WHAT IS CLAIMED IS:

1. A non-transitory computer-readable storage medium storing instructions for estimating an amplitude of a first quantum oracle using a direction of arrival (DOA) estimation algorithm, the instructions, when executed by a computing system, causes the computing system to perform operations comprising:

determining a set of values each corresponding to a number of oracle calls of a second quantum oracle to be performed, the second quantum oracle based on the first quantum oracle;

for each value *n* in the set:

causing a quantum computing system to execute a first quantum circuit that performs *n* oracle calls of the second quantum oracle to generate a first output quantum state;

causing the quantum computing system to measure the target qubit in a first basis;

estimating the first output quantum state based on a measurement of the target qubit in the first basis;

causing the quantum computing system or a different quantum computing system to execute a second quantum circuit that performs *n* oracle calls of the second quantum oracle to generate a second output quantum state; and

estimating the second output quantum state based on a measurement of the target qubit in a second basis different than the first basis;

forming a signal vector based on the estimated output quantum states for each value in the set;

applying the signal vector to the DOA estimation algorithm; and

estimating an amplitude of the first quantum oracle based on an output of the DOA estimation algorithm.

2. The non-transitory computer-readable storage medium of claim 1, wherein the operations do not include performing phase estimation to estimate the amplitude of the first quantum oracle.

3. The non-transitory computer-readable storage medium of claim 1 or claim 2, wherein:

executing the first and second quantum circuits and measuring the corresponding output quantum states for a first value in the set is performed in parallel to executing the first and second quantum circuits and measuring the corresponding output quantum states for a second value in the set; and/or

the second quantum circuit includes the first quantum circuit and a Hadamard quantum gate.

4. The non-transitory computer-readable storage medium of any preceding claim, wherein the signal vector has the form $y_n = e^{i\omega_n}$, where ω_n is based on the estimated output quantum states for the value of *n* in the set.

5. The non-transitory computer-readable storage medium of claim 4, wherein ω_n is the arctan of: $\frac{p_0^X(n)-p_1^X(n)}{p_0(n)-p_1(n)}$, where $p_0(n)$ is the estimated probability of measuring the target qubit in the $|0\rangle$ state in the Z basis after performing *n* oracle calls of the second quantum oracle, $p_1(n)$ is the estimated probability of measuring the target qubit in the $|1\rangle$ state in the Z basis after performing *n* oracle calls of the second quantum oracle, $p_0^X(n)$ is the estimated probability of measuring the target qubit in the $|0\rangle$ state in the X basis after performing *n* oracle calls of the second quantum oracle, and $p_1^X(n)$ is the estimated probability of measuring the target qubit in the $|1\rangle$ state in the X basis after performing *n* oracle calls of the second quantum oracle.

6. The non-transitory computer-readable storage medium of any preceding claim, wherein forming the signal vector comprises:

forming an initial vector with initial vector components having the form y_n; and

expanding the initial vector by computing additional vector components based on the initial vector components, where optionally computing the additional vector components comprises computing the outer product of the initial vector with itself.

7. The non-transitory computer-readable storage medium of any preceding claim, wherein:

executing the first quantum circuit is performed by a first quantum computer and executing the second quantum circuit is performed by a second quantum computer different than the first quantum computer; and/or

the DOA estimation algorithm is a MUltiple SIgnal Classification (MUSIC) algorithm or a Estimation of Signal Parameters via Rotational Invariance Techniques (ESPRIT) algorithm.

8. A method for estimating an amplitude of a first quantum oracle using a direction of arrival (DOA) estimation algorithm, the method comprising:

determining a set of values each corresponding to a number of oracle calls of a second quantum oracle to be performed, the second quantum oracle based on the first quantum oracle;

for each value *n* in the set:

causing a quantum computing system to execute a first quantum circuit that performs *n* oracle calls of the second quantum oracle to generate a first output quantum state;

causing the quantum computing system to measure the target qubit in a first basis;

estimating the first output quantum state based on the measurement of the target qubit in the first basis;

causing the quantum computing system or a different quantum computing system to execute a second quantum circuit that performs *n* oracle calls of the second quantum oracle to generate a second output quantum state; and

causing the quantum computing system or the different quantum computing system to measure the target qubit in a second basis different than the first basis;

estimating the second output quantum state based on the measurement of the target qubit in the second basis;

forming a signal vector based on the measured outputs for each value in the set;

applying the signal vector to the DOA estimation algorithm; and

estimating an amplitude of the first quantum oracle based on an output of the DOA estimation algorithm.

9. The method of claim 8, wherein estimating an amplitude of the first quantum oracle is performed without phase estimation.

10. The method of claim 8 or claim 9, wherein execution of the first and second quantum circuits and for a first value in the set is performed in parallel to execution the first and second quantum circuits for a second value in the set; and/or the second quantum circuit includes the first quantum circuit and a Hadamard quantum gate.

11. The method of claim 8 to 10, wherein the signal vector has the form $y_n = e^{i\omega_n}$, where ω_n is based on the estimated output quantum states for the value of *n* in the set.

12. The method of claim 11, wherein ω_n is the arctan of: $\frac{p_0^X(n)-p_1^X(n)}{p_0(n)-p_1(n)}$, where $p_0(n)$ is the estimated probability of measuring the target qubit in the $|0\rangle$ state in the Z basis after performing *n* oracle calls of the second quantum oracle, $p_1(n)$ is the estimated probability of measuring the target qubit in the $|1\rangle$ state in the Z basis after performing *n* oracle calls of the second quantum oracle, $p_0^X(n)$ is the estimated probability of measuring the target qubit in the $|0\rangle$ state in the X basis after performing *n* oracle calls of the second quantum oracle, and

$p_1^X(n)$ is the estimated probability of measuring the target qubit in the $|1\rangle$ state in the X basis after performing *n* oracle calls of the second quantum oracle.

13. The method of any of claims 8 to 12, wherein forming the signal vector comprises:

forming an initial vector with initial vector components having the form y_n; and

expanding the initial vector by computing additional vector components based on the initial vector components, where, optionally computing the additional vector components comprises computing the outer product of the initial vector with itself.

14. The method of any of claims 8 to 13, wherein:

executing the first quantum circuit is performed by a first quantum computer and executing the second quantum circuit is performed by a second quantum computer different than the first quantum computer, and/orthe DOA estimation algorithm is the MUltiple SIgnal Classification (MUSIC) algorithm or a Estimation of Signal Parameters via Rotational Invariance Techniques (ESPRIT) algorithm.

15. A computing system configured to perform the method of any of claims 8 to 14.