescence excitation wavelengths of ~700 nm and extending well above 1500 nm or more. These unwanted wavelengths can be troublesome when using silicon detectors for power measurement, or indeed can affect the imaging process itself. Furthermore, some of the early units did not produce an adequately large synchronization signal which could be used for signal acquisition triggering purposes. We thus developed a simple device to kill two birds with one stone: to remove unwanted wavelengths and to provide a trigger output synchronous with the optical pulse used in the experiment.

## 2. The Fianium laser head mount

We use Thorlabs (http://www.thorlabs.de) opto-mechanics for optical instrument construction in our laboratory and we thus made this subassembly compatible with these components. The Fianium laser output head includes collimating optics in a cylindrical assembly that permits beam centering and tip-tilt adjustment. This head is housed in a custom machined assembly as shown in Figure 1. This assembly is drilled out to the laser head diameter and held in place with a nylon-tipped screw.

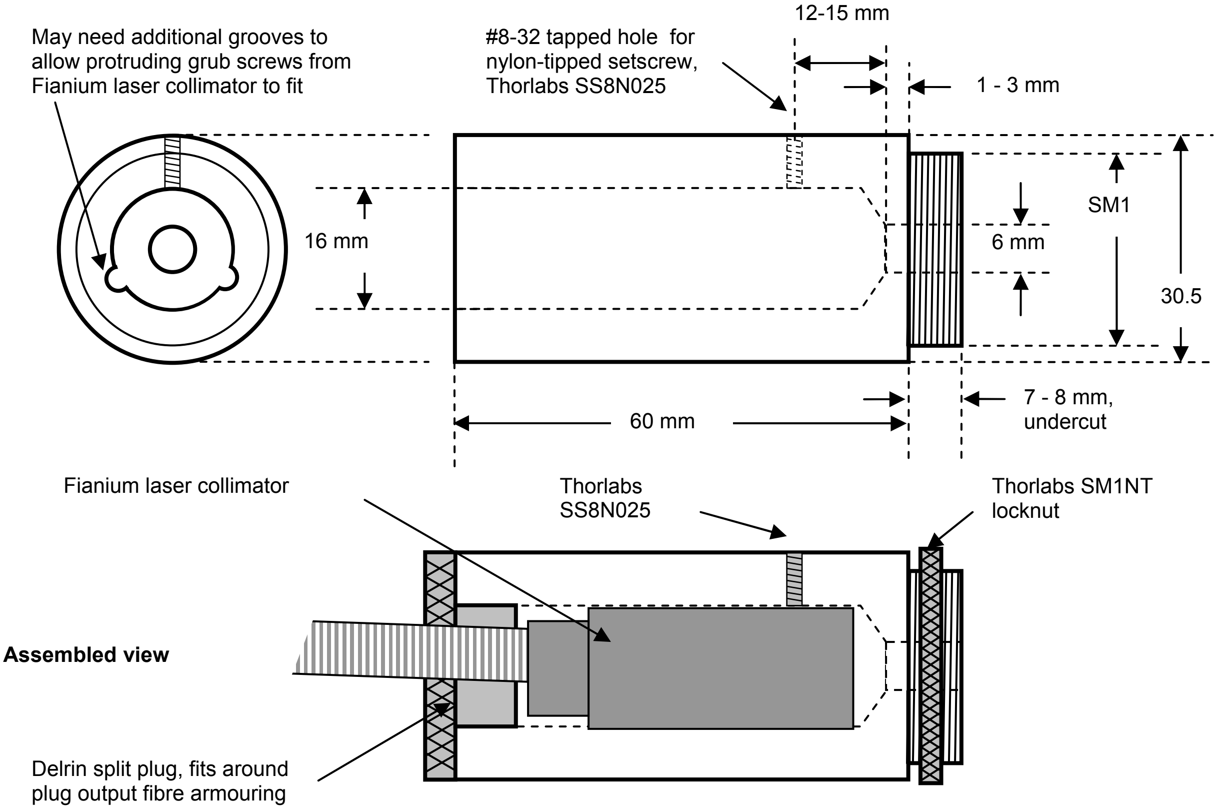



Figure 1: Laser head to SM1 mount, shown a cross-section (above) and assembled cross-sectional (below) views.

It is pointed out that the diameters of the heads seem to vary slightly between models and obviously the mount should be drilled to the appropriate diameter. It is advisable to first check that the beam exiting from the laser head is coaxial with the mount – tit can be adjusted to be so by placing the head in a wide 'V' block and rotating it while viewing the beam spot on a distant wall, taking care of all appropriate laser safety considerations (i.e. not doing this when you are tired and not doing it with other people present!). The same process is repeated when the head is in the mount. With a little care, this can be performed quite quickly, checking that the beam position stays constant with rotation.

