Programming Quantum Computers (Apps III: Graphics)

(**Subtrack of** Quantum Computing: An App-Oriented Approach)

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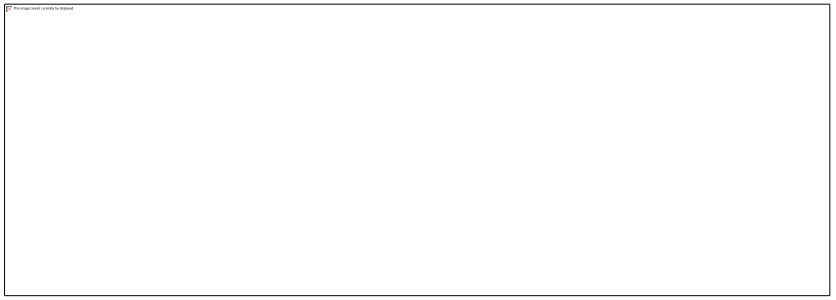
Quantum Computers are Real

- What are they useful for?
  - Let's discover, by programming them!
  - And seeing *examples* of how others programmed them.
- A hands-on approach to programming QCs/QPUs.
  - By doing; i.e., by writing code & building programs.
  - Using simulators, since real QCs are harder-to-access (so far).
- Goals: Read, understand, write, and *debug* quantum programs.
  - Ones like this program.



Topics Covered

- Introduction:
  - Qubit, Superposition, and Entanglement.
  - Single-Qubit Ops: H, NOT and Phase.
  - Multi-Qubit Ops: Conditional Ops (e.g., CNOT).
  - Teleportation.

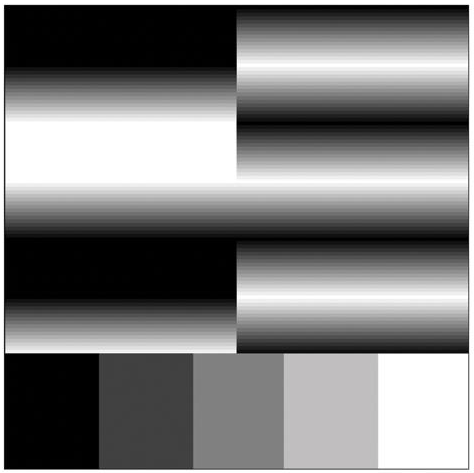
- Modules:
  - Quantum Arithmetic and Logic.
  - (Quantum) Amplitude Amplification.
    - Converting phase info into magnitude info.
  - Quantum Fourier Transform.
    - Revealing patterns (frequencies).
  - (Quantum) Phase Estimation.
    - Characterization of quantum operations.
  - Quantum Simulation and Real Data.
    - QRAM, Quantum Vector & Matrix Encodings.

Quantum Apps

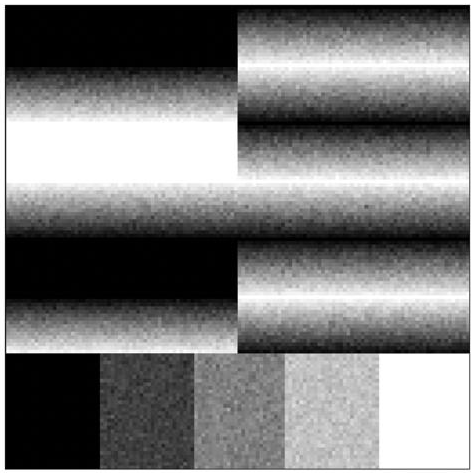
- Quantum Simulation.
  - Using quantum operations to approximate unitary matrices that describe quantum operations representing Hermitian matrices (the Hamiltonians).
- Quantum Search (Grover's algorithm).
  - Using quantum phase logic and amplitude amplification to check the satisfiability of logical formulas.
- **Quantum Graphics (Quantum Supersampling).**
  - Using quantum arithmetic, quantum search, and QFT to improve the quality of supersampled images.
- Quantum Cryptography (Shor's algorithm).
- Quantum Machine Learning (QML).

