Problem 1

1) The signal is superimposed to an integrated noise (1/f^2 component). Therefore, the optimum filter consists of a **whitening filter** followed by the **matched filter**. At the output of the whitening filter, the noise is white (limited only by the preamp pole) and the signal has its original exponential shape. For each pulse we have $SNR_{OPT}=A_P/\mathrm{sqrt}(S_V/2) * \mathrm{sqrt}(T_P/2)$. $A_{P,MIN}$ = 7.1µV.
2) The repetitive nature of the signal can be exploited either with a **Boxcar Integrator or with a Ratemeter Integrator (following the whitening filter)**, obtaining the same result by fairly sizing their parameters. On the single pulse we apply a GI with $T_G = 1.25T_P$ and the enhancement factor of either BI or RI is 20.
$A_{P,MIN}$ = 0.395µV
3) Keeping the whitening filter, we have 1/f noise in addition to white noise, potentially causing a divergent noise contribution. In a real case, we can consider a **zero setting** once every 20min. 1/f noise contribution on the single integration window is 1.1.35µV, lower than 4.47µV due to white noise. However, **the BI or RI reduce the white noise contribution, and 1/f noise becomes the dominant contribution**. To reduce its impact, we can use a **CDF** with an integration window for only noise placed right before the integration of each pulse and 10 times longer to **avoid noise doubling**. By doing so $A_{P,MIN}$ = 0.73µV

Problem 2

1) Reasonable parameters for an APD for the NIR are **R=0.2, t_N=0.2µm, t_D=10µm**; as a result: PDE(800nm)=0.5, S_D=0.32A/W. The overall light reaching the detector is a constant contribution due to the fluid and a rectangular signal caused by the bubble. We can use a **zero setting** to remove the fluid contribution that is 5 times higher than the signal of interest (bubble). The duration of the bubble pulse is 5µs. We can use a **Gated Integrator** with the same duration of the bubble. In the best case (the whole bubble falls within the integration window), the noise associated with the bubble and fluid is the dominant contribution. In this case, I_{SMIN}=38.4pA and $P_{LASER,MIN}=I_{SMIN}/0.01/S_D$ = 12nW.
2) With a larger pulse due to the bubble, we can use a **larger integration window** (5ms). In this case, the electronics noise is the dominant contribution. I_{SMIN}=59.4fA and $P_{LASER,MIN}=I_{SMIN}/0.01/S_D$ = 18.56pW.
3) Without modulation, 1/f noise is only limited by a **zero setting**, leading to I_{SMIN}=834.4fA and $P_{LASER,MIN}=I_{SMIN}/0.01/S_D$ = 260.8pW. To modulate the signal, we can use a **chopper and a LIA with +/-1 demodulation** and a GI. In this case, we collect only white noise and half of the signal. Therefore, $Plaser_{MIN} \approx 2 * Plaser,_{MIN}$ of point 2.