quantum states of each of a plurality of pairs of the top layer quantum systems; extend the entanglement of each of the plurality of pairs of top level quantum systems to a respective pair of the intermediate layer quantum systems; and purify the entanglement of the entangled pairs of intermediate layer quantum systems.

[0091] In some embodiments, the controller is configured to cause teleportation of the quantum state of the first bottom layer quantum system to the second bottom layer quantum system using the entanglement of the quantum states of the first and second intermediate layer quantum systems.

[0092] In some embodiments, the controller is configured to cause teleportation of a quantum gate controlled by the first bottom layer quantum system to apply the quantum gate to the second bottom layer quantum system using the entanglement of the quantum states of the first and second intermediate layer quantum systems.

[0093] Further aspects and example embodiments are illustrated in the accompanying drawings and/or described in the following description.

[0094] It is emphasized that the invention relates to all combinations of the above features, even if these are recited in different claims.

Brief Description of the Drawings

[0095] The accompanying drawings illustrate non-limiting example embodiments of the invention.

[0096] Fig. 1 is a schematic depiction of a system according to a simple example embodiment of the present technology.

[0097] Fig.1A is a schematic depiction of an example node that may be used in a system of the present technology.

[0098] Fig. 2 is a flow chart for a method according to an example embodiment.

[0098A] Fig. 2A illustrates an example optical path of a network that is optically connected between two quantum systems by suitable optical couplers.

[0099] Fig.3 is a block diagram for a hardware implementation of an example node.

[0100] Fig. 4 is a block diagram for a hardware implementation of an example inter-node network.

[0101] Fig. 5 is a schematic cross section of a substrate supporting a quantum system and apparatus for working with a quantum state of the quantum system.

[0102] Fig. 6 is an example energy level diagram for quantum systems that may be incorporated in systems according to the present technology.

[0103] Fig. 7 is a flowchart illustrating a method for creating and distributing entanglement applicable to the case where individual quantum systems include broker elements and client elements.

WHAT IS CLAIMED IS:

1. A method for establishing and distributing quantum entanglement, the method comprising:

providing first and second nodes each node comprising one or more alpha quantum systems and a plurality of higher level quantum systems, the alpha and higher level quantum systems of each node interconnected by an intra-node optical network and the higher level quantum systems of the first node connectable to at least corresponding higher level quantum systems of the second node by an inter-node optical network;

attempting to establish quantum entanglement of quantum states of each of a first plurality of pairs of the higher level quantum systems by way of the inter-node optical network, wherein each of the pairs comprises one of the plurality of higher level quantum systems of the first node and a respective corresponding one of the plurality of higher level quantum systems of the second node;

detecting success in entangling the quantum states of an entangled pair of the pairs of higher level quantum systems; and

at each of the first node and the second node, transferring the entanglement of a respective higher level quantum system of the entangled pair of higher level quantum systems to a quantum state of a selected one of the alpha quantum systems of the respective node using the respective intra-node optical network.

2. The method according to claim 1, wherein the inter-node optical network is lossier than the intra-node optical networks of the first and second nodes.

3. The method according to claim 1 or 2 wherein attempting to establish quantum entanglement of quantum states of different ones of the plurality of pairs of the higher level quantum systems is performed concurrently.

4. The method according to claim 1 wherein the alpha and higher level quantum systems each comprises a broker element having a broker state and a client element having a client state and the method comprises:

entangling the broker states of the one of the pairs of higher level quantum systems;

transferring the entanglement to the client states of the higher level quantum systems of the one of the pairs of higher level quantum systems; and

transferring the entanglement to the client state of the selected one of the alpha quantum systems of the first node.

5. The method according to claim 4 further comprising, at the second node, entangling the broker state of the one of the pair of higher level quantum systems of the second node with the broker state of the selected one of the alpha quantum systems of the second node; and

at the second node transferring the entanglement of the client state of the higher level quantum system of the one of the pairs of higher level quantum systems of the second node to the client state of the selected one of the alpha quantum systems of the second node.