QUANTUM APPLICATIONS

QUANTUM GRAPHICS



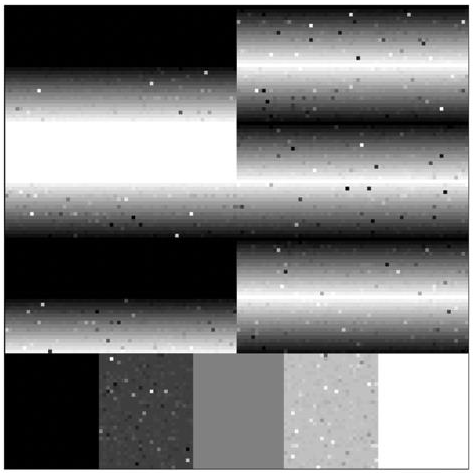
Ideal sampling reference



Conventional Monte Carlo

Mean pixel error: 2%

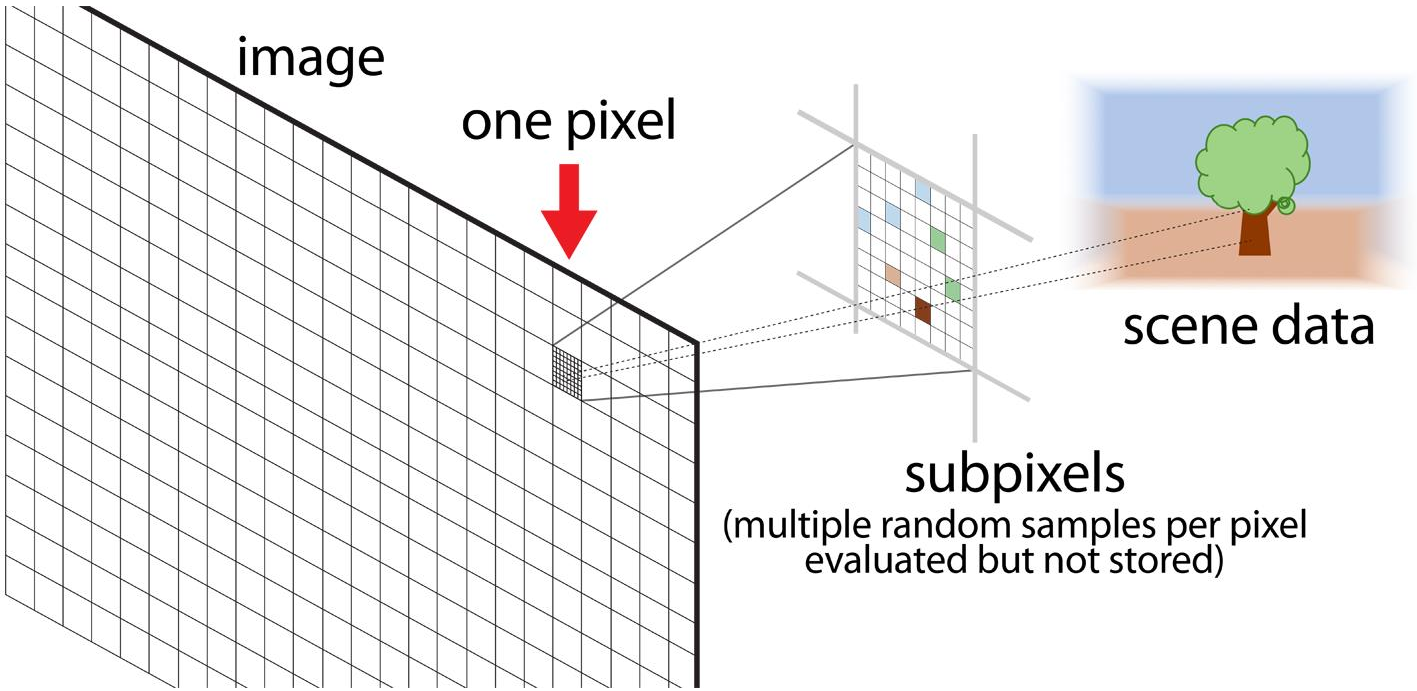
Error-free pixels: 34%