### 3. The NIR filter and trigger pick-off

The arrangement used for this is shown in Figure 2. The idea is to use two 'extended hot mirrors' to reflect the NIR portions of the beam off to the side while maintaining the beam direction. The first mirror (Edmund Optics NT46-386, left side of Figure 2) is mounted at 45 degrees to the beam direction and reflects the NIR portions of the beam towards a heatsink/beam dump (Thorlabs LB1/M). The mostly visible light beam components are transmitted and deviated by ~1 mm due to the reflector thickness (~ 3mm). Any remaining NIR components and a few percent of the visible light components are reflected off a second, identical extended hot mirror onto a small high speed photodiode (Centronic AEPX65, Farnell 548777) which provides the trigger pulses. This second mirror, also mounted at 45 degrees brings the beam back such that the total beam deviation is negligible. The assembly is constructed around a Thorlabs C6W cube. The 2 x 45 deg. block (shown in orange in Figure 2) containing the mirrors is machined from one piece, ensuring the correct mirror angles. The mirrors are glued onto this assembly. Within this block a small removable disc (shown in green in Figure 2) is inserted, through which the output connector is mounted. The photodiode is soldered directly to it and 'adjusted' by bending its legs so as to intercept the second reflection.

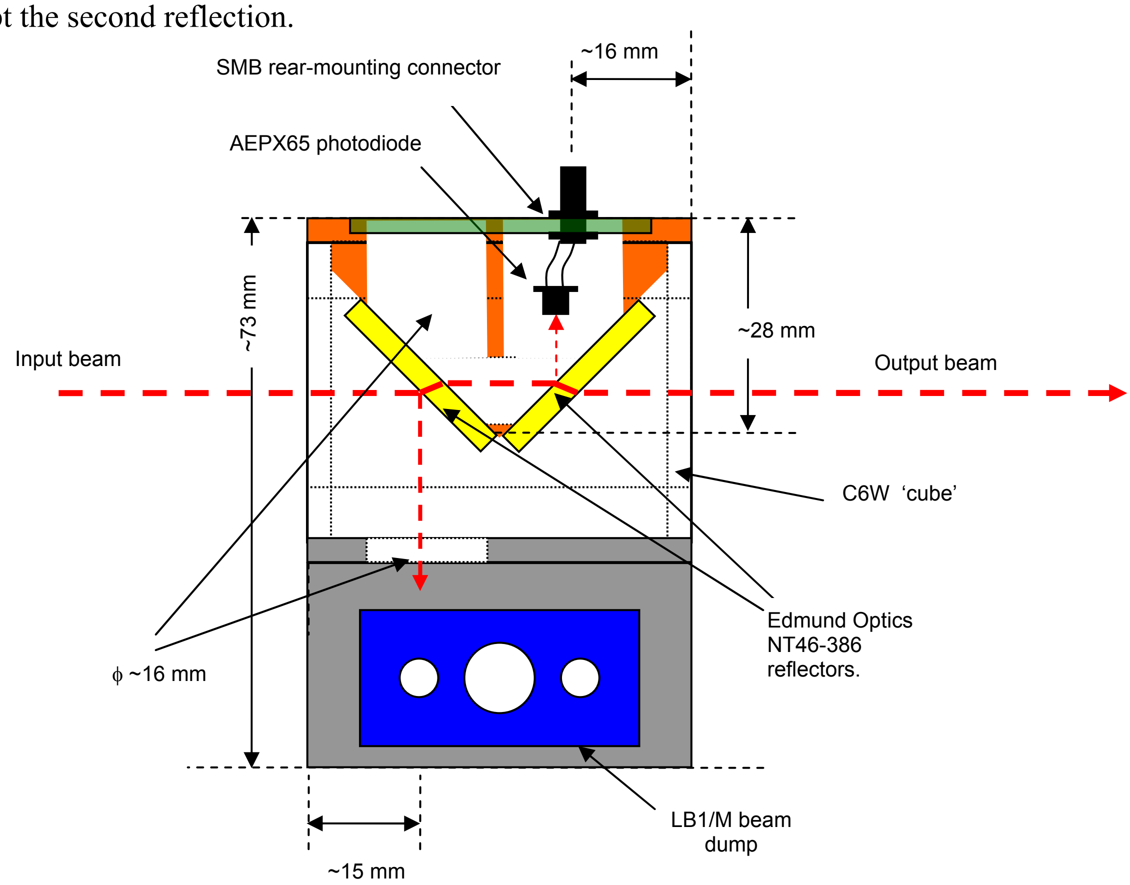
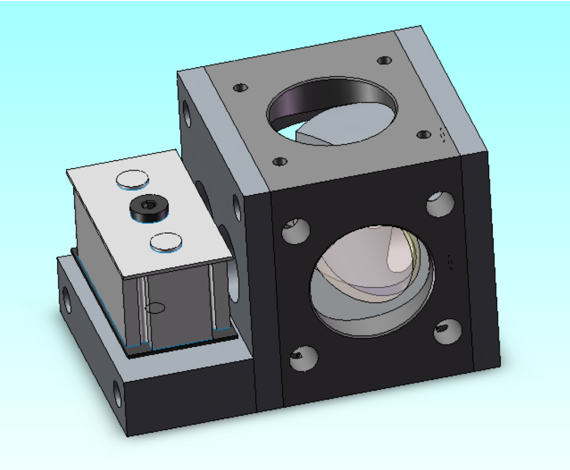



