

Influence of Magnetic Fields on the IRF of High-Speed Detectors for TCSPC

Abstract: We tested bh HPM hybrid detectors and bh PMCS PMT detectors for IRF changes induced by external magnetic fields. The effects were found surprisingly small. For a magnetic-field strength on the order of 100 Gauss the shift in the IRFs was between 1.75 ps and 14.5 ps compared to the field-free case, depending on the direction of the field. The FWHM changed from 16.4 ps to 18.4 ps for the HPM and 97 ps to 109 ps for the PMCS.

Motivation

It is commonly known that magnetic fields influence the detection efficiency and the temporal response of PMTs. For conventional PMTs the effects are so large that careful magnetic shielding is recommended. Understandably, users of TCSPC systems with PMTs or other vacuum-tube detectors are concerned that the temporal instrument-response function (IRF) of their system may change in the presence of magnetic fields. We therefore tested the bh HPM hybrid detector modules and the bh PMCS PMT detector modules for possible IRF changes by externally applied magnetic fields.

Experimental Setup

As a source of the field we used DD2 type disc magnets from K&J Magnetics, Inc., see Fig. 1, left. The magnet has a field perpendicular to the plane of the disc, with a surface strength of 1940 Gauss. For the tests we placed the magnet at the outside of the detector under test. For the HPM detector, the distance of the magnet from the detector axis was about 25 mm. The field strength in this distance is about 100 Gauss. For comparison, the magnetic field of the earth is about 0.5 Gauss. The field strength was calculated by the ‘K&J Magnetic Field Calculator’, available on www.kjmagnetics.com/fieldcalculator.asp. The field configuration is shown in Fig. 1, right.

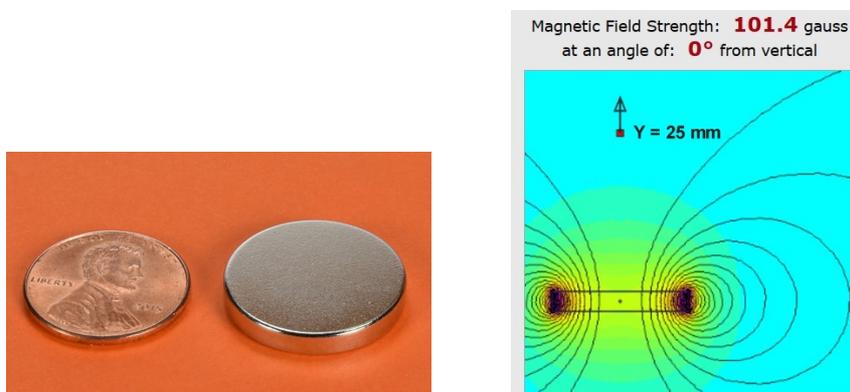


Fig. 1: Left: Magnet used for the test. Right: Field configuration and field strength at the magnetic axis 25 mm from the magnet. Both figures from www.kjmagnetics.com

IRF measurements were performed on a bh HPM-100-07 hybrid detector and a PMCS-150-01 PMT detector. Both detectors belong to the fastest of their kind. The HPM-100-07 yields an IRF width of < 20 ps [2]. The IRF with of the PMCs-150 is between 100 ps and 120 ps, depending on the size of the illuminated spot [1]. Both detectors have multialkali cathodes. Different than for detectors with GaAsP or GaAs cathodes, the electron emission from the multi-alkali cathode occurs instantaneously and thus does not contribute to the IRF. A possible effect of a magnetic field on the electron trajectories and thus on the IRF therefore should stand out clearly.

The IRFs were recorded with a bh SPC-150NX TCSPC module, with an electrical IRF of about 3.5 ps FWHM [1]. As a test light source we used a FemtoFibre pro femtosecond-fibre laser from Toptica. The wavelength is 780 nm, the beam diameter 1.5 mm. The laser beam was attenuated by a package of ND filters and, without other optical elements, projected to the photocathode of the detector. The magnets were applied with their magnetic axis perpendicular to the detector axis and under 45 degrees to it. The test configurations are shown in Fig. 2.



