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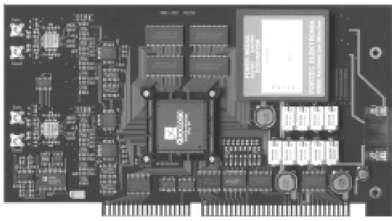
The Event Mode of the PMS-300 Multiscaler

The 'Event Mode' was implemented in the PMS-300 to detect bursts of photons which appear in irregular intervals or to record wide dynamic range signals over extremely long time intervals. Typical applications are

Single Molecule Detection
Optical Particle Detection
Gas Discharges
Radioactive Decay
Long Range Lidar
Testing PMTs for Glass Scintillation
Phosphorescence, Delayed Fluorescence
Recording Wide Dynamic Range Optical Signals



The PMS-300 Module

In the event mode the incoming detector pulses are counted within subsequent collection time intervals. The counting results are compared to a user defined 'event threshold' value. If the counting result is greater than the event threshold it is stored together with the time since the start of the measurement.

The principle is shown in figure 1.

The detector pulses are counted within the subsequent collection time intervals. At the end of each collection time interval the counter value is compared to the predefined 'Event Threshold'. If the counter value exceeds this threshold, it is stored together with the number of the collection time interval in which it appeared. Since the length of the recording is determined by the number of events recorded rather than by the overall measurement time a very long time scale can be covered by one measurement.

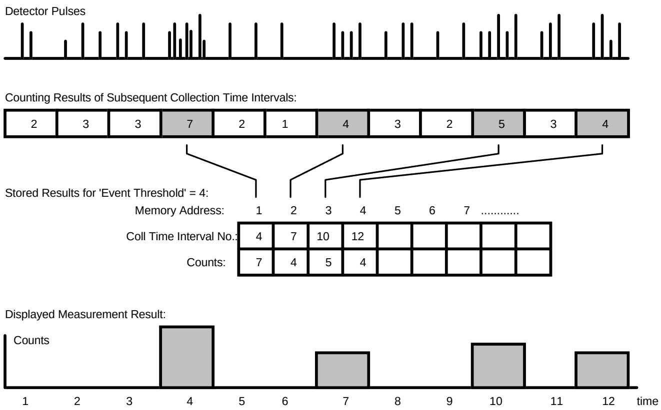


Fig. 1: The ‘Event Mode’ of the PMS-300

The figure below shows a typical setup for DNA sequencing or other single molecule detection problems. The molecules are running through a capillary. If a molecule travels through the laser focus it can perform some 10 000 absorption/emission cycles. Thus, short bursts of photons are generated in irregular intervals due to the fluorescence of the individual molecules.

The overall measurement time is usually very long (several hours) compared to the required resolution (microseconds). Thus, a usual multiscaler cannot be used because its memory depth is insufficient.

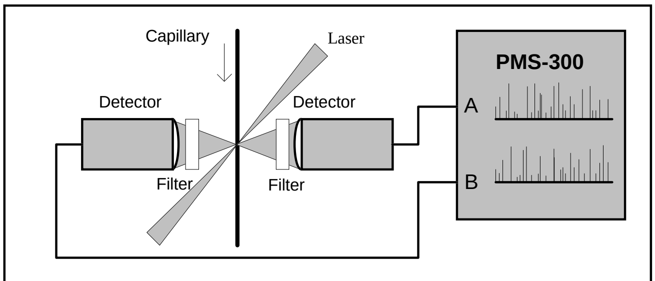


Fig. 2: Single Molecule Detection

The PMS-300 in the Event Mode, however, has no problems to record the signals. By setting the ‘Event Threshold’ > 1 the detector dark counts can be effectively suppressed and only the busts caused by the molecule transits are recorded. Up to 32 768 events can be recorded in one measurement.

To identify false events caused by glass scintillation in PMTs or by radioactive decay a dual channel setup can be used. Detector pulse bursts caused by these effects normally do not appear in both channels simultaneously and can be rejected by suitable processing of the data.

In the example below an insulator is exposed to a strong electric field. As the strength of the field varies, small discharges appear which are detected optically. Because the discharges are short and appear in long and completely undefined intervals a long measurement time interval must be covered with a high resolution - a problem which is easily solved by the PMS Event Mode.

