17/01/2024 – solution draft

Pb1)

1) The signal shape is not affected by the preamplifier, which provides an upper limitation to white noise. At the sampling frequency, noise samples are uncorrelated. Therefore, a digital weighting function featuring the same exponential shape of the signal maximizes the SNR.

$$\frac{S}{N} = \frac{V_P}{\sqrt{S_V \frac{\pi}{2} f_A}} * \sqrt{\frac{\tau_P}{2T_S}} \rightarrow V_{P,MIN} \cong 79\mu V.$$

2) The reduced sampling frequency allows us to collect up to 3 samples (within $5\tau_P$). The additional wideband noise is correlated with a time constant of 160ns therefore its noise samples are correlated. Considering 3 samples with exponentially decreasing weight ($1, e^{-\frac{T_S}{\tau_P}}, e^{-\frac{2T_S}{\tau_P}}$), the autocorrelation function of the weighting function has five values centered around zero. Noise contribution is dominated by the correlated noise, leading to $V_{P,MIN} \cong 113\mu V$
3) See theory

Pb2)

A 50Ω resistor is considered to collect the PMT signal along with an excess noise factor of the PMT F=2. It can be assumed that no background is present.

1) A low pass filter with fp=50Hz can be used to limit noise. A high pass filtering action is also necessary due to the presence of 1/f noise, i.e. a zero with equivalent fp,eq=44µHz setting (worst case: 1h before the measurement). The dominant contribution of electronics noise with respect to shot noise of both signal and dark current results into $I_{S,MIN} = 334pA$ and thus $P_{MIN} = 8{,}35nW$.
2) The exploitation of a chopper (fmod = 20kHz) provides a modulated light signal. A squarewave LIA (+/-1) provides the best possible filtering action. The DC component of the signal is inevitably lost. In this scenario, $I_{S,MIN} = 0{,}2fA$ and thus $P_{MIN} = 5fW$
3) See theory