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Clock recovery for a CV-QKD system

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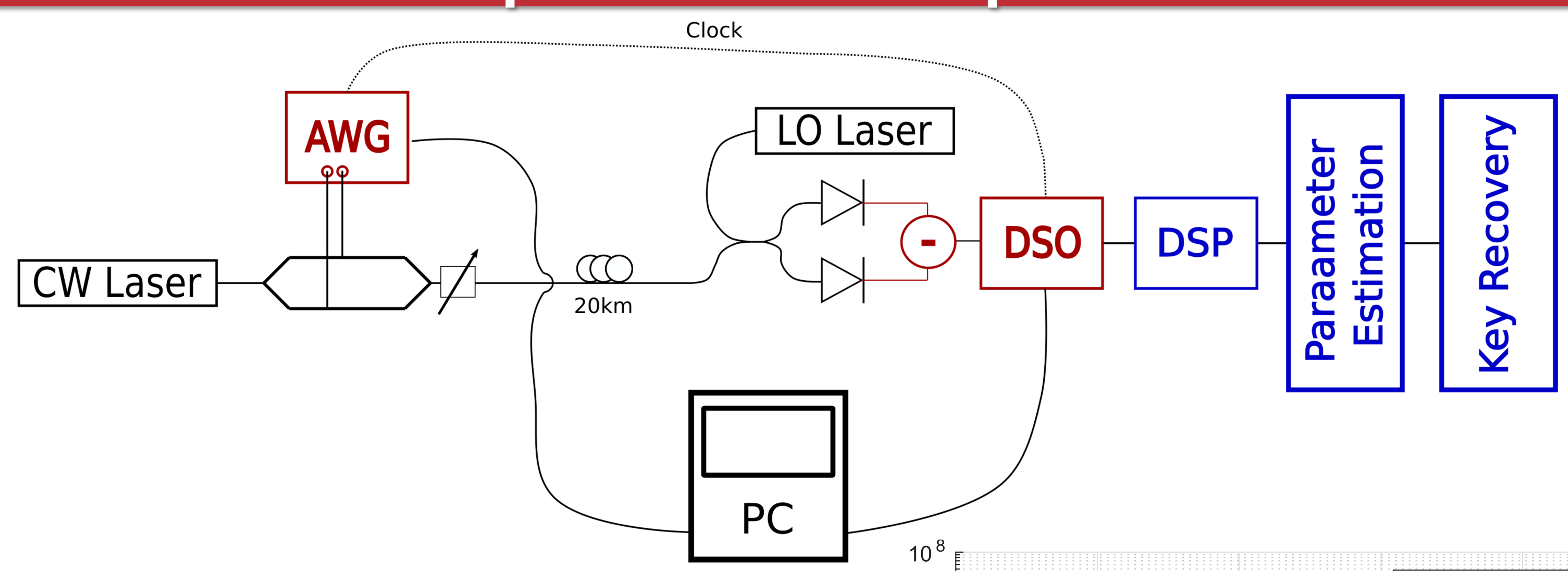
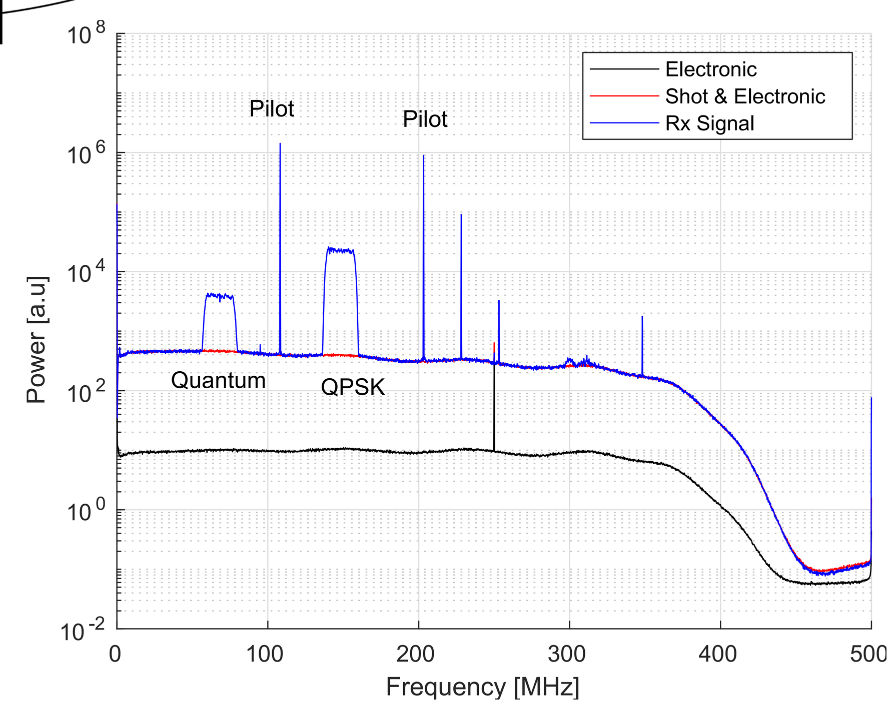
1. Introduction

