High Sensitivity Luminescence Measurements of Materials – The St Andrews Luminescence Facility by Adrian A Finch, Yafang Wang, Peter D Townsend, Martin Ingle

Supplementary Information 1 – Detailed description of the IPD detectors

Photek's IPD340 is a vacuum detector comprising an input window, photocathode, stack of microchannel plates (MCP's) and a resistive anode *(Diagram 1)*. Light passes through the input window where visible photons are converted to photoelectrons by the photocathode. The number of photons converted to photoelectrons is dependent on wavelength and defined by the quantum efficiency of the photocathode. The photoelectrons are then amplified by the MCP with a modal gain of approximately 10^7.

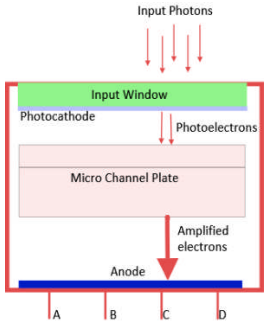

Diagram 1. Structure of IPD Detector

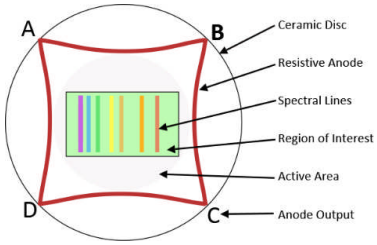

Diagram 2. Resitive Anode

The emerging cloud of electrons is focussed onto a resistive sheet anode with four collecting points at the corners labelled A, B, C and D. Charge detected by the anode is proportionally shared to the four corner outputs *(Diagram 2)*. These signals are then amplified using a charge amplifier and pulse shaping network before being digitised and processed using a FPGA. The arrival time of each photon is also tagged with time to an accuracy of 10 ns. The digitised data and the time stamp for each event are transferred to a PC computer via a USB interface. Software on the PC then calculates the position of the event using the charge measured on each of the A, B, C and D outputs from the anode using the following algorithms:

$$X = (A+B)/(A+B+C+D) \text{ and } Y = (B+C)/(A+B+C+D)$$

Total charge is measured by summing the ABCD data and generating a pulse height distribution (PHD) histogram. Low energy or coincident events can be eliminated by the use of a lower and upper PHD discriminator. An optional distortion correction algorithm helps maintain a flat field image.

Two modes of operation are possible; continuous and fluorescence imaging. In continuous mode a two dimensional image is constructed by integrating the event position into a two dimensional image buffer. Image coordinates are calculated using charge data collected from each corner of the anode rather than a

Irvine Building, North Street, St Andrews, Fife KY16 9AL
Tel: 01334 462384 Fax: 01334 463949 Email: Adrian.Finch@st-andrews.ac.uk

fixed pixel structure found in conventional CCD or CMOS sensors. The default size of the image is set to 512 x 512 pixels with each pixel being 16 bits deep but because of the adaptable image format this is fully reconfigurable by the user. The system also allows a region of interest to be defined and this would normally be set to encompass the spectral output from the monochromator. The two dimensional image may also be compressed to form a 1D spectrum and plotted as a graph. In the continuous mode of operation timing information from the detector is ignored.

In fluorescence imaging mode the event time is used to create a stack of images where each image corresponds to a defined sequential time window. Before starting an experiment two sets of parameters must be configured which control the triggering of the light source and image integration. Triggering of the camera may be controlled from an internal programmable time base or from an external source. Following a trigger pulse the illumination light source is switched on for a pre-defined period of time (typically 1-10 μs) and this is used to stimulate the sample. An optional blocking delay can be added prior to data acquisition to reduce the effects of phosphorescence of the sample following stimulation by the light source. The detector uses a technique known as gating to make the detector "blind" except when acquiring the fluorescence spectrum. This is accomplished by reverse biasing the photocathode. The system automatically resets the internal counter each time the photocathode is enabled and this defines t_0 for the fluorescence measurements.

Three other parameters are required for data acquisition. The image time defines an image bin size. The number of images defines the size of the image stack that is created. The length of fluorescence decay that can be measured is calculated by multiplying the image time by the number of images. The final piece of information is how many repetitions are required in order to build a series of fluorescence decay images with the required statistical sensitivity. Once the final image has been acquired the detector is gated off until the next trigger is generated.

A typical experiment may set an image time of 10 μs, with 1000 images in the stack. This would allow a decay of 10 ms to be acquired. To improve statistics the number of repetitions may be set to 10,000 resulting in a total acquisition time of 100 s (*Diagram 3*).

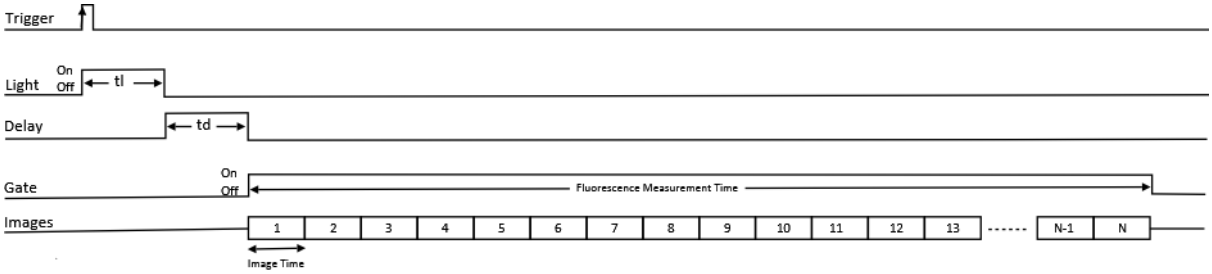

Diagram 3. Timing information

By controlling the temperature of the sample it is possible to generate a full thermo-luminescence profile of the sample under test. Software for controlling the IPD camera is controlled by Photek's Image32 software. Full functionality of the software may be controlled by using the integrated scripting language based around LUA or by code wrappers that allow all aspects of the software to be controlled via National Instruments Labview software. Mulitple IPD detectors maybe controlled from a single computer. In this case two detectors are used one of which is optimised for the blue end of the spectrum (300nm to 500nm) using a Bialkali photocathode and the other optimised for the red end of the spectrum (500nm to 800nm) using a S25 based photocathode.