Claims

1. A method of time synchronisation in a satellite based quantum key distribution (QKD) system, the method comprising:

at a transmitter, emitting a first series of laser pulses, the first series of laser pulses being encoded to form a quantum beam;

at the transmitter, emitting a second series of laser pulses, the second series of laser pulses having a predetermined repeating pattern; and

at the transmitter, sending the first and second series of laser pulses to a receiver;

at a receiver, receiving the first series of laser pulses and the second series of laser pulses at the receiver and determining reception times of pulses of the first series of laser pulses and pulses of the second series of laser pulses;

comparing the received second series of laser pulses to the predetermined pattern at different points in the predetermined pattern, and determining the point at which the received second series of laser pulses is most strongly correlated to the predetermined pattern;

with the received second series of laser pulses aligned to the predetermined pattern at the determined point, determining a relationship fitting respective reception times of a plurality of the received second series of laser pulses to respective emission times of corresponding ones of the second series of laser pulses; and

using the determined relationship to convert between reception times of the first series of laser pulses and emission times of corresponding ones of the first series of laser pulses.

2. The method as claimed in claim 1, wherein the reception times of the first series of laser pulses are converted into emission times of corresponding ones of the first series of laser pulses.

3. The method as claimed in claim 1, wherein the emission times of the first series of laser pulses are converted into reception times of corresponding ones of the first series of laser pulses.

4. The method as claimed in any preceding claim, wherein the relationship fitting respective reception times of a plurality of the received pulses to respective emission times of corresponding ones of the second series of laser pulses is a polynomial function.

5. The method as claimed in any preceding claim, wherein the predetermined pattern comprises a series of frames, and the comparing the received second series of laser pulses to the predetermined pattern at different points in the predetermined pattern, and the determining the point at which the received second series of laser pulses is most strongly correlated to the predetermined pattern, are carried out for each frame of the predetermined pattern; and

preferably, wherein the predetermined pattern is a pseudo-random pattern; and

preferably, wherein the pseudo-random pattern is a de Bruin sequence.

6. The method as claimed in any preceding claim, wherein the second series of laser pulses have a predetermined baud rate according to a transmitter clock; and

the method further comprising:

measuring the baud rate of the second series of laser pulses at the receiver using a receiver clock;

comparing the measured baud rate to the predetermined baud rate to determine a clock slope corresponding to a difference between a receiver clock rate and an apparent transmitter clock rate; and

using the clock slope to adjust the determined reception times of pulses of the first series of laser pulses before comparing the received second series of laser pulses to the predetermined pattern at different points in the predetermined pattern; and

preferably, wherein the predetermined pattern comprises a series of frames, and wherein measuring the baud rate of the second series of laser pulses at the receiver using a receiver clock comprises:

measuring the total time taken to receive a frame of the predetermined pattern using the receiver clock;

determining the difference between the measured total time and a total frame time at the predetermined baud rate; and

dividing the difference between the measured total time and the total frame time by a number of symbols in the frame.

7. The method as claimed in any preceding claim, wherein the first series of laser pulses have a first wavelength, and the second series of laser pulses have a second wavelength different from the first wavelength; and

preferably, wherein the first series of laser pulses and the second series of laser pulses are combined into a single beam at the transmitter using a dichroic mirror; or

wherein the first series of laser pulses and the second series of laser pulses are separated at the receiver using a dichroic mirror.

8. The method as claimed in any one of claims 1 to 6, wherein emitting the first series of laser pulses and the second series of laser pulses comprises emitting a single series of laser pulses, with predetermined pulses of the single series of laser pulses being used as the second series of laser pulses; and

preferably, wherein the remaining laser pulses of the single series of laser pulses which are not the predetermined pulses are used as the first series of laser pulses.

9. The method as claimed in claim 8, wherein the first series of laser pulses and the second series of laser pulses are produced by the same laser source.

10. The method as claimed in claim 8 or claim 9, wherein every n-th laser pulse of the single series of laser pulses is used as the second series of laser pulses and the remaining laser pulses of the single series of laser pulses are used as the second series of laser pulses, wherein n is an integer greater than 1.

11. The method as claimed in any one of claims 8 to 10, wherein the second series of laser pulses are encoded in a different manner to the first series of laser pulses.

12. The method as claimed in claim 11, wherein the second series of laser pulses are encoded in a manner having a bias between different states compared to the first series of laser pulses; or

wherein the first series of laser pulses are encoded with a plurality of different polarisation states and the second series of laser pulses are encoded using a sub-set of the plurality of different polarisation states; and

preferably, wherein the second series of laser pulses are encoded in a manner having a bias between different polarisation states compared to the first series of laser pulses.

13. The method as claimed in claim 10 or claim 11, wherein the first series of laser pulses are encoded with a plurality of different polarisation states and each pulse of the second series of laser pulses is sent using all of the plurality of different polarisation states.

14. The method as claimed in any one of claims 9 to 13, wherein the first series of laser pulses are faint laser pulses and the second series of laser pulses have a higher intensity than the first series of laser pulses.

15. The method as claimed in claim 9, wherein the first series of laser pulses are faint laser pulses and the second series of laser pulses have a higher intensity than the first series

of laser pulses, and wherein the first series of laser pulses are attenuated and the second series of laser pulses are not attenuated.