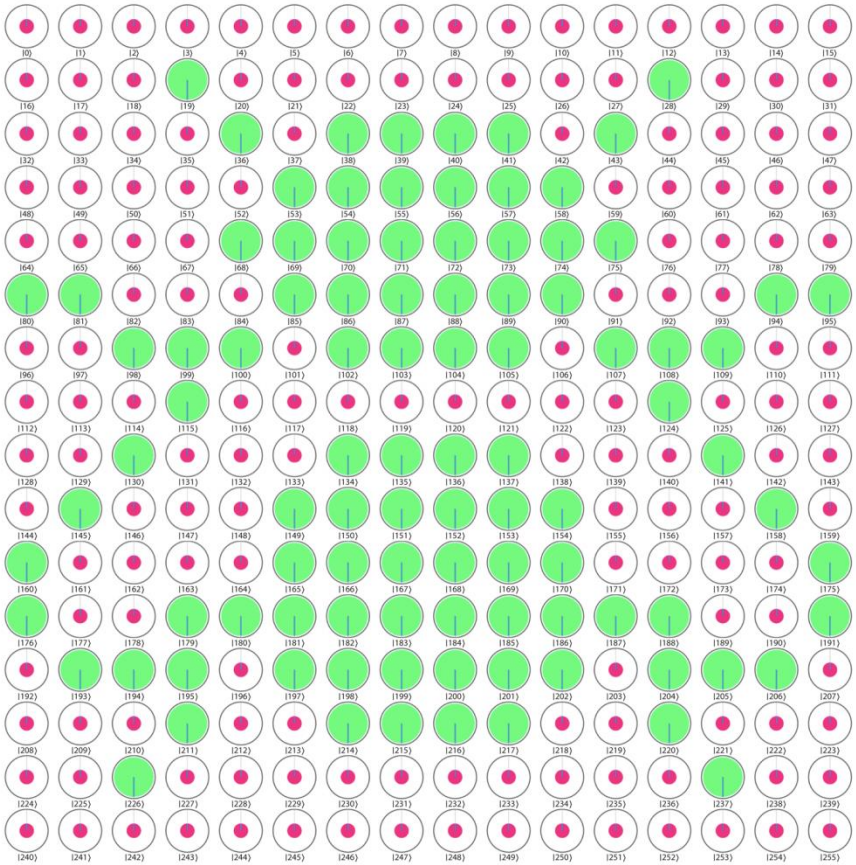


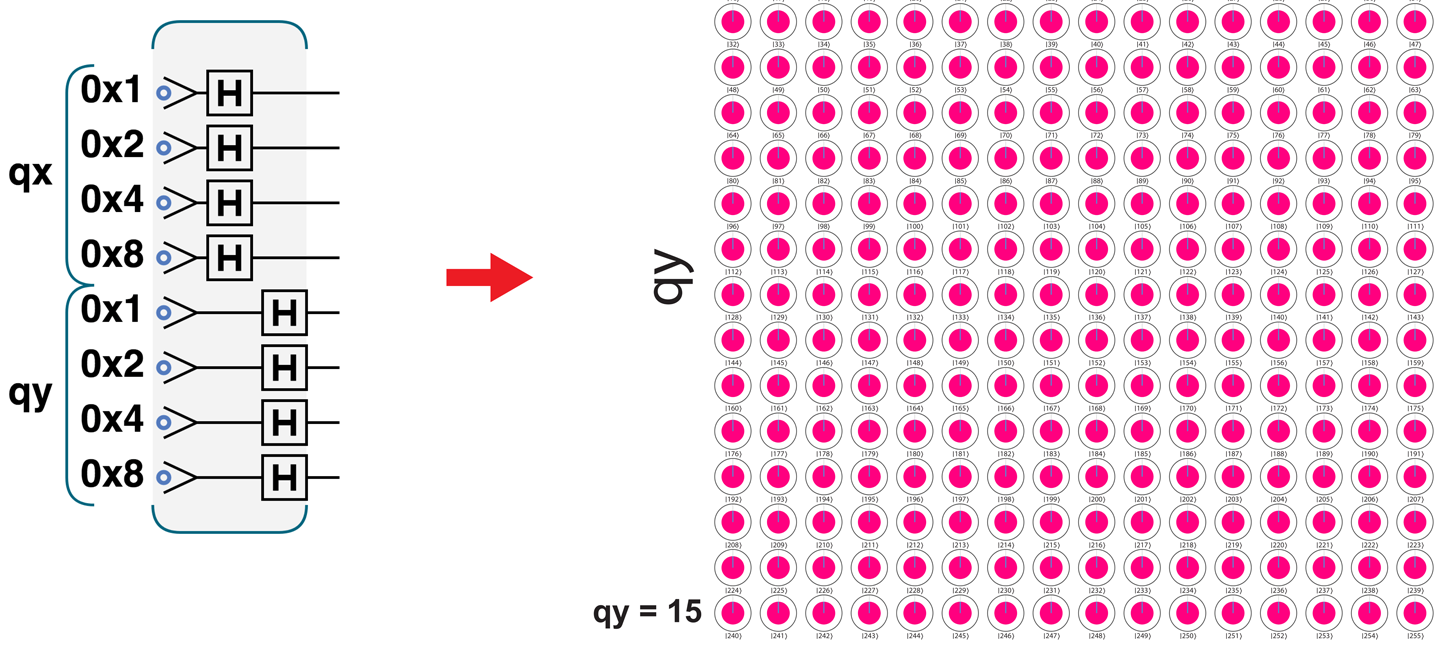
Quantum Supersampling

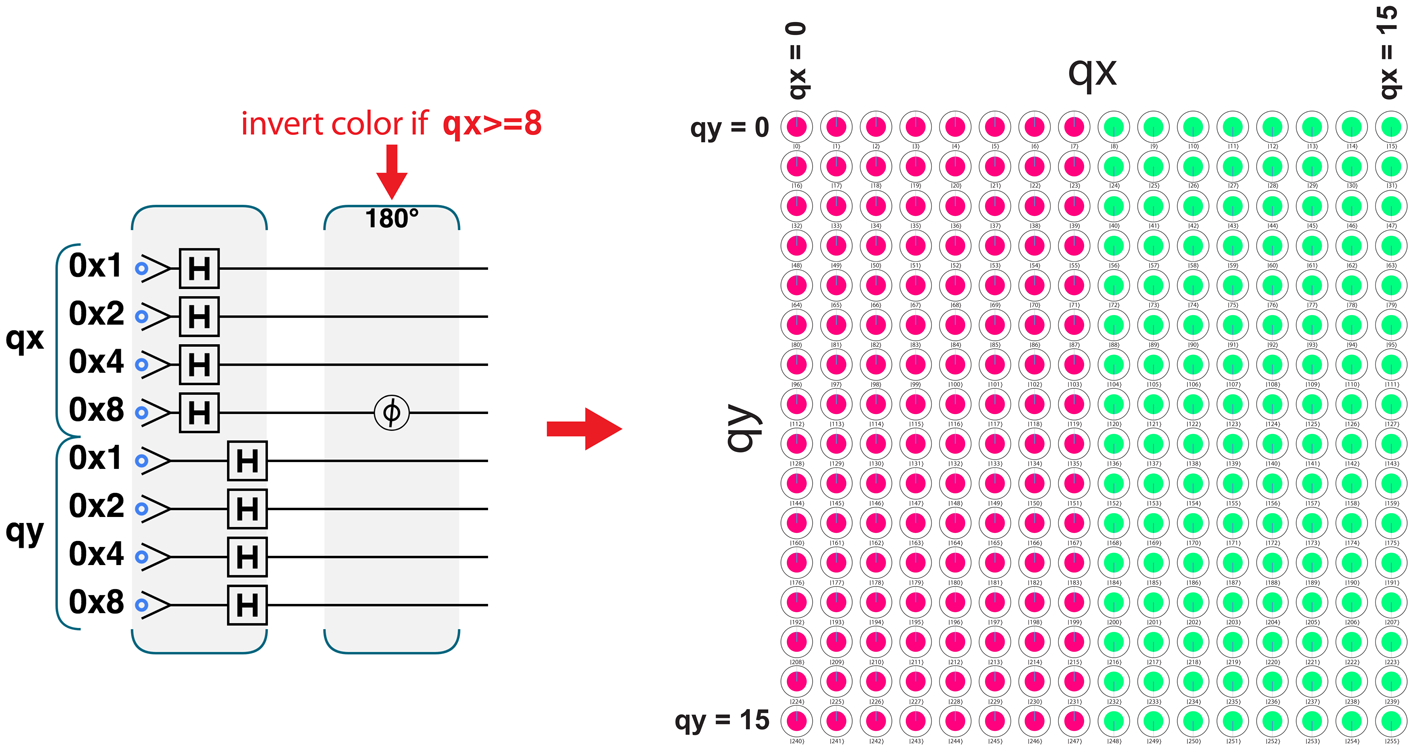
