

Claims

1. A method of performing coherent optical communication of quantum information between an emitter A and a distant receiver B connected by an optical channel, wherein emitter A comprises a laser LA and wherein receiver B comprises a laser LB used as a local local oscillator LLO to operate a coherent receiver, said method comprising the steps of:
 - at A, deriving phase-coherently one or two optical pulses from a same optical wavefront produced by the laser LA at cycle i, said pulses being self-coherent with the laser LA;
 - at A, encoding logical quantum information Q_i and physical phase reference information R_i onto said one or two self-coherent optical pulses by using a coherent multiplexed encoding mechanism;
 - sending multiplexed Q_i and R_i through the optical channel from A to B;
 - at B, measuring logical quantum information Q_i and physical phase reference information R_i with a multiplexed coherent measurement with said one or two self-coherent pulses derived from a single optical wavefront produced by laser LB and used as local oscillators to perform a coherent detection, thereby obtaining classical measurements Q_{mi} of Q_i and R_{mi} of R_i
 - at B, determining the relative phase Ph_{ii} at interference at cycle i between Q_i optical pulse and corresponding LLO pulse by estimating the relative phase between R_i optical pulse and corresponding LLO pulse,
 - at B, determining logical quantum information Q_i by correcting Q_{mi} measurement using relative phase Ph_{ii} estimation.
2. The method of Claim 1, comprising the steps of:
 - at A, deriving a single optical coherent state pulse $Alpha_i$ from the optical wavefront produced by LA at cycle i;
 - at A, encoding bath phase reference information R_i and quantum information Q_i onto the quadratures of the pulse $Alpha_i$, said encoding being obtained by displacing coherently the quantum information Q_i to encode the phase reference information R_i as the displacement of the mean value of Q_i ;

- sending the coherent state Alpha_i from A to B through the optical channel;
 - at B, measuring the two quadratures of the received pulse Alpha_i at reception time of cycle i wherein the laser LB is used as a local-local oscillator LLO to produce a coherent state pulse mode matched with the received pulse;
 - 5 - at B, determining the relative phase Phi_i between LA and LB with said two quadratures;
 - at B, determining quantum information Q_i using relative phase estimation Phi_i and the two quadrature measurement outcomes.
- 10 3. The method of Claim 2, further comprising the step of correcting the relative phase by performing the steps of:
- at A, encoding quantum information and phase reference information on the same optical coherent state pulse Alpha_i wherein the phase reference information R_i is encoded as the displaced mean value of quantum information Q_i ;
 - 15 - sending the coherent state Alpha_i from A to B through the optical channel;
 - at B, measuring the two quadratures of the received pulse Alpha_i leading to classical measurement outcomes X_{mi} and P_{mi} ;
 - at B, computing an estimate Theta_esti of the relative phase between local oscillator and reference by processing measurement results anterior to i , X_{mj} and P_{mj} ,
 - 20 over windows of size W wherein $Q_{::i-j::};W$;
 - at B, correcting the relative phase drift on quantum information measurement outcomes X_{mi} and P_{mi} by applying phase correction rotation on the raw results based on the Theta_esti estimate and then by compensating the value of the displacement R_i .
- 25 4. The method of claim 1, comprising the steps of:
- at A, deriving two different optical coherent state pulses Q_{Pi} and R_{Pi} , said two pulses being generated by splitting a single optical pulse produced by LA at cycle i into two pulses and by delaying the second pulse with respect to the first one;
 - at A, encoding quantum information Q_i on the quadratures of the optical
 - 30 coherent state Q_{Pi} ;