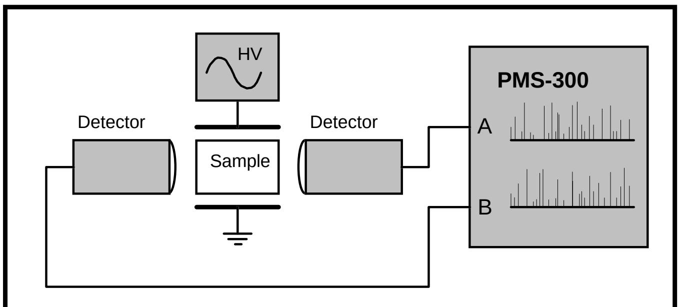


Fig. 3: Measurement of Discharge Effects in an Isolator

The performance of Photomultipliers used for single photon counters can be seriously impaired by scintillation effects in the glass near the photocathode. The reasons of the problem are manifold and not completely understood. Natural radioactive decay, cosmic ray particles and electrons moving in the electric field in front of the PMT window are seen as the main sources. The effect shows up as short bursts of pulses appearing in irregular intervals. In fast tubes some tens of pulses can appear within 100 ns. It is not simple to detect the bursts with an ordinary multiscaler. The PMS Event Mode, however, shows the effect very clearly. Fig. 4 shows bursts of pulses from a PMT recorded over 50 seconds. The event threshold was set to 4 to suppress the recording of the normal dark count pulses. The collection time interval was 250ns. Up to 25 pulses appeared within the collection time interval. This is a peak count rate of more than 100 MHz - a value at the limit of the count capability of the PMT.

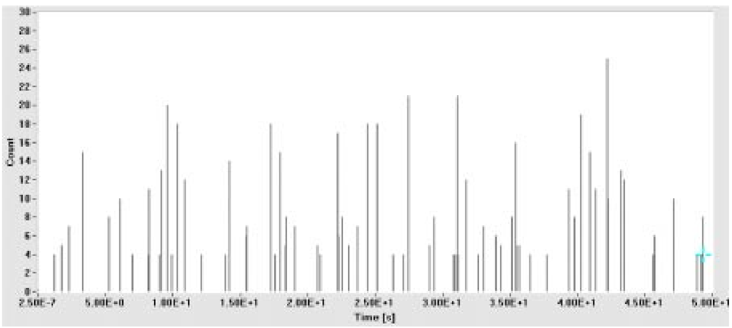


Fig. 4: Scintillation Effects in a PMT

Event Threshold = 4, Collection Time = 250 ns, Overall Time = 50 s

Measurements of decay functions of inorganic luminophores, phosphorescence decay functions or delayed fluorescence functions can be extremely difficult if the decay functions start with a fast peak and end with an weak and slow tail. To resolve the fast peak, a short collection time interval is required. The tail, however, requires a long measurement time.

Recording the whole function in the 'Multiscaler Mode', the measurement requires an enormous amount of memory, because the long tail is measured with the same short collection time. If the same signal is measured in the 'Event Mode' with 'Event Threshold' = 1 the situation is usually much better (fig. 5). Because the signal decays quickly below an intensity of 1 photon per collection time interval, the storing of an 'Event' becomes less likely with the time. At the end, many collection time intervals elapse without recording a photon, and the recording can be extended to very long times without reaching to the end of the device memory. A practical example is given in figure 6. The measurement covers an overall time interval of 10 seconds with a resolution 10 us, i.e. 10^6 collection time intervals. The curves show subsequently zoomed displays of the same measurement data.