- A typical laboratory CV-QKD setup has the benefit of being clock synchronized using a RF cable
- A realistic CV-QKD system must be able to perform clock synchronization without this capability
- Existing solutions consist of:
  - Transmitting the clock on a different frequency [1]
  - Time multiplexing the clock tone [2,3]
- Alice and Bob must hold classical communications with each other
- We propose to use the classical signal to aide in performing clock recovery on the QKD signal

2. Experimental setup



- Alice modulates a 20 Mbaud quantum signal with mean photon number $N \approx 2.5$, frequency multiplexed QPSK signal and two pilot tones onto laser with a 1 Gsample/s AWG and transmits over 20 km SMF
- Bob detects the signal with a balanced heterodyne setup with $\eta \approx 0.84$
- Tx and Rx lasers are free running
- Measurement performed with 40 blocks of 25 frames 40 x 10^3 symbols long



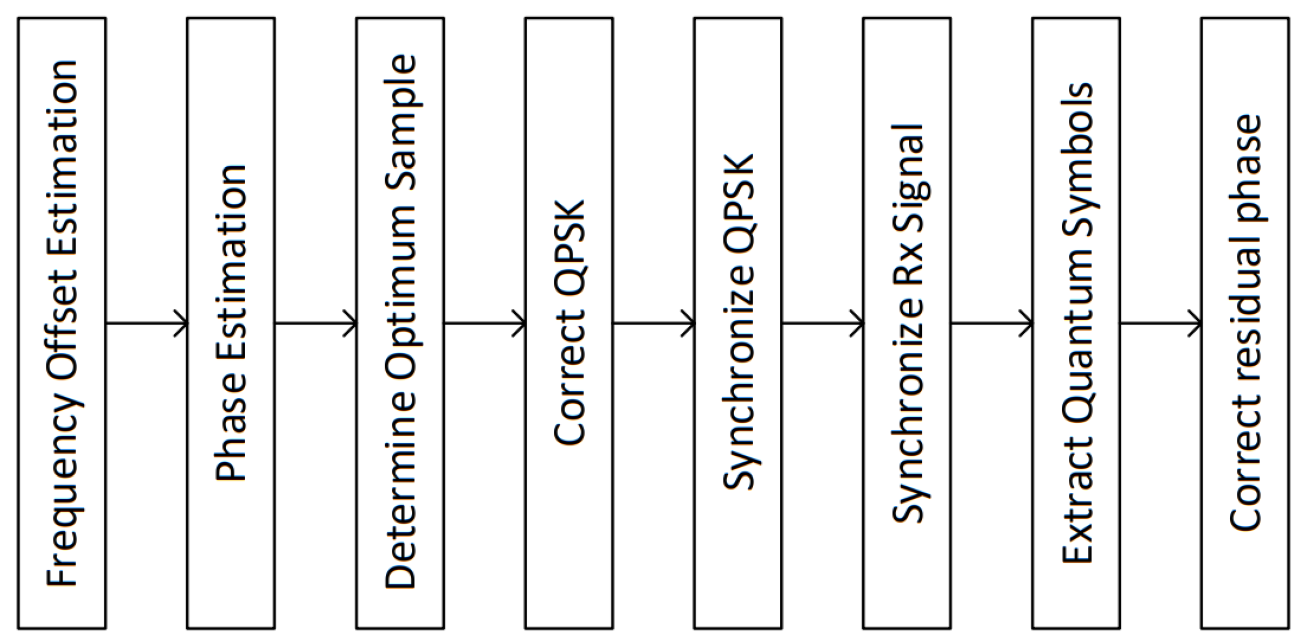
3. Digital Signal Processing

- Frequency offset estimation performed by estimating location of both pilot tones and then calculating the relative error per Hz to determine frequency of received signals as defined by Bob
- Phase estimation performed using machine learning framework [4]
- Modified Gardner timing error detector for optimum sampling point

$$\tau_{err}(n) = \left(\left|y\left(n - {}^{sps}/_{2}\right)\right|^2 - \left|y\left(n + {}^{sps}/_{2}\right)\right|^2\right) \times |y(n)|^2$$

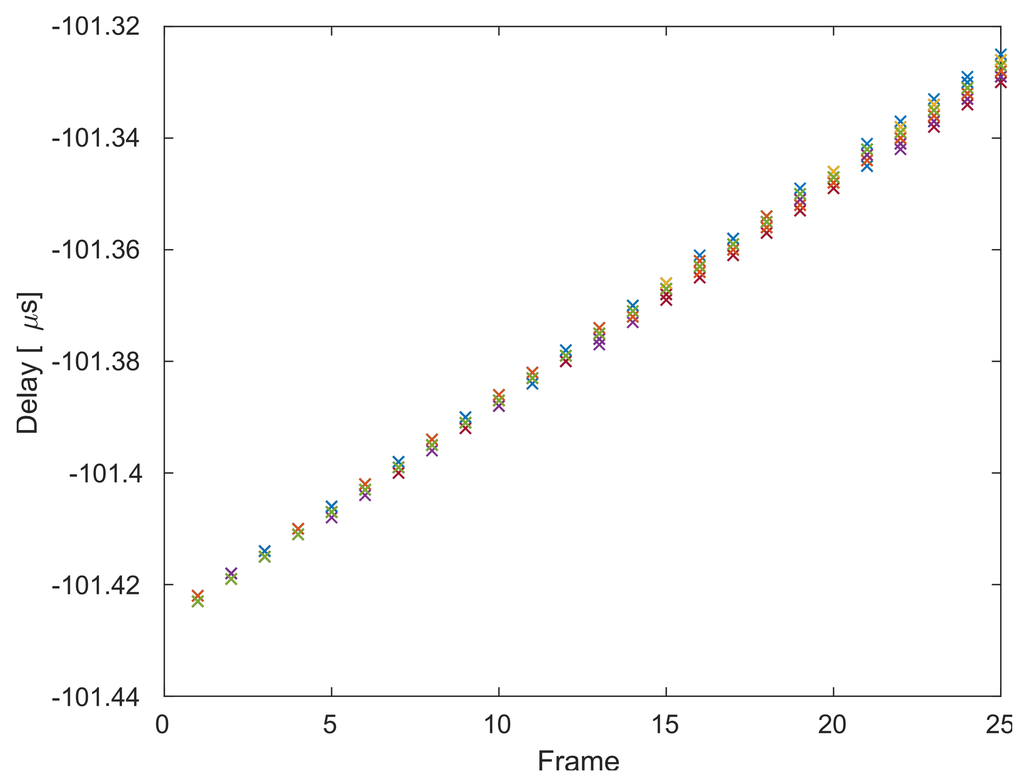
- Extract and find known QPSK header symbols
- Synchronize quantum signal
- Extract quantum symbols
- Correct for any residual phase