Mean pixel error: 1%

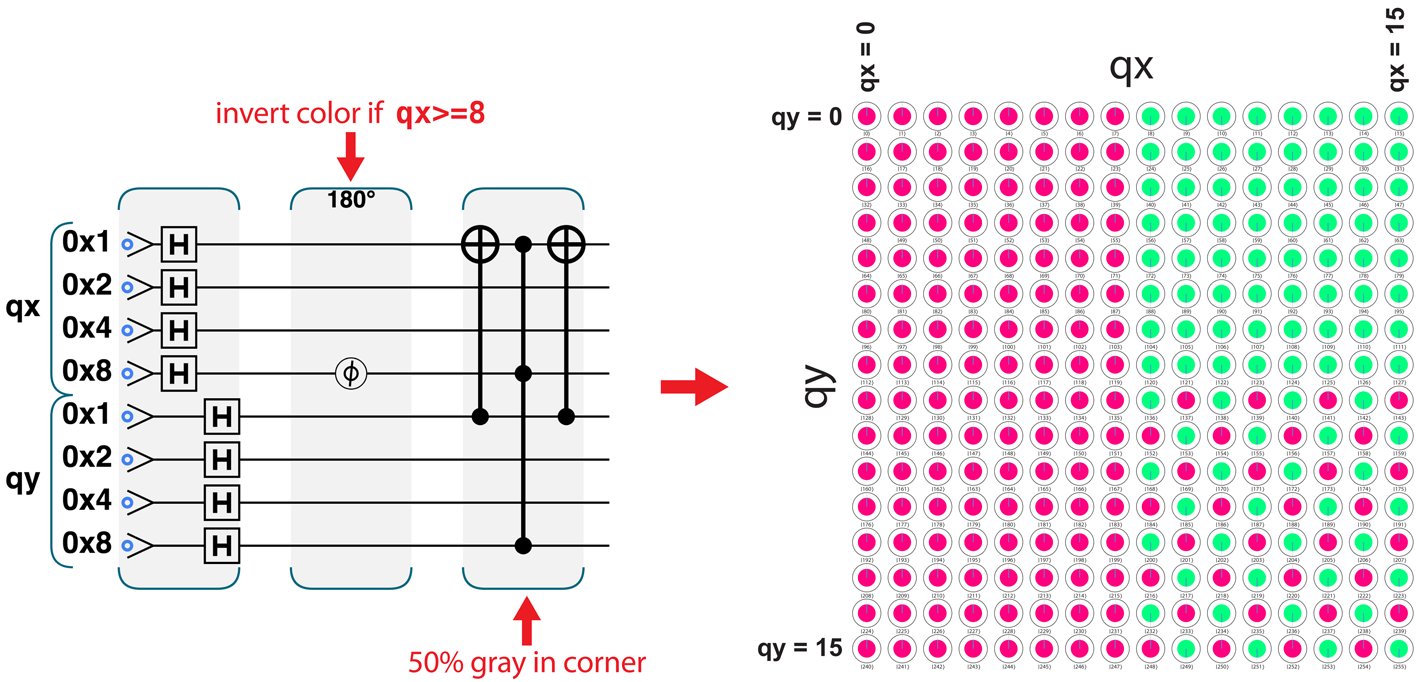
Error-free pixels: 41%

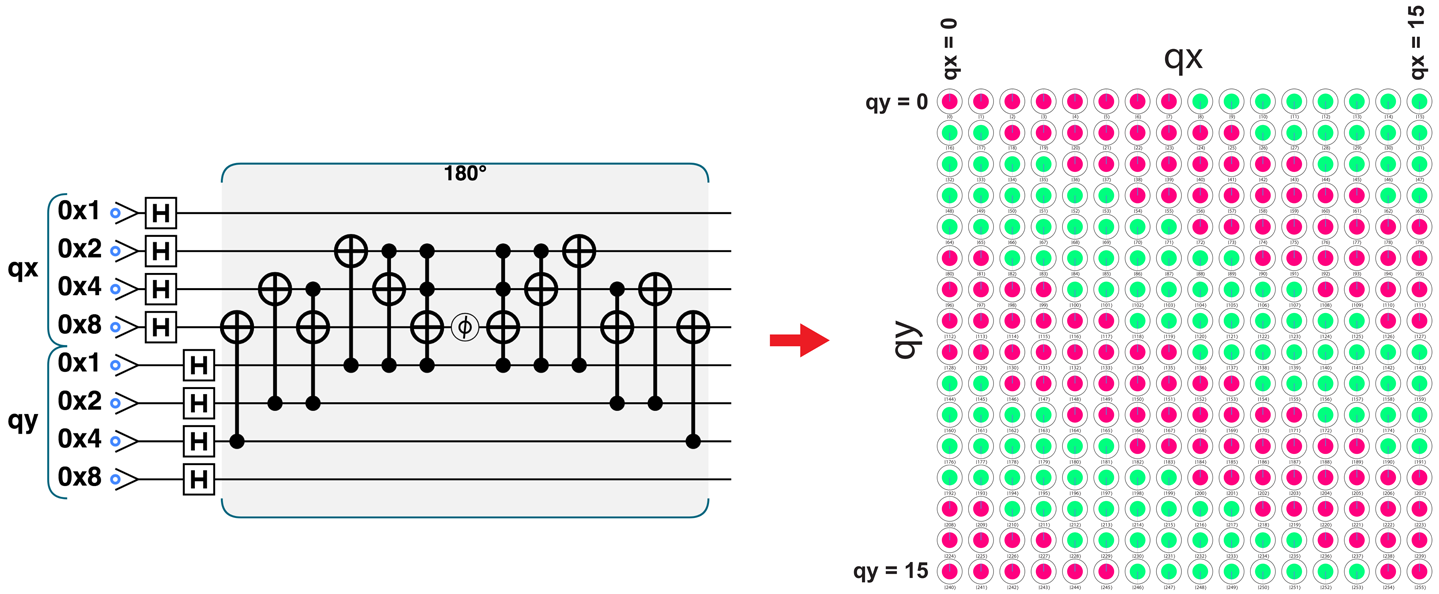