- at A, encoding phase reference information R_i on the optical coherent state R_{Pi} , whose quadrature value in phase with LA is displaced by a large value E_r coherently with laser LA;
 - sending coherent states Q_{Pi} and R_{Pi} from A to B through the optical channel;
 - 5 - at B, deriving two phase-coherent local-local oscillator pulses $LLOQ_i$ and $LLOR_i$, said pulses being generated by splitting a single optical pulse produced by LB at cycle i into two pulses and by delaying the second pulse with respect to the first one;
 - at B, measuring the two quadratures of the received reference pulse R_{Pi} with a coherent detection wherein the optical pulse $LLOQ_i$ is used as a local-local oscillator
 - 10 LLO mode-matched with R_{Pi} , obtaining measurement outcomes X_{refi} and P_{refi} ;
 - at B, determining the relative phase drift Θ_{esti} between LA and LB with the quadrature measurement outcomes X_{refi} and P_{refi} ;
 - at B, measuring quantum information Q_i on the received pulse Q_{Pi} with a coherent detection at cycle i , wherein the optical pulse $LLOQ_i$ is used as local-local
 - 15 oscillator LLO mode-matched with Q_{Pi} , obtaining classical information Q_{mi} ;
 - at B, correcting Q_{mi} with phase correction processing using Θ_{esti} and determining logical quantum information Q_i .
5. The method of claim 1, comprising the steps of:
- 20 - at A, deriving two different optical coherent state pulses Q_{Pi} and R_{Pi} , said two pulses being generated by splitting a single optical pulse produced by LA at cycle i into two pulses and by delaying the second pulse with respect to the first one;
- at A, encoding quantum information Q_i on the quadratures of the optical coherent state, Q_{Pi} ;
- 25 - at A, encoding phase reference information R_i on the optical coherent state R_{Pi} , whose quadrature value in phase with LA is displaced by a large value E_r coherently with laser LA;
- sending coherent states Q_{Pi} and R_{Pi} from A to B through the optical channel;
- at B, deriving two phase-coherent local-local oscillator pulses $LLOQ_i$ and
- 30 $LLOR_i$, said pulses being generated by splitting a single optical pulse produced by LB at cycle i into two pulses and by delaying the second pulse with respect to the first one;
- at B, demultiplexing or separating Q_{Pi} and R_{Pi} onto two different optical paths;

- at B, measuring the two quadratures of the received reference pulse R_{Pi} with a coherent detection, wherein the LLO_{Ri} pulses is used as a local-local oscillator LLO mode-matched with R_{Pi} obtaining measurement outcomes X_{refi} and P_{refi} ;

- at B, determining the relative phase drift Θ_{esti} between LA and LB with the quadrature measurement outcomes X_{refi} and P_{refi} ;

- at B, physically loop-locking the phase of the LLO_{Qi} pulse with the phase of the optical reference pulses R_{Pi} with a feedback mechanism and the Θ_{esti} estimate;

- at B, measuring the received pulse Q_{Pi} with a coherent detection wherein the phase-locked LLO_{Qi} pulses is used as a local-local oscillator LLO mode-matched with R_{Pi} ;

- at B, determining the quantum information Q_i .

6. A system comprising means to perform the steps of the method according to any one of the preceding claims 1 to 5.

7. A system for coherent optical communication of quantum information between an emitter A and a distant receiver B connected by an optical channel, wherein emitter A comprises a laser LA and wherein receiver B comprises a laser LB used as a local local oscillator LLO to operate a coherent receiver, said system further comprising:

- at A, a laser LA configured to derive phase-coherently one or two optical pulses from a same optical wavefront at cycle i , said pulses being self-coherent with the laser LA;

- at A, a coherent multiplexed encoder to encode logical quantum information Q_i and physical phase reference information R_i onto said one or two self-coherent optical pulses;

- an optical channel from A to B configured to send multiplexed Q_i and R_i ;

- at B, a multiplexed coherent measurement device configured to measure logical quantum information Q_i and physical phase reference information R_i with said one or two self-coherent pulses derived from a single optical wavefront produced by laser LB and used as local oscillators to perform a coherent detection, thereby obtaining classical measurements Q_{mi} of Q_i and R_{mi} of R_i ;

- at B, a device configured to determine the relative phase Φ_{ii} at interference at cycle i between Q_i optical pulse and corresponding LLO pulse by estimating the relative phase between R_i optical pulse and corresponding LLO pulse; and

- at B, a device configured to determine logical quantum information Q_i by
5 correcting Q_{mi} measurement using relative phase Φ_{ii} estimation.

