

# Improving the performance of CV-QKD with multi-mode signals

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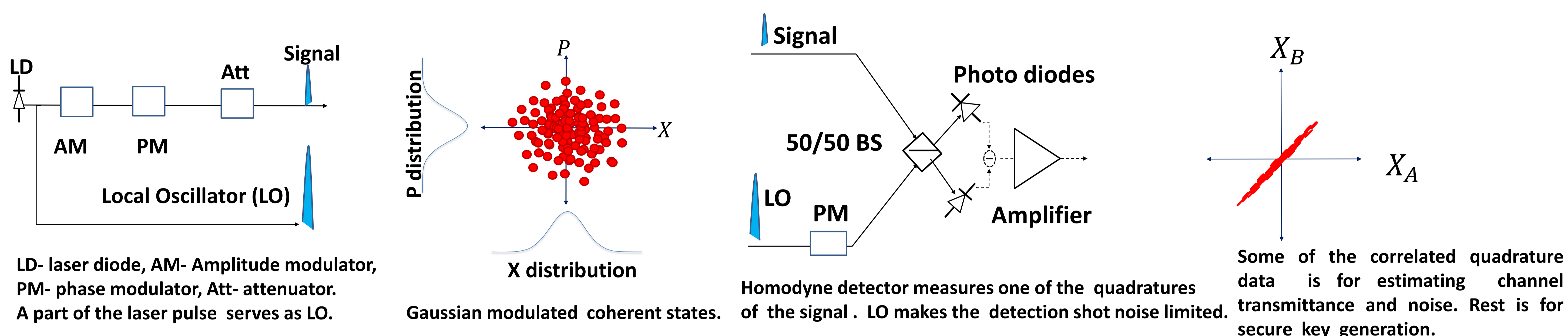
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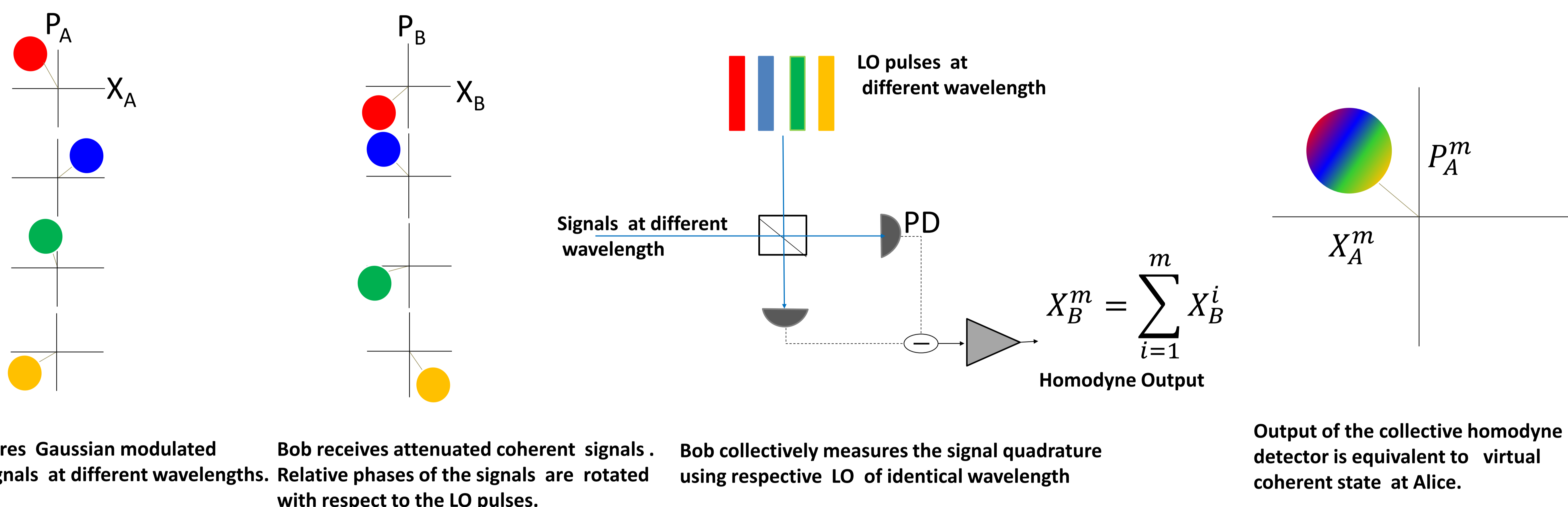


**Introduction-** One of the limitation of CV-QKD systems is low secure key generation rate at longer transmission distances. One can consider using high bandwidth operation for increasing the key rate, but elevated electronic noise at higher bandwidth decreases the signal to noise ratio (SNR) and makes it difficult to perform error correction. In order to improve the SNR, multi-mode signals can be used with a collective detection of all the signal quadrature at once using mode matched local oscillators[1][2].