16. The method as claimed in any preceding claim, wherein the first series of laser pulses are faint laser pulses, and preferably are single photon events; or

wherein the first series of laser pulses are encoded with a plurality of different polarisation states through different polarisation channels, wherein the method further comprises:

generating a histogram of photon detection events having different polarisation states; and

analysing the histogram to determine time offsets between the different polarisation channels.

17. The method as claimed in any one of claims 1 to 8, wherein the method further comprises a calibration mode; and

further comprising, in the calibration mode:

at the transmitter, emitting a third series of laser pulses having specific predetermined encoding states, and emitting the second series of laser pulses, and sending the third series of laser pulses and the second series of laser pulses to the receiver;

at the receiver, receiving the second series of laser pulses and the third series of laser pulses and determining reception times of pulses of the second series of laser pulses and pulses of the third series of laser pulses;

calculating the quantum error bit rate (QBER) for the third laser pulses having each encoding state at each of a plurality of different time offset values relative to a timing of pulses of the second series of laser pulses; and

for each encoding state, identifying a time offset value having the lowest QBER as the timing offset value for laser pulses having that encoding state from a timing of pulses of the second series of laser pulses; or

further comprising, in the calibration mode:

at the transmitter, emitting a third series of laser pulses having specific predetermined encoding states, and emitting the second series of laser pulses, and sending the third series of laser pulses and the second series of laser pulses to the receiver;

at the receiver, determining a timing offset between the ones of the third series of laser pulses having each encoding state and the timing of pulses of the second series of laser pulses.

18. The method as claimed in any preceding claim, wherein the using the determined relationship to convert between reception times of the first series of laser pulses and emission times of corresponding ones of the first series of laser pulses is carried out at the receiver.

19. A system for time synchronisation in a satellite based quantum key distribution (QKD) system, the system comprising:

a transmitter arranged to:

emit a first series of laser pulses, the first series of laser pulses being encoded to form a quantum beam;

emit a second series of laser pulses, the second series of laser pulses having a predetermined repeating pattern; and

sending the first and second series of laser pulses to a receiver; and

a receiver arranged to receive the first series of laser pulses and the second series of laser pulses and determine reception times of pulses of the first series of laser pulses and pulses of the second series of laser pulses;

the system being arranged to:

compare the received second series of laser pulses to the predetermined pattern at different points in the predetermined pattern, and determine the point at which the received second series of laser pulses is most strongly correlated to the predetermined pattern;

with the received second series of laser pulses aligned to the predetermined pattern at the determined point, determine a relationship fitting respective reception times of a plurality of the received second series of laser pulses to respective emission times of corresponding ones of the second series of laser pulses; and

use the determined relationship to convert between reception times of the first series of laser pulses and emission times of corresponding ones of the first series of laser pulses.

20. A method of time synchronisation at a receiver in a satellite based quantum key distribution (QKD) system, the method comprising:

receiving a first series of laser pulses encoded to form a quantum beam and a second series of laser pulses having a predetermined repeating pattern, and determining reception times of pulses of the first series of laser pulses and pulses of the second series of laser pulses;

comparing the received second series of laser pulses to the predetermined pattern at different points in the predetermined pattern, and determining the point at which the received second series of laser pulses is most strongly correlated to the predetermined pattern;

with the received second series of laser pulses aligned to the predetermined pattern at the determined point, determining a relationship fitting respective reception times of a plurality of the received second series of laser pulses to respective emission times of corresponding ones of the second series of laser pulses; and

using the determined relationship to convert between reception times of the first series of laser pulses and emission times of corresponding ones of the first series of laser pulses.

21. A system for time synchronisation in a satellite based quantum key distribution (QKD) system, the system comprising a receiver arranged to:

receive a first series of laser pulses encoded to form a quantum beam and a second series of laser pulses having a predetermined repeating pattern, and to determine reception times of pulses of the first series of laser pulses and pulses of the second series of laser pulses;

compare the received second series of laser pulses to the predetermined pattern at different points in the predetermined pattern, and determine the point at which the received second series of laser pulses is most strongly correlated to the predetermined pattern;

with the received second series of laser pulses aligned to the predetermined pattern at the determined point, determine a relationship fitting respective reception times of a plurality of the received second series of laser pulses to respective emission times of corresponding ones of the second series of laser pulses; and

use the determined relationship to convert between reception times of the first series of laser pulses and emission times of corresponding ones of the first series of laser pulses.

22. A method of time synchronisation at a transmitter in a satellite based quantum key distribution (QKD) system, the method comprising:

emitting a first series of laser pulses, the first series of laser pulses being encoded to form a quantum beam;

emitting a second series of laser pulses, the second series of laser pulses having a predetermined repeating pattern; and

sending the first and second series of laser pulses to a receiver.

23. A system for time synchronisation in a satellite based quantum key distribution (QKD) system, the system comprising:

a transmitter arranged to:

emit a first series of laser pulses, the first series of laser pulses being encoded to form a quantum beam;

emit a second series of laser pulses, the second series of laser pulses having a predetermined repeating pattern; and

send the first and second series of laser pulses to a receiver.

24. A computer-readable medium comprising code or computer instructions stored thereon, which when executed by a processor, causes the processor to perform the method according to any one of claims 1 to 18, 20 or 22.