Fig. 2: Magnetic-field configurations tested. Field direction from detector axis: Left (a) 90 deg horizontal, middle (b) +45 degree vertical, right (c) -45 degree vertical

Results

The results were a surprise. For none of the field configurations large changes in the IRF shape and IRF position were detected. The results for the hybrid detector are shown in Fig. 3. The black curves are reference curves recorded without the magnetic field. One curve was recorded at the beginning, the other at the end of the experiments. The FWHM is 16.3 ps and 16.5 ps, and the shift in the first moment is 0.5 ps. This is within the natural fluctuation by the low-frequency timing wobble of the laser sync output and the photon timing in the SPC module. The blue curve shows the IRF for field configuration a, i.e. with the field axis horizontally and perpendicular to the axis of the detector. The shift in the first moment versus the averaged reference curves is 1.75 ps, the FWHM is 16.5 ps. The green and the red curves show the IRF for the +45-degree and -45-degree configurations. The shifts are 9.45 ps and 14.4 ps. The FWHMs increased slightly to 18.4 ps and 17.7 ps, respectively. It seems that the magnitude of the IRF shift depends on the location of the illuminated spot on the photocathode. The shifts given here are the largest we were able to obtain when we varied the beam position.

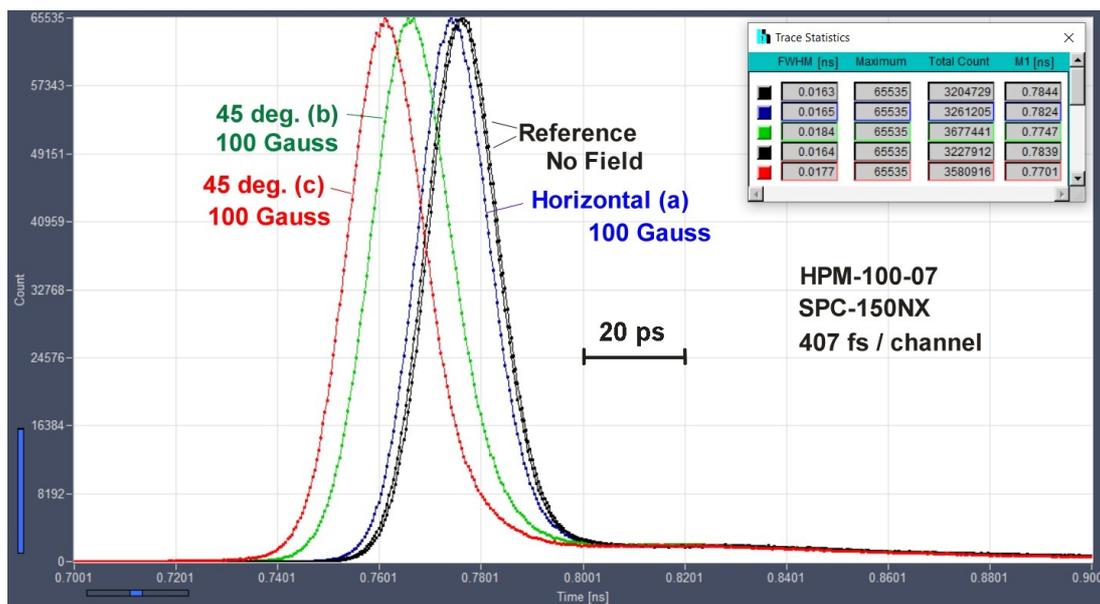


Fig. 3: IRFs recorded for the field-free case and for configurations a, b, and c. Time scale 20 ps / division, 200 ps for entire time axis

Similar measurements were performed on a bh PMCS-150 detector. The field configurations were 90 degree horizontal, 90 degree vertical, and +45 degrees, see Fig. 4. Due to the smaller size of the PMCS module, the magnet comes closer to the detector. The field strength in the axis of the detector was therefore 150 Gauss, i.e. slightly higher than for the HPM module. The results are shown in Fig. 5. The ‘no field’ IRF and the two 90-degree IRFs are indistinguishable. The IRF widths are about 97 ps FWHM. The 45-degree IRF is shifted by 9.7 ps toward later times, and the FWHM is increased to 109 ps.