**Single-mode CV-QKD** - Conventional CV-QKD uses single wavelength, polarization, spatial-temporal mode.



**Multi-mode CV-QKD** – Alice prepares multiple wavelength signals each with random quadrature modulation.



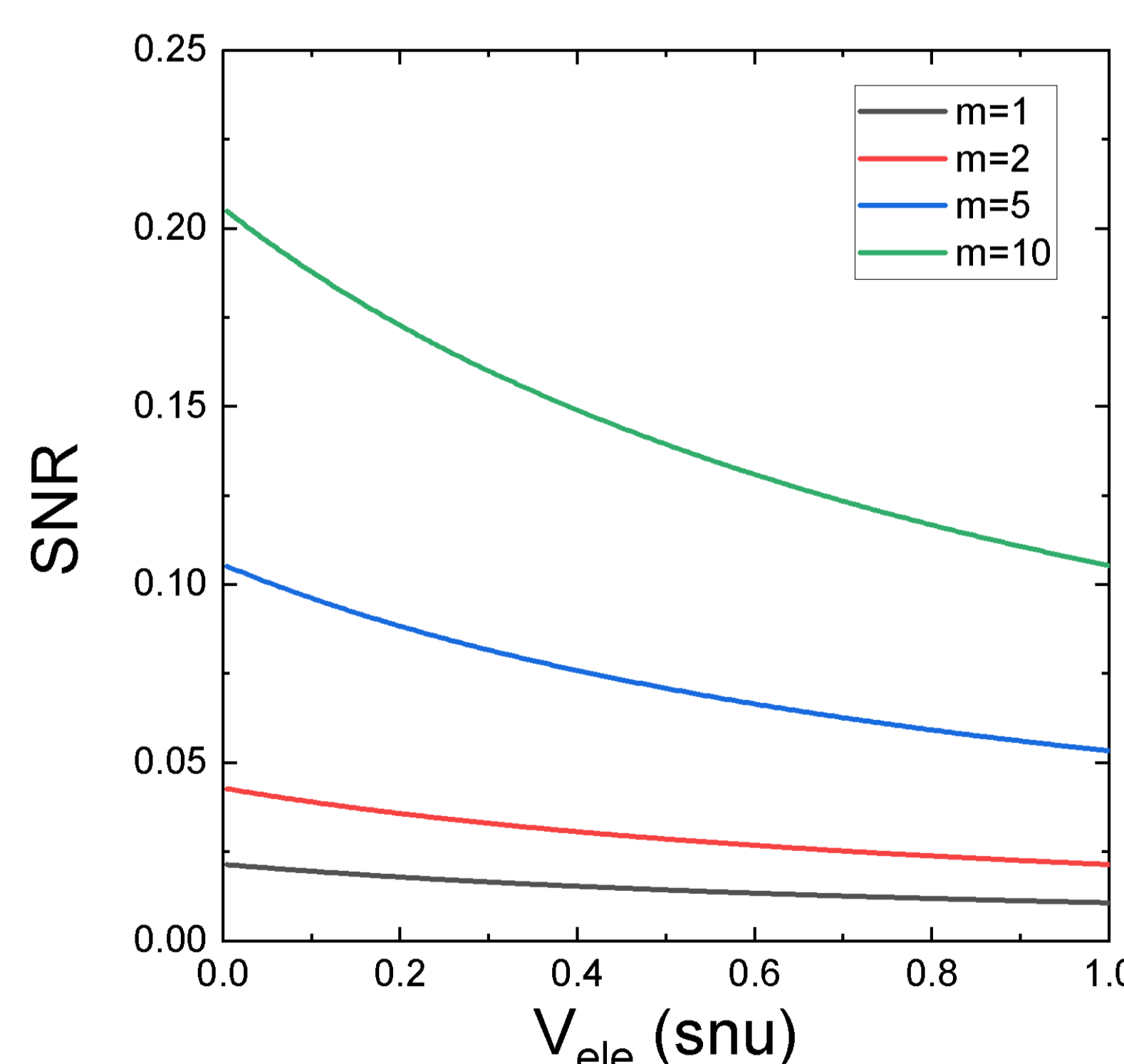
**Results-** Collective detection of multi-mode signals effectively reduces the contribution of electronic noise.