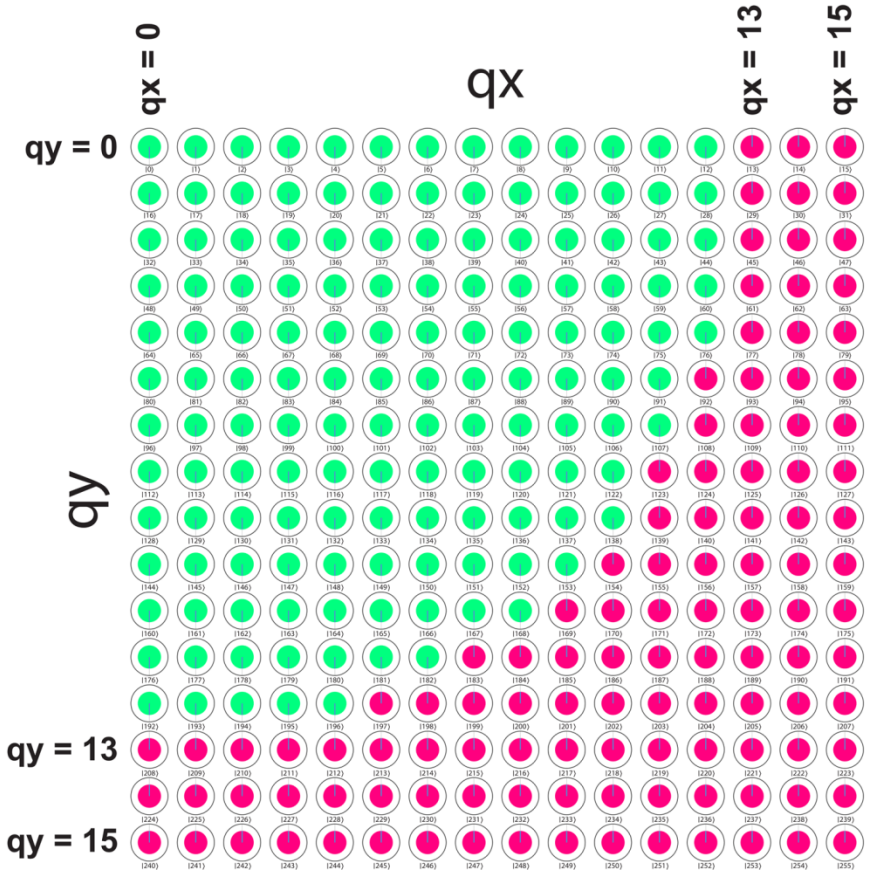


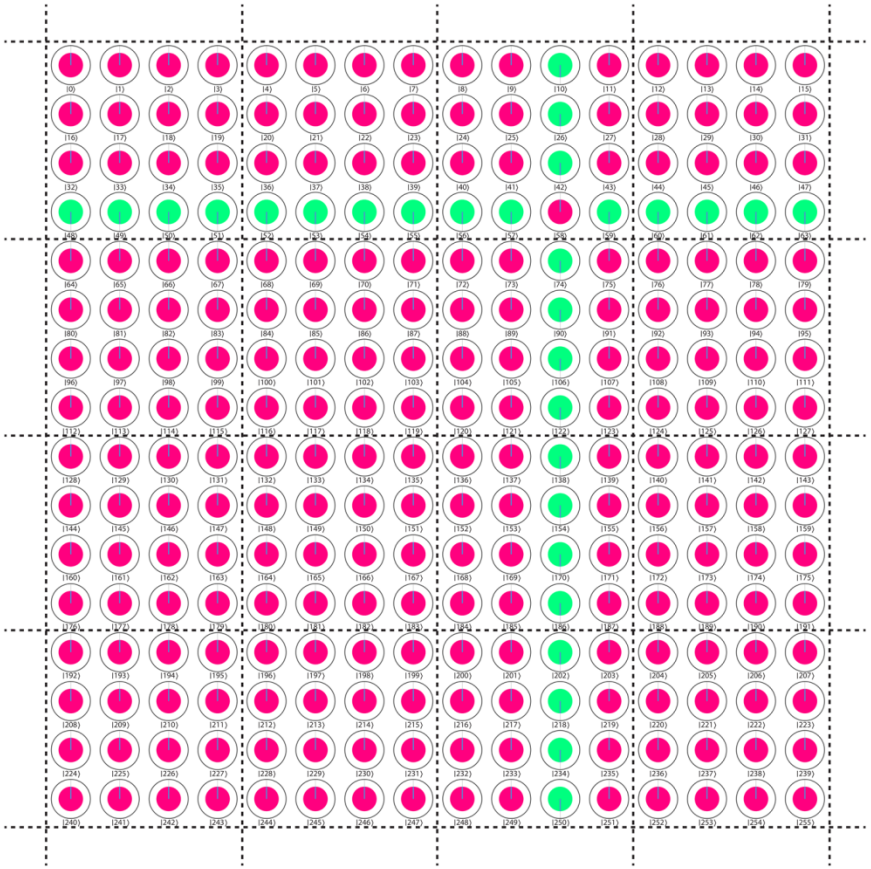


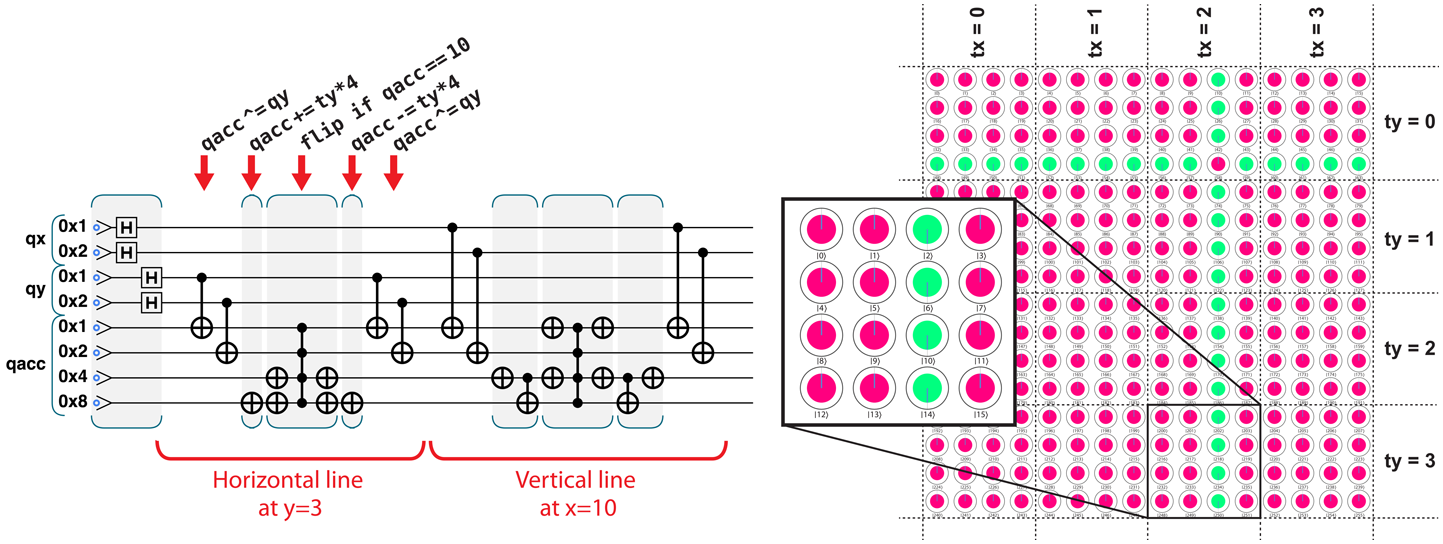