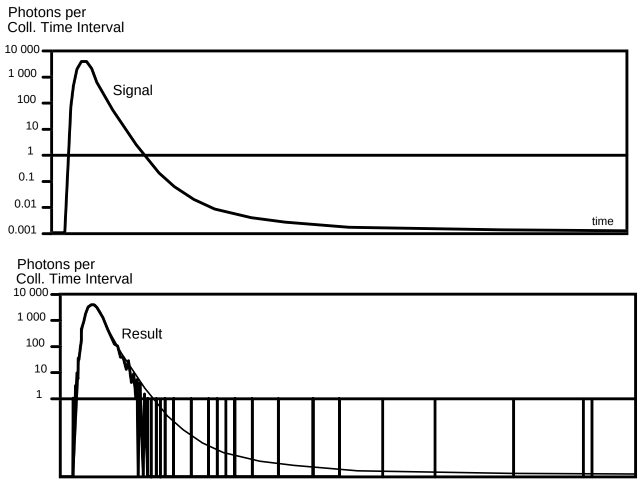


Fig. 5: Recording a wide dynamic range signal in the Event Mode

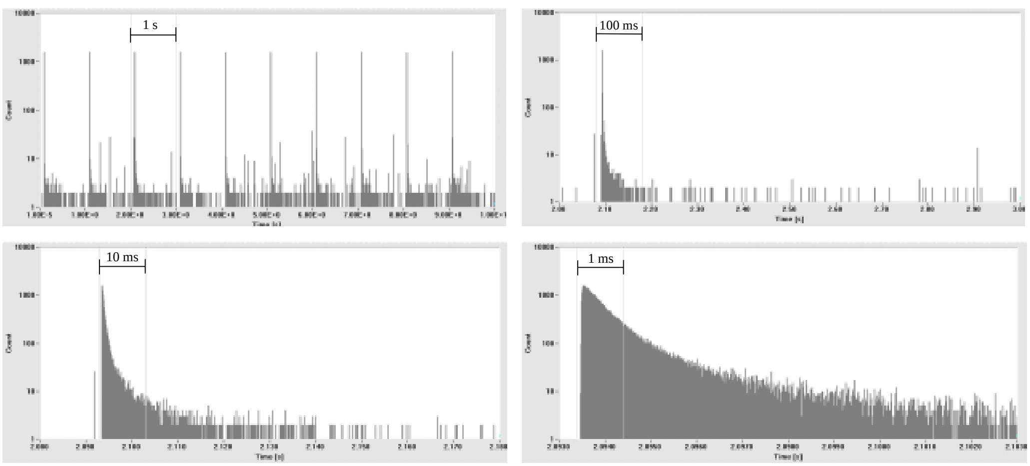


Fig. 6: Wide Dynamic Range Signal recorded in the Event Mode.
Event Threshold = 1, Collection Time = 10us

Fig. 7 shows an event mode recording of lightning bolts in a nightly thunderstorm over Berlin in June 2000. The collection time interval is 10 us. An event threshold of 4 counts was used to avoid triggering by light pollution. The overall recording time was 50 seconds. More than 30 thunderbolts were recorded within this time (fig. 7, top left). Zooming of the an interval of

1.5s around the big bolt left of centre resolves it into a double strike (top right). Further zooming (fig. 7, bottom) reveals the true shape of the light pulse.

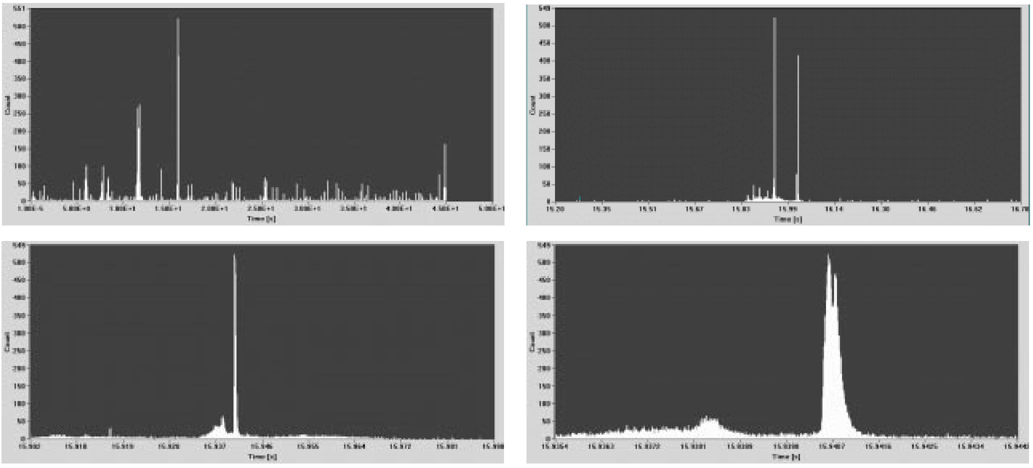


Fig. 7: Lightning bolts in a thunderstorm. Collection Time 10 us, Event Threshold 4 counts.