8. The system according to claim 7 further comprising a heterodyne detector and a local-local oscillator LLO wherein:

- information sent from A to B is encoded on a single optical coherent state
10 pulse, derived from the optical wavefront produced by LA at cycle i ;

- quantum information Q_i is encoded on both quadratures of the coherent state while phase reference information R_i is encoded as a displacement of amplitude Δ of the quadrature in phase with LA at cycle i ;

- a heterodyne detector measures both two quadratures of the received pulse at
15 cycle i at wherein the laser LB is used as a local-local oscillator LLO to produce a coherent state pulse mode matched with the received pulse; and wherein

- quadrature measurement results are used to estimate the phase drift between LA and LB, and then to determine the quantum information Q_i .

20 9. The system according to claim 8 further comprising a splitter, an optical delay line and a homodyne or heterodyne detector wherein:

- quantum information Q_i and phase reference information R_i are encoded onto two different optical coherent state pulses, this two pulses being generated by splitting onto a beamsplitter an optical pulse produced by LA, at cycle i , and by delaying the
25 second pulse by a time ΔT with respect to the first one, with an optical delay line;

- quantum information Q_i is encoded on the quadratures of one of the pulses Q_{Pi} ;

- phase reference information R_i is encoded on the second pulse R_{Pi} whose quadrature value is in phase with LA and displaced by a value Δ , while its other quadrature value is not modulated;

30 - a measurement DQ of the quadratures of the received pulse Q_{Pi} is performed at a homodyne or heterodyne detector at Bob at cycle i , with LB used as local-local oscillator, LLO, to produce a coherent state pulse LLO Q_i mode-matched with Q_{Pi} ;

- a heterodyne measurement DR of the two quadratures of the received reference pulse RPi is performed at Bob at cycle i. The laser LB is used as local local oscillator LLO to produce a coherent state pulse LLORi that is obtained by delaying using a delayline a part of the wavefront used to produced LLOQi by at cycle i with a delay line;

5 - the quadrature measurement results obtained with DR are used to determine the phase drift Phii between LA and LB, said determined phase drift being then used to correct the quadrature measurement results of OPi and to determine the quantum information Qi.

10 10. The system according to claim 9 wherein the coherent detector DQ or the coherent detector DR are different single detectors.

11. A system according to claim 9 wherein the coherent detector DQ and the coherent detector DR are the same coherent detector.

15

12. A system according to claim 9 wherein the coherent detector DQ OR the coherent detector DR is associated with an intensity of the coherent state pulse LLOR which is decreased with respect to the intensity of the coherent state pulse LLOQ.

20 13. A system according to claim 9, wherein:

- quantum information Qi and phase reference information Ri are encoded onto two different optical coherent state pulses, bath pulses being coherently derived from the optical wavefront produced by LA at cycle i, the second pulse being delayed with respect to the first one, with an optical delay line;

25 - quantum information Qi is encoded on the quadratures of one of the pulses, called QPi;

- phase reference information Ri is encoded on the second pulse, called RPi, whose quadrature value in phase with LA is displace by a large value, Delta, while its other quadrature value is not modulated;

30 - the phase reference pulse Rpi is used to operate an optical phase lock-loop OPLL at B, locking the phase of laser LB to the phase of optical reference pulses RPi with feedback mechanisms;

- a dual-homodyne measurement DQ of the quadratures of the received pulse Q_{Pi} is performed at B at cycle i , with LB used as local local oscillator LLO to produce a coherent state pulse PLLOQ mode-matched with Q_{Pi} .