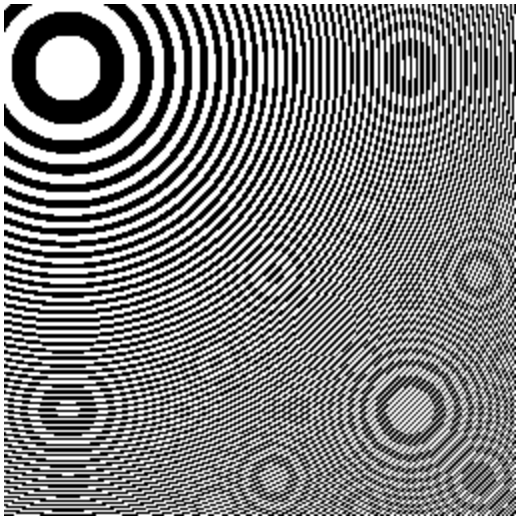


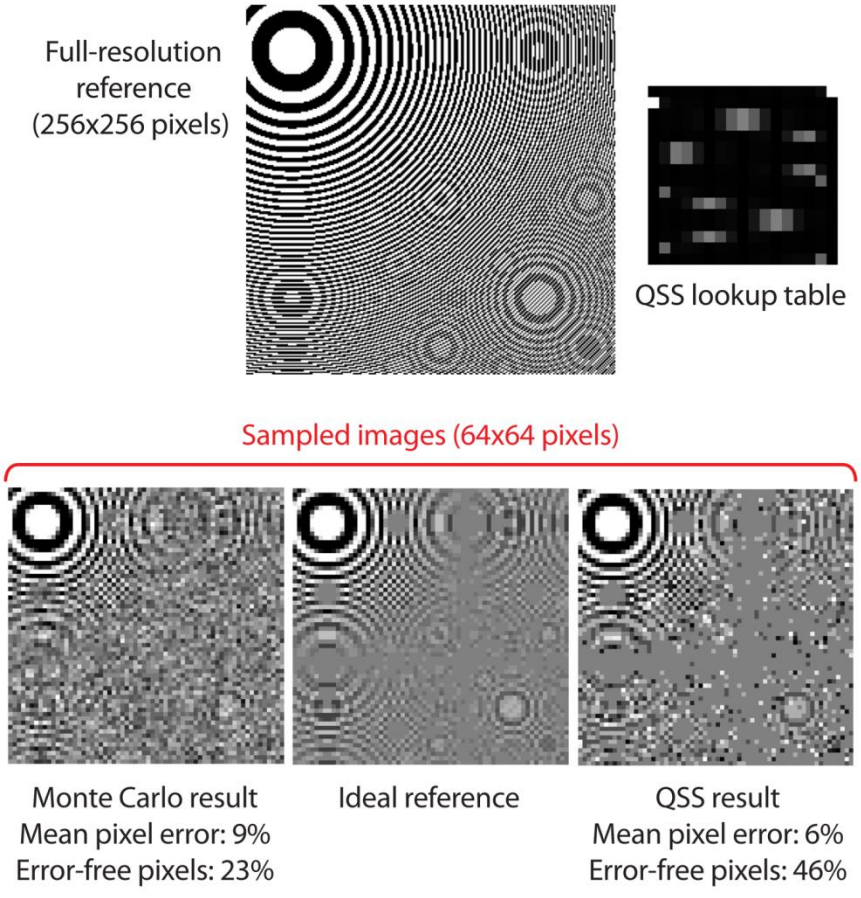