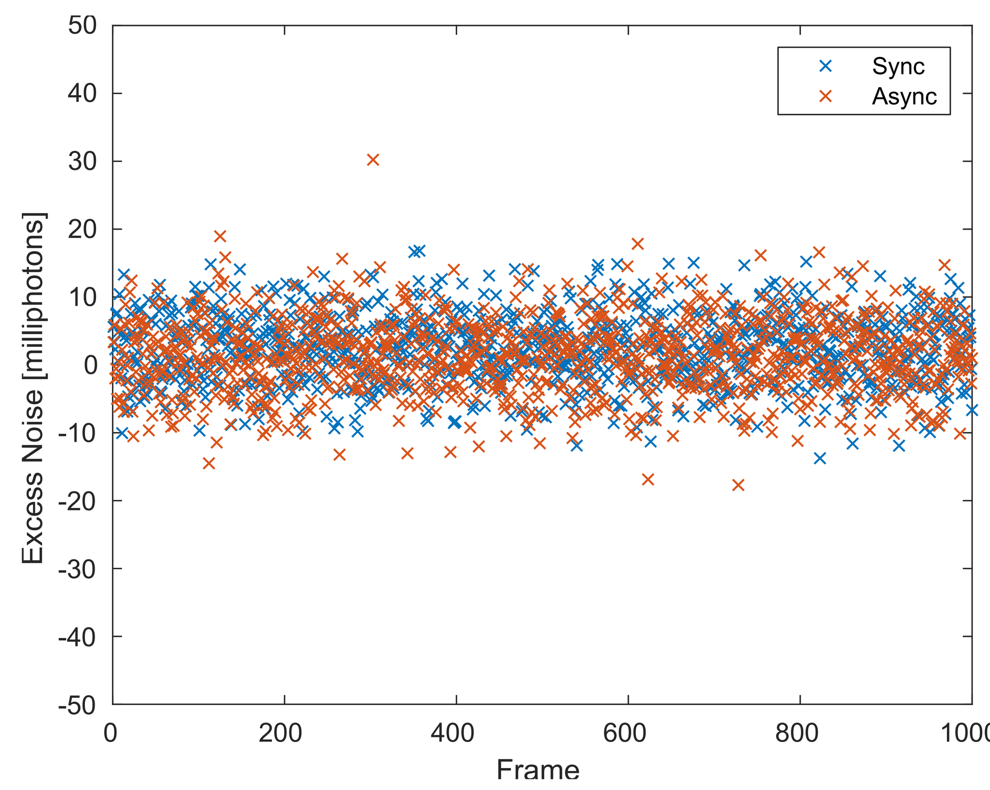
sps	Samples per symbol
y	Rx signal
n	Sample index per symbol
τ_{err}	Timing error



4. Results

- Initial benchmark performed with a 10 MHz external clock synchronizing Alice and Bob
- Modulation and detection are triggered hence the spread of delays increase with progression through frame numbers
- Asynchronous measurements yielded similar values of excess noise to synchronized with respective means of 1.3 and 2.2 mEP, $\sigma = 5.5$ and 5.2 mEP
- This corresponds to asymptotic key rates of 0.0587 and 0.0476 bits per symbol





5. Conclusions

- The proposed clock synchronization procedure performs well when performed for an asynchronous CV-QKD system yielding similar performance to an externally clock synchronized system
- The algorithm doesn't require additional hardware complexity
- The performance is bounded by the signal to noise ratio of the classical channel which, over typical CV-QKD transmission distances is more than sufficient

References

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