6. The method according to claim 5 wherein the broker state and the client state respectively comprise first and second spin states, wherein the first spin state comprises an electron spin state and the second spin state comprises a nuclear spin state.

7. The method according to any of claims 1 to 6 wherein, for at least one of the first and second nodes, transferring the entanglement of a respective higher level quantum system of the entangled pair of higher level quantum systems to a quantum state of a selected one of the alpha quantum systems of the respective node using the respective intra-node optical network comprises transferring the entanglement to the selected one of the alpha quantum systems comprises transferring the entanglement in sequence from the respective higher level quantum system to one or more intermediate level quantum systems and from one of the one or more intermediate level quantum systems to the selected alpha quantum system.

8. The method according to claim 7, wherein the one or more intermediate level quantum systems are used to purify the entanglement.

9. The method according to any of claims 1 to 8 wherein the quantum systems are embedded in a crystalline substrate, and wherein the quantum systems comprise

luminescent centres.

10. The method according to claim 9 wherein the higher level quantum systems each comprise a T centre.

11. A quantum network comprising:

a plurality of nodes, each node comprising:

at least one alpha quantum system, a plurality of higher level quantum systems; and an intra-node optical network optically coupled to the at least one alpha quantum system and the plurality of higher level quantum systems;

an inter-node optical network configurable to provide a plurality of optical paths, each of the optical paths optically connecting a corresponding pair of the higher-level quantum systems, each of the pairs including one of the higher level quantum systems of a first one of the nodes and a corresponding higher level quantum system of a second one of the nodes; and

a controller configured to:

execute, via the inter-node optical network, attempts to entangle the higher level quantum systems of each of the pairs of higher level quantum systems; and

upon detecting entanglement of the higher level quantum systems of an entangled one of the pairs of higher level quantum systems, transfer, via the intra-node optical network, an entangled state of the entangled one of the pairs of higher level quantum systems to a selected alpha quantum system of the one or more alpha quantum systems of the first one of the nodes and/or a selected alpha quantum system of the one or more alpha quantum systems of the second one of the nodes.

12. The quantum network according to claim 11, wherein the controller is configured to execute the attempts to entangle the higher level quantum systems of each of the pairs of higher level quantum systems concurrently.

13. The quantum network according to claim 11 or 12 wherein the alpha and

higher level quantum systems each comprises a broker element having a broker state and at least one client element having a client state.

14. The quantum network according to claim 13 wherein the controller is further configured to:

execute a protocol for entangling the broker states of the pairs of higher level quantum systems;

upon entanglement of the broker states of the entangled one of the pairs of higher level quantum systems, execute a protocol for transferring the entanglement to the client states of the higher level quantum systems of the entangled one of the pairs of higher level quantum systems;

execute a protocol for entangling the broker state of the higher level quantum system of the entangled one of the pairs of higher level quantum systems of the first node with the broker state of the selected one of the alpha quantum systems of the first node;

execute a protocol for transferring the entanglement of the client state of the higher level quantum system of the entangled one of the pairs of higher level quantum systems of the first node to the client state of the selected one of the alpha quantum systems of the first node.

15. The quantum network according to claim 13 or 14 wherein the broker state and the client state respectively comprise first and second spin states, wherein the first spin state comprises an electron spin state and the second spin state comprises a nuclear spin state.

16. The quantum network according to claim 15 wherein a strength of hyperfine coupling between the broker element and the client element is the same for each of the alpha quantum systems.

17. The quantum network according to any of claims 11 to 16 wherein each of the alpha quantum systems and/or each of the higher level quantum systems is embedded in a crystalline substrate.

18. The quantum network according to claim 17 wherein the quantum systems

comprise luminescent centres.

19. The method according to claim 17 or 18 wherein the higher level quantum systems each comprise a T centre.

20. The quantum network according to any of claims 11 to 19 wherein the inter-node optical network is lossier than the intra-node optical networks of the first and second nodes.