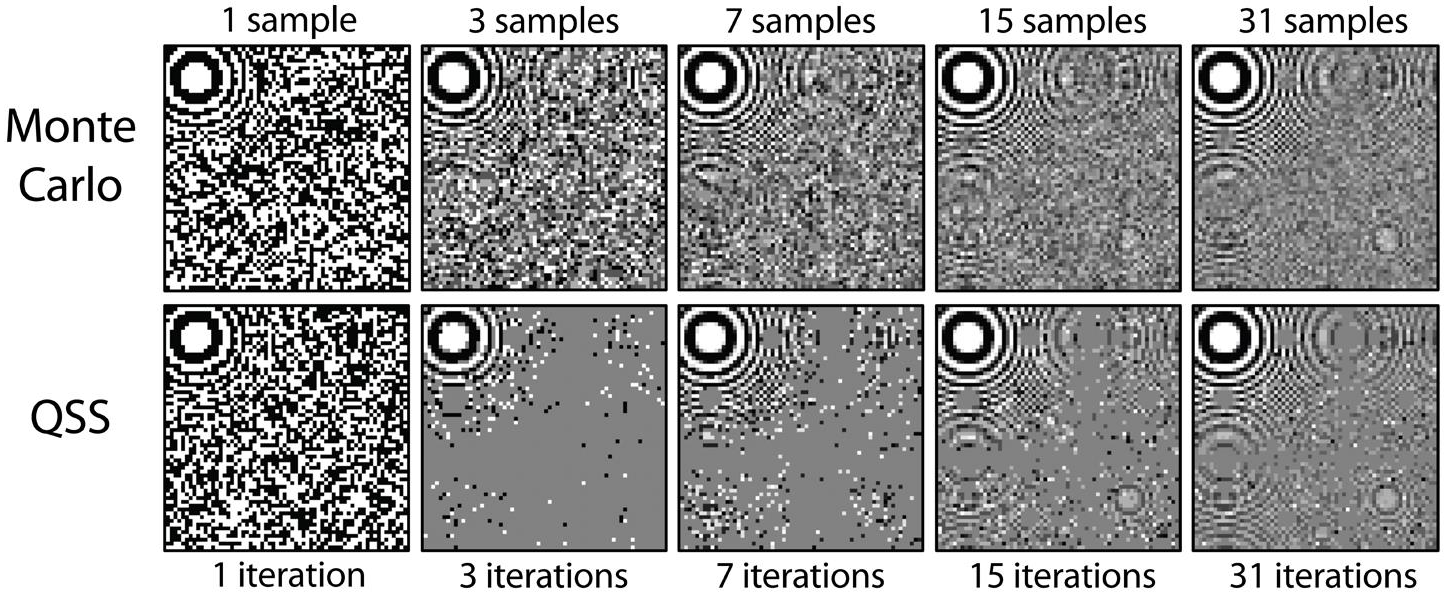


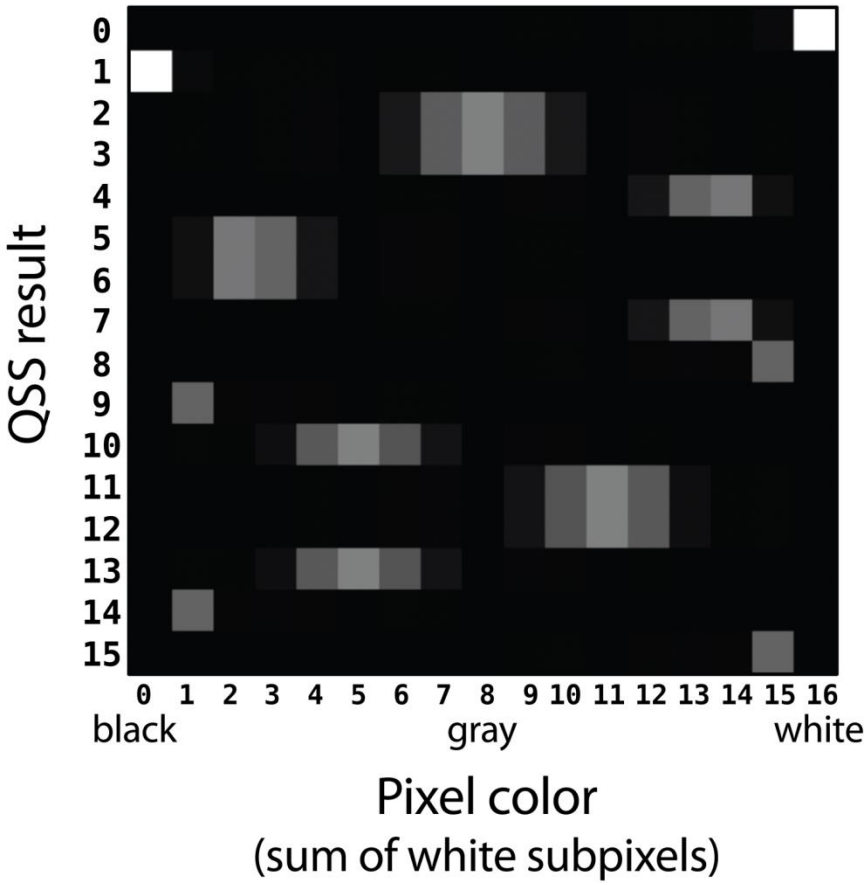




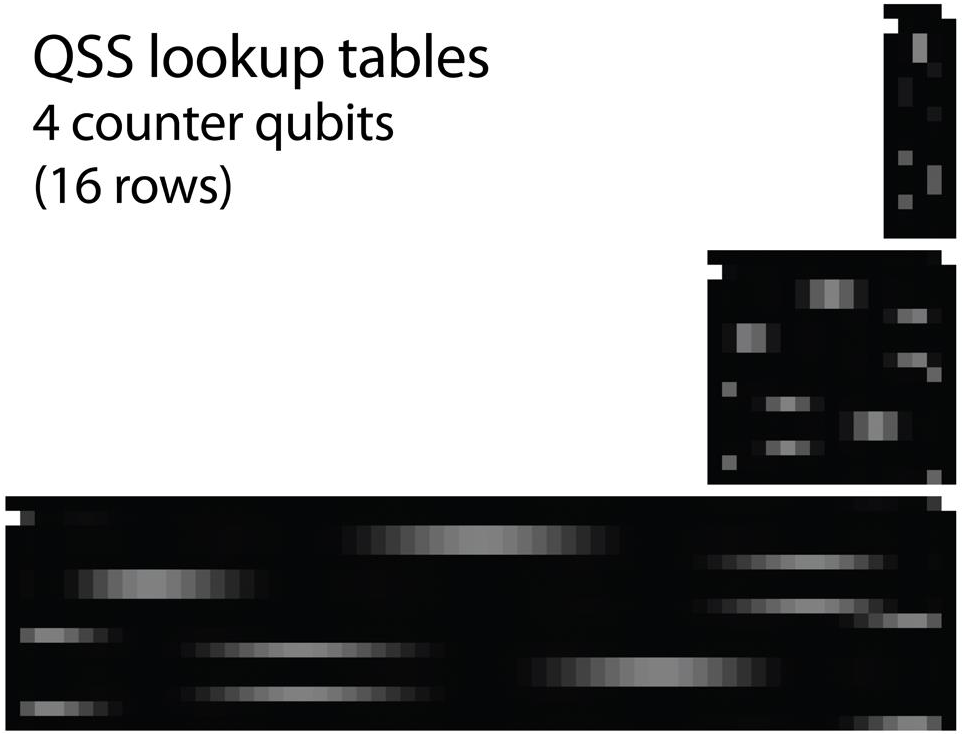