Figure 2: The heat filter and trigger pick-off assembly constructed around a C6W cube. The sides of the cube (orange and grey above) are custom machined components. Please see text for explanation.

On the other side of the cube, we mount the beam dump on a support plate held by the side plate. The NIR beam reaches it through a 16 mm hole and it advisable to place a small rubber gasket (with a hole in it!) between the beam dump and the side plate so as to make sure that no scattered NIR light exits the assembly. Although the temperature of the assembly increases after prolonged operation (>>1W is dissipated in the beam dump), we have not experienced any problems with beam stability.

A SolidWorks model of the assembly can be seen in Figure 3



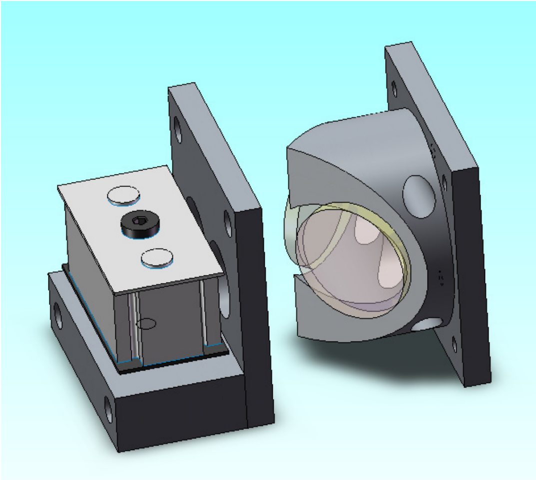
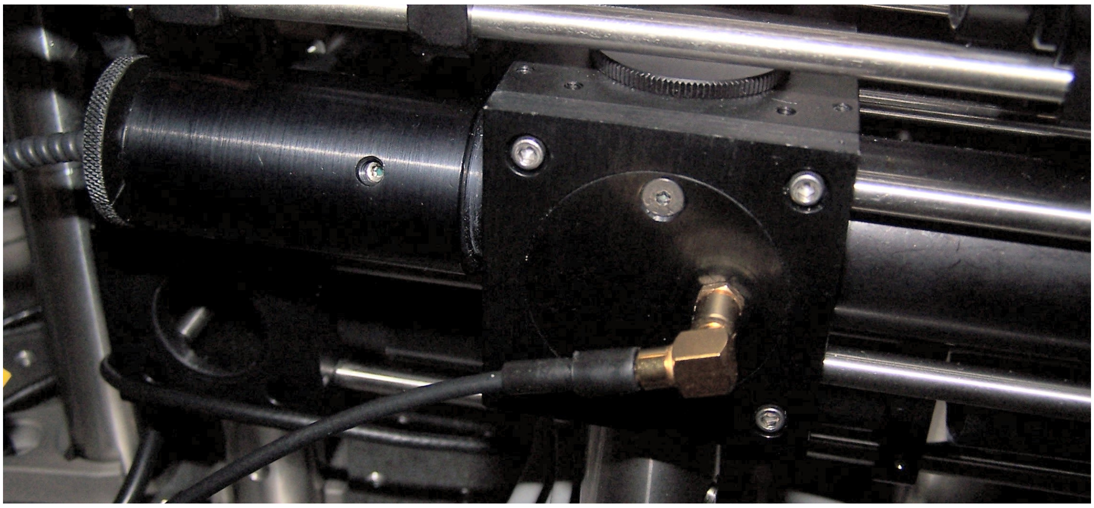


Figure 3: Model of the NIR filter and trigger assembly. Left: assembly in a Thorlabs C6W cube. Right: relative placements of the machined units holding the filters and the heatsink.