$$\text{Single-mode } SNR_1 = \frac{V_A}{1 + \chi_{tot}}$$

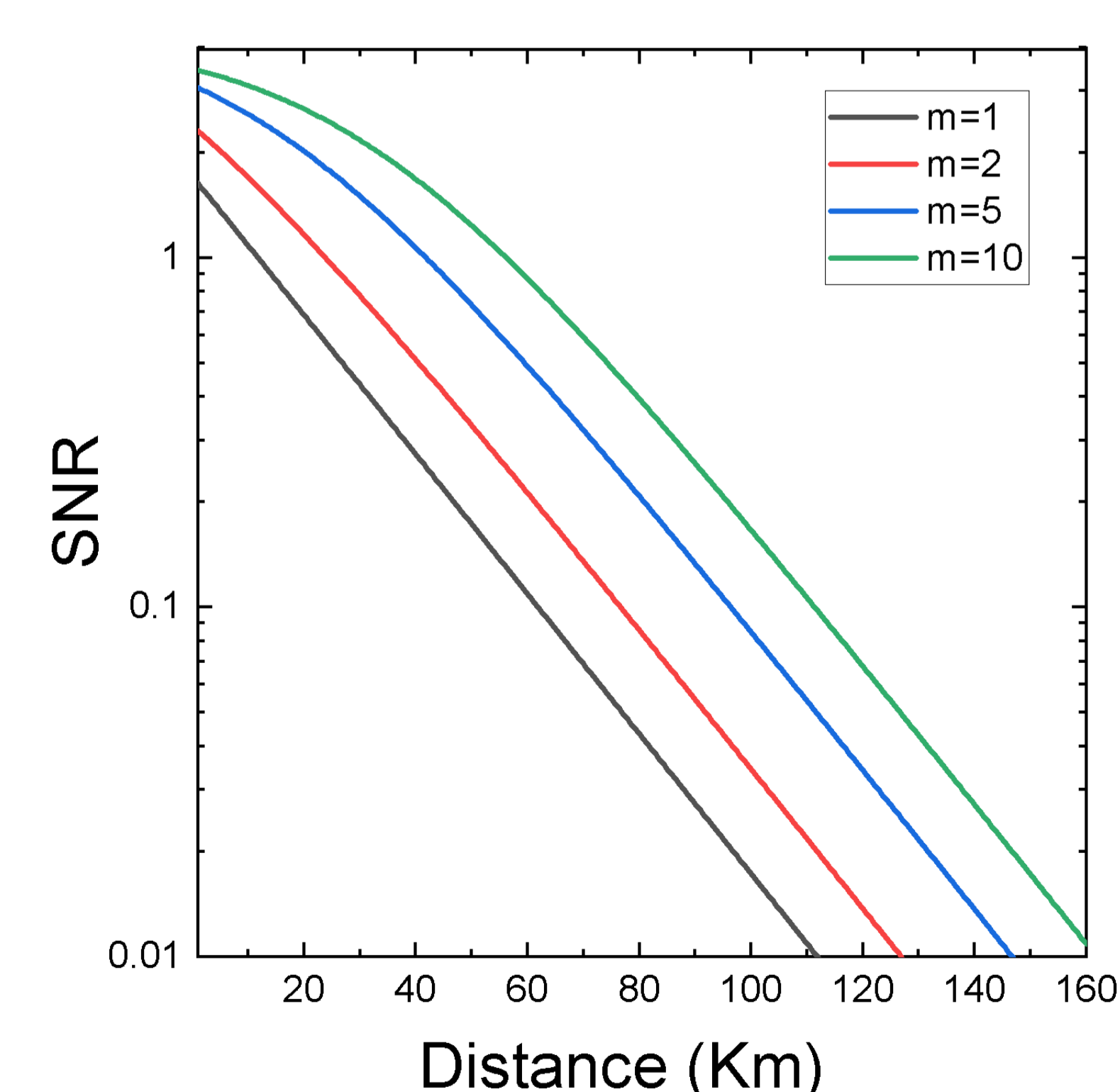
$$\text{Multi-mode } SNR_m = \frac{mV_A}{m + \chi_{tot} + (m - 1)\xi}$$

$V_A$  - signal variance,  $\chi_{tot}$  -total noise,  $m$  -number of modes and  $\xi$  -excess noise.

**Conclusion** - Error correction is a bottleneck in CV-QKD for achieving secure key generation at longer transmission distances. LDPC codes are widely used in CV-QKD and the construction of these ,at very low SNR, is very difficult. Using multi-mode signals with collective quadrature detection can increases the SNR in CVQKD and improves the overall transmission distance . With  $m=5$ , the SNR is increased by 5 times and the transmission distance by 30 percent.



SNR at various electronic noise. The black line represents the SNR of single mode CVQKD, while red, blue and green lines represents multi-mode signals with number of mode  $m = 2, 5$  and  $10$  respectively.



SNR at various transmission distances. Consider the error correction code to function at  $SNR > 0.01$ , then for higher  $m$  the same code can generate key at longer distance.