

REMOVING LEAKAGE IN A QUANTUM BIT

BACKGROUND

[0001] Removing the parasitic occupation of a quantum bit is a task in
5 quantum computing, as well as other applications.

SUMMARY

[0002] This specification describes technologies relating to quantum
hardware and methods for removing the parasitic occupation of higher levels, e.g.,
10 leakage, in a quantum bit (qubit) using a damped cavity mode, without requiring
prior knowledge of the state of the quantum bit. By moving the quantum bit in
frequency close to the damped cavity frequency, parasitic occupation of higher
levels will transfer to the cavity. The parasitic occupation may be damped in the
cavity using the damped cavity mode.

15 [0002a] According to a first aspect of the present invention, there is provided an
apparatus, comprising:
one or more qubits, wherein each qubit facilitates occupation of at least one of a
plurality of qubit levels, the qubit levels including a reset qubit level and one or more
non-reset qubit levels that are each higher than the reset qubit level, and wherein the
20 qubit facilitates transitions between qubit levels associated with a corresponding
transition frequency;
a cavity, wherein the cavity defines a cavity frequency;
one or more couplers coupling each qubit to the cavity; and
one or more couplers coupling the cavity to an environment external to the one
25 or more qubits and the cavity;
a frequency controller that controls the frequency of qubits such that, for each
qubit that the frequency controller controls, the qubit is reset by adjusting the frequency
of the qubit relative to the cavity frequency such that a population of a non-reset level is
transferred to the cavity.

30 [0002b] According to a second aspect of the present invention, there is provided a
method, comprising:

accessing a quantum system that comprises:

one or more qubits, wherein each qubit facilitates occupation of at least one of a plurality of qubit levels, the qubit levels including a reset qubit levels and one or more non-reset qubit levels that are each higher than the reset qubit level, and

5 wherein the qubit facilitates transitions between qubit levels associated with a corresponding transition frequency;

a cavity, wherein the cavity defines a cavity frequency;

one or more couplers coupling each qubit to the cavity; and

one or more couplers coupling the cavity to an environment external to

10 the one or more qubits and the cavity;

a frequency controller that controls the frequency of qubits such that, for each qubit that the frequency controller controls, the qubit is reset by adjusting the frequency of the qubit relative to the cavity frequency such that a population of a non-reset level is transferred to the cavity; and

15 controlling the frequency of each qubit such that, for each qubit, the frequency of the qubit is adjusted relative to the cavity frequency such that a population of a non-reset qubit level is transferred to the cavity.

[0002c] According to a third aspect of the present invention, there is provided a method, comprising:

20 in response to performing a computation in a quantum system that comprises:

one or more qubits, wherein each qubit facilitates occupation of at least one of a plurality of qubit levels, the qubit levels including a reset qubit level and one or more non-reset qubit levels that are each higher than the reset qubit levels, and

wherein the qubit facilitates transitions between qubit levels associated with a

25 corresponding transition frequency;

a cavity, wherein the cavity defines a cavity frequency; and

a frequency controller that controls the frequency of qubits such that, for each qubit that the frequency controller controls, the qubit is reset by adjusting the frequency of the qubit relative to the cavity frequency such that a population of a non-

30 reset level is transferred to the cavity;

controlling the frequency of each qubit that the frequency controller controls without prior knowledge of the population of the qubit levels such that, for each qubit that the frequency controller controls, the qubit is reset by adjusting the frequency of the qubit relative to the cavity frequency such that a population of the non-reset level is transferred to the cavity.

[0002d] According to a fourth aspect of the present invention, there is provided an apparatus, comprising:

one or more qubits, wherein each qubit facilitates occupation of at least one of a plurality of qubit levels, the qubit levels including two computational qubit levels and one or more non-computational qubit levels that are each higher than the computational qubit levels, and wherein the qubit facilitates transitions between qubit levels associated with a corresponding transition frequency;

a cavity, wherein the cavity defines a cavity frequency;

one or more couplers coupling each qubit to the cavity; and

one or more couplers coupling the cavity to an environment external to the one or more qubits and the cavity;

a frequency controller that controls the frequency of qubits, wherein for each qubit that the frequency controller controls, the frequency controller is configured to continuously sweep the qubit frequency past the cavity frequency such that a population of a non-computational level is transferred to the cavity.

