The HPM-100-50 Hybrid Detector: Increased Dynamic Range for DOT

The bh HPM-100-50 module combines a Hamamatsu R10467-50 GaAs hybrid PMT tube with the preamplifier and the generators for the PMT operating voltages in one compact housing. The principle of the hybrid PMT in combination with the GaAs cathode of the R10467-50 yields excellent NIR sensitivity, a clean TCSPC instrument response function, and virtually non-existent afterpulsing. The absence of afterpulsing results in a substantially increased dynamic range of TCSPC experiments. We demonstrate the performance of the new detector for the recording of time-of-flight distributions in experiments of diffuse optical tomography.

The bh HPM-100 modules combine a Hamamatsu R10467 hybrid detector tube [5] with the generator of the -8000 V acceleration voltage, the generator of the avalanche diode reverse voltage, and the preamplifier an a compact housing. We have shown before that the principle of the hybrid detector yields excellent timing resolution, a clean TCSPC instrument response function, high detection quantum efficiency, and large detection area [1, 2]. The most intriguing feature of the hybrid detectors is, however, that they are free of afterpulsing. Afterpulsing has been present in all photon counting detectors so far. In TCSPC experiments it results in a signal-dependent background that can be orders of magnitude higher than the thermal background [1]. The HPM detectors are free of this background and thus reach an unprecedented dynamic range for any kind of TCSPC measurements.

The hybrid detectors come in two cathode versions. The HPM-100-40 has a GaAsP cathode with a detection wavelength range of 300 to 700 nm and about 40% detection efficiency [2]. It is an excellent detector for fluorescence decay, FLIM, and FCS measurements. For applications in microscopy please see [3, 4]. The HPM-100-50 has a GaAs cathode and can be used from 400 to 900nm [5]. It has a detection efficiency of about 15% between 500 and 820 nm. Its typical application is in diffuse optical tomography and fluorescence decay measurement of NIR dyes.

To demonstrate the performance of the HPM-100-50 the test setup shown in Fig. 1 was used. A scattering phantom was placed directly between a bh BHL-600 (785 nm) laser and the detector (Fig. 1, left). Filters were inserted to adjust the light intensity and reduce the sensitivity to daylight. For IRF recording the phantom was replaced with barrel that contained an additional ND filter and a thin scattering foil (Fig. 1, right). Both for the phantom measurement and the IRF recording the same distance between laser and detector was maintained. The photon pulses of the HPM-100-50 were recorded by a bh SPC-150 TCSPC module [1].

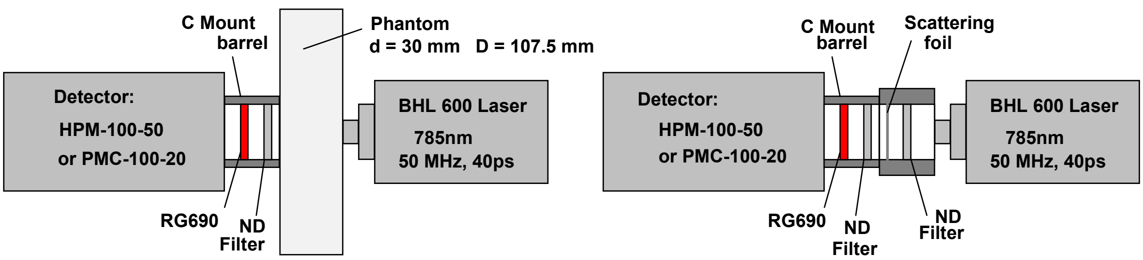

Fig. 1: Test setup. Left: Measurement of time-of-fight distribution in a phantom. Right: Measurement of instrument response function.

A recording obtained with the HPM-100-50 is shown in Fig. 2. For comparison, Fig. 3 shows reference data recorded with a conventional NIR PMT. A PMC-100-20 cooled PMT module was used for this measurement. The PMC-100-20 contains an R7400-20 TO-9 PMT within an H573-20 photosensor module [1]. To obtain comparable results the count rates for both detectors were adjusted to 1 MHz. The dark count rate was 2700 s^{-1} for the hybrid detector and 900 s^{-1} for the cooled PMT.