The completed assembly, including the laser head mount is shown in Figure 4.



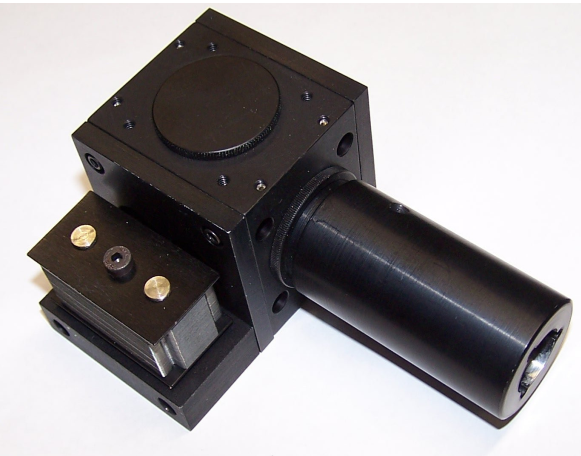


Figure 4: The completed assembly, showing the photodiode side (above) and from above, showing the beam dump (left).

We have found this assembly to be very stable and convenient to use. The relative positions of the heat filter block and the beam dump blocks can be easily interchanged to suit different orientations. Although similar NIR-removal arrangements can be constructed from reflective optics, these have a considerably larger footprint and thus not as convenient to fit into tight spaces. The use of 'standard' Thorlabs components makes integration into various instruments straightforward and convenient. The assembly shown in the upper part of Figure 4 is mounted on a post with an SM1 thread at the top, mounting the cube directly onto the post, though other configurations are possible. Mounting rods can be inserted into the side of the C6W cube, as can SM1 tubes, again as shown in Figure 4.

## 4. Performance

The photodiode used is a low capacitance, fast risetime device, which inevitably has a small area (0.55 $mm^2$, 0.84 mm diameter sensitive area). It can produce *pulse* currents in excess of 100 mA and can thus deliver high trigger output voltages in a 50 Ω system.

We reverse bias this photodiode as shown in Figure 5, using +12V bias. The maximum bias voltage should be less than 20V, although we have found little change in performance above about +9V. The arrangement shown in Figure 5 allows the outer of the RG174 photodiode cable to be at ground potential, and the output signal consists of negative-going pulses. A ceramic 10 nF capacitors removes the bias from the output and couples the output pulses to a 50 Ω-terminated cable. The unit is constructed on a small circuit board and is connected to the photodiode with a short (500 mm) cable.

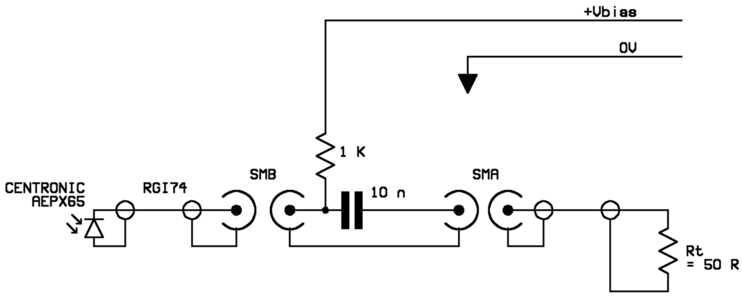



Figure 5: The photodiode bias insertion unit.

The trigger signal waveform (from an 80 MHz repetition rate laser) is shown in Figure 6. We present data acquired at 10 ns/division and at 4 ns/division, at a sensitivity of 20 mV/division. The upper two panels are acquired at long persistence time and show the output amplitude variations typical of supercontinuum lasers (typically ~10%). The reflections introduced by the bias insertion unit are discernable but very small. Of course the actual amplitude depends both on laser power and