[0002e] According to a fifth aspect of the present invention, there is provided a method, comprising:

accessing a quantum system that comprises:

one or more qubits, wherein each qubit facilitates occupation of at least one of a plurality of qubit levels, the qubit levels including two computational qubit levels and one or more non-computational qubit levels that are each higher than the computational qubit levels, and wherein the qubit facilitates transitions between qubit levels associated with a corresponding transition frequency;

a cavity, wherein the cavity defines a cavity frequency;

one or more couplers coupling each qubit to the cavity; and

one or more couplers coupling the cavity to an environment external to the one or more qubits and the cavity;

_____ a frequency controller that controls the frequency of qubits, wherein for each qubit that the frequency controller controls, the frequency controller is configured to continuously sweep the qubit frequency past the cavity frequency such that a population of a non-computational level is transferred to the cavity; and

5 _____ controlling the frequency of each qubit such that, for each qubit, the frequency of the qubit is swept past the cavity frequency such that a population of a non-computational level is transferred to the cavity.

[0002f] According to a sixth aspect of the present invention, there is provided an apparatus, comprising:

10 _____ one or more qubits, wherein each qubit facilitates occupation of at least one of a plurality of qubit levels, the qubit levels including two computational qubit levels and one or more non-computational qubit levels that are each higher than the computational qubit levels, and wherein the qubit facilitates transitions between qubit levels associated
15 with a corresponding transition frequency;

_____ a cavity, wherein the cavity defines a cavity frequency;

_____ one or more couplers coupling each qubit to the cavity; and

_____ one or more couplers coupling the cavity to an environment external to the one or more qubits and the cavity;

20 _____ a frequency controller that controls the frequency of qubits, wherein for each qubit that the frequency controller controls, the frequency controller is configured to iteratively perform downward qubit level transitions until a population of a non-computational level is transferred to the cavity.

25 [0002g] According to a seventh aspect of the present invention, there is provided a method, comprising:

_____ accessing a quantum system that comprises:

_____ one or more qubits, wherein each qubit facilitates occupation of at least one of a plurality of qubit levels, the qubit levels including two computational qubit
30 levels and one or more non-computational qubit levels that are each higher than the computational qubit levels, and wherein the qubit facilitates transitions between qubit levels associated with a corresponding transition frequency;

a cavity, wherein the cavity defines a cavity frequency;
one or more couplers coupling each qubit to the cavity; and
one or more couplers coupling the cavity to an environment external to
the one or more qubits and the cavity;

5 a frequency controller that controls the frequency of qubits, wherein for
each qubit that the frequency controller controls, the frequency controller is configured
to iteratively perform downward qubit level transitions until a population of a non-
computational level is transferred to the cavity; and

controlling the frequency of each qubit such that, for each qubit, downward
10 qubit level transitions are iteratively performed such that a population of a non-
computational level is transferred to the cavity.

[0003] ~~In general, one innovative aspect of the subject matter described in~~
~~this specification can be embodied in~~ There are disclosed methods that include the

15 actions of accessing a quantum system that comprises one or more qubits, wherein
each qubit facilitates occupation of at least one of a plurality of qubit levels, the
qubit levels including two computational qubit levels and one or more non-
computational qubit levels that are each higher than the computational qubit levels,
and wherein the qubit facilitates transitions between qubit levels associated with a
20 corresponding transition frequency; a cavity, wherein the cavity defines a cavity
frequency; one or more couplers coupling each qubit to the cavity; and one or more
couplers coupling the cavity to an environment external to the one or more qubits
and the cavity; a frequency controller that controls the frequency of qubits such
that, for each qubit that the frequency controller controls, the frequency of the qubit
25 is adjusted relative to the cavity frequency such that a population of a non-
computational level may be transferred to the cavity; and controlling the frequency
of each qubit such that, for each qubit, the frequency of the qubit may be adjusted
relative to the cavity frequency such that a population of a non-computational level
may be transferred to the cavity.