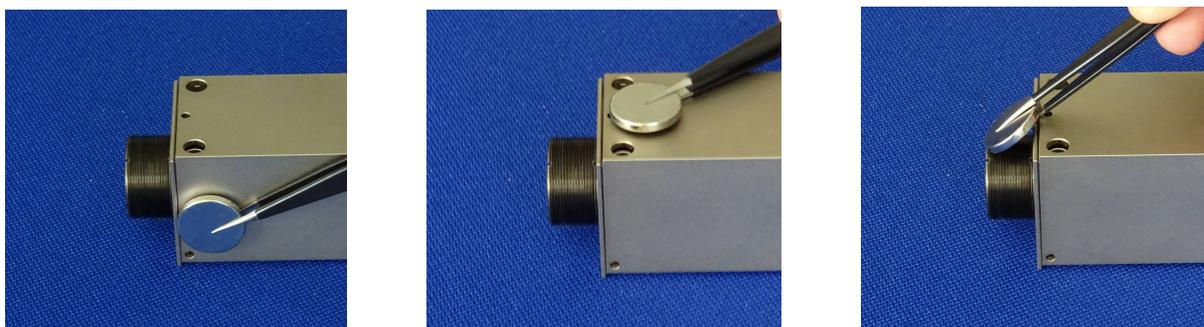


Fig. 4: Magnetic-field test configurations for the PMC-150 detector. Field direction from detector axis: Left (a) 90 deg horizontal, middle (b) 90 degree vertical, right (c) +45 degree vertical

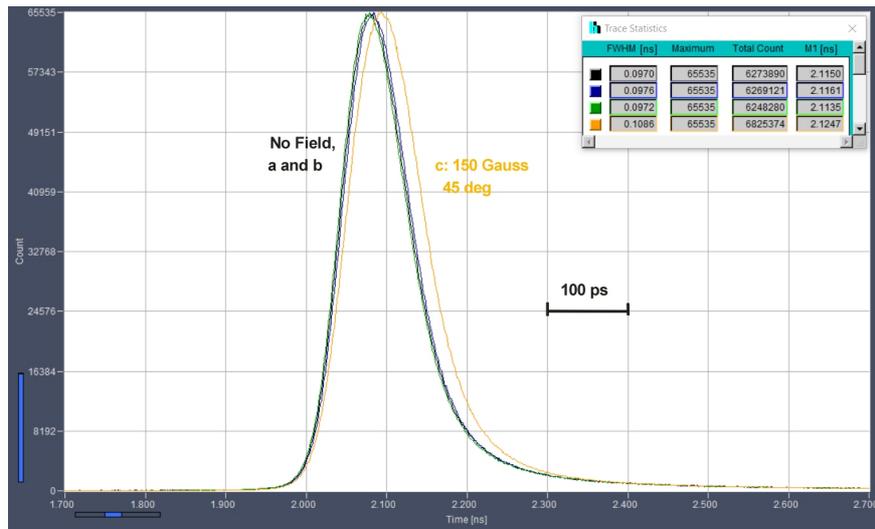


Fig. 5: Magnetic-field dependence of IRF of PMCS-150 detector. Time scale 100 ps / div, entire time axis is 1 ns. Note different time scale compared to Fig. 3

Discussion of the Results

The IRF shifts found in our experiments were surprisingly small. The shift observed for the HPM (see Fig. 3) may look large in comparison to the IRF width. However, it is only 14.4 ps, which is on the order of the timing instability of medium-resolution TCSPC devices. The small size of the shift is even more surprising, as the detector does not incorporate any magnetic shielding. The explanation is the high acceleration voltage of 8000 V, which results in a high electrical field strength inside the hybrid-detector tube [3]. It is also plausible that the shift is largest for the 45-degree configurations. In these cases, the strongest magnetic field is in the vicinity of the cathode, where the velocity of the photoelectrons is lowest.

The small size of the effect of the magnetic field on the PMCS is similarly surprising. The detector contains a Hamamatsu H11901 photosensor module [4], which is based on a TO9 miniature PMT. Different than for the HPM, the acceleration voltages between the cathode and the first dynode and between the dynodes are on the order of only 100 V. The explanation of the small influence of the magnetic field is the small size of the detector. The cathode-dynode distance and the interdynode distances are about 1 mm. This results in relatively high electrical-field strengths, and in short electron trajectories. Moreover, the H11901 modules incorporate magnetic shielding. The only way the magnetic field can get into the tube is via the cathode window. This is supported by the fact that the largest variation in the IRF was found for the 45-degree configuration.

References

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3. R10467 Series high speed compact HPD, www.hamamatsu.com
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