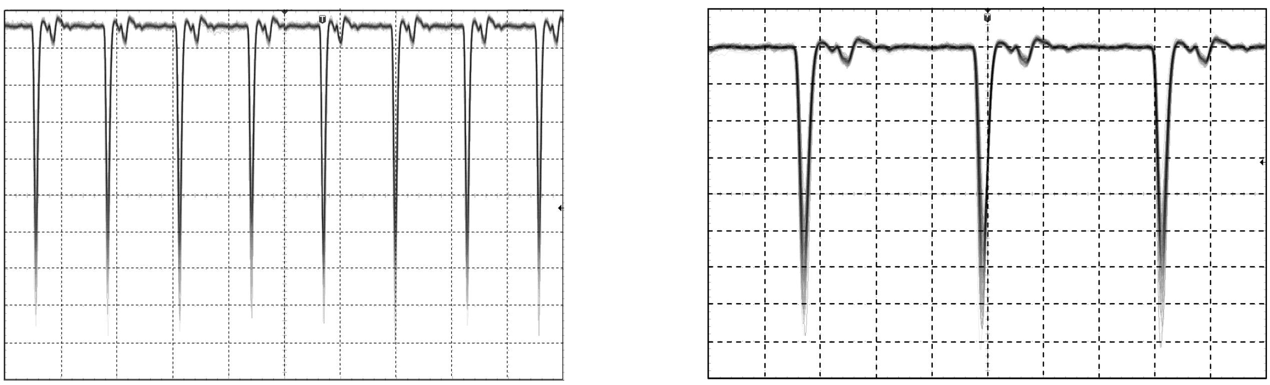


Figure 6: Output waveform produced by the photodiode (20 mV/div 10 ns/div (left), 4 ns/div (right)); data acquired in repetitive trigger mode with the digitising oscilloscope persistence mode enabled.

on the mechanical alignment of diode with respect to the reflected beam and the data presented here should only be considered as being 'typical'. In practice, although the fall/rise times are of the order of 500 ps, as shown in Figure 7, certainly fast enough for FLIM work at time resolutions of the order of 100 ps, as can be obtained with the use of constant fraction discriminators on the signal and trigger inputs of digitising instrumentation. The speed is comparable to that that which can be obtained from Hamamatsu metal dynode photomultiplier tubes often used as single-photon detectors in fluorescence lifetime imaging applications.

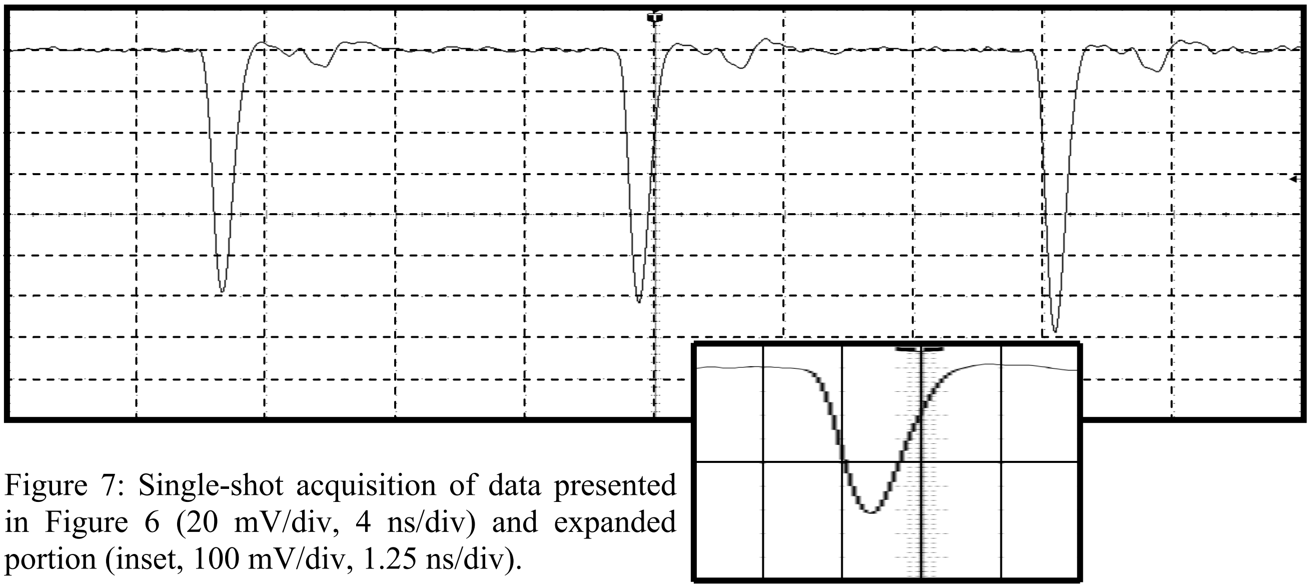


Figure 7: Single-shot acquisition of data presented in Figure 6 (20 mV/div, 4 ns/div) and expanded portion (inset, 100 mV/div, 1.25 ns/div).

The NIR component in the output beam are significantly reduced, to a level that we cannot readily measure with the equipment available to us.

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