Avalanche Photodiodes and Direct Detection

One way to reduce the effect of noise in direct detection is to use gain. This gain can be from a fiber amplifier before detection, but the most common type of gain is avalanche gain after detection. Expanding the noise terms results in

\[
SNR = \frac{\langle i_s^2 \rangle}{\langle i_n^2 \rangle} = \frac{G^2 R^2 P_s^2}{2eBG^2F[\Re(P_s + P_{LO} + P_{bk}) + P_{dks}] + 2eBi_{dks} + 4(kTB/R_L)}
\]

Gain after detection reduces the influence of surface dark current and thermal noise. Background radiation is amplified in the same way that the signal is amplified. Bulk dark current can also be amplified in an APD.

Amplification adds noise. For a background-limited direct detection receiver,

\[
SNR = \frac{\eta_DP_s^2}{2h\nu BP_{bk}}
\]

Within the limit in which the signal shot noise dominates the other noise terms, the SNR is given by

\[
SNR_{\text{shot,lim}} = \frac{\eta_DP_R}{2h\nu B}
\]

Within this limit, the SNR is directly proportional to the number of photons received. This is the best that can be achieved and is the goal of using gain.