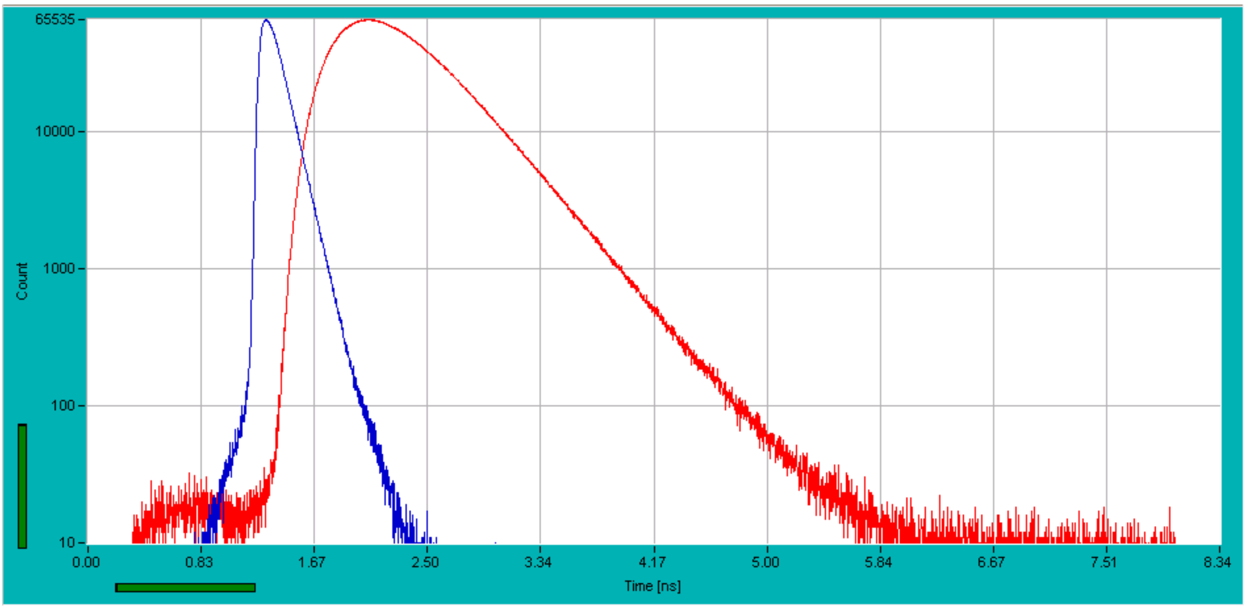

Fig. 2: DTOF (red) measured at the 30 mm phantom and IRF (blue). HPM-100-50 hybrid detector

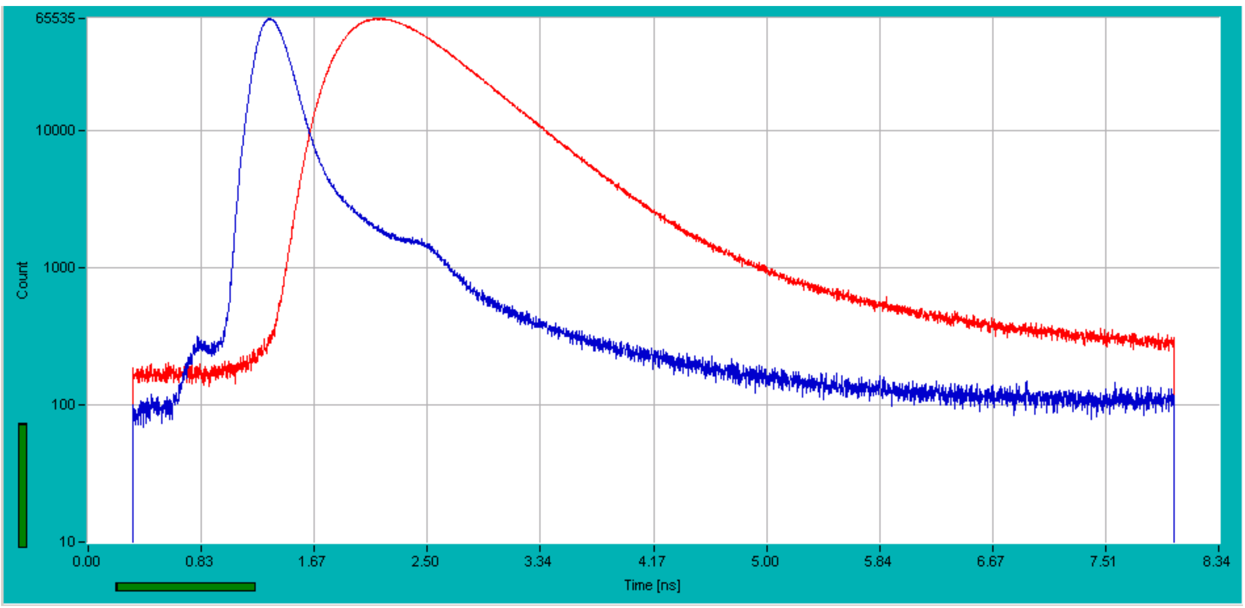

Fig. 3: DTOF (red) measured at the 30 mm phantom and IRF (blue). PMC-100-20 NIR PMT module

At first glance, it can be seen hat the dynamic range obtained with the HPM-100-50 detector is much higher. Despite of the higher dark count rate the background in the HPM recording is by about a factor of 20 lower than for the PMT. A comparison of the two recordings also shows that the HPM delivers a much cleaner IRF. Photons arriving only 1 ns after the peak of the DTOF are virtually free of IRF influence.

Conclusions

Compared to conventional NIR-sensitive PMTs the HPM-100-50 hybrid detectors deliver a dramatically increased dynamic range of TCSPC measurements. This is an obvious advantage for data analysis. The increased dynamic range is important especially for the detection of late photons. Clean detection of late photons is essential to DOT measurements because these are more likely to have travelled through deep layers of the tissue.

Moreover, the HPM-100-50 have an IRF free of tails or bumps. IRF measurement in DOT setups is still hampered by a number of pitfalls. A smaller influence of the IRF is therefore a clear advantage, no matter whether a diffusion model, or time-gates or moments of times-of-flight are used to analyse the data.

Considering the fact that the reverse problem of DOT sets extreme requirements to the raw data hybrid detectors are likely to improve the reliability at which tissue parameters can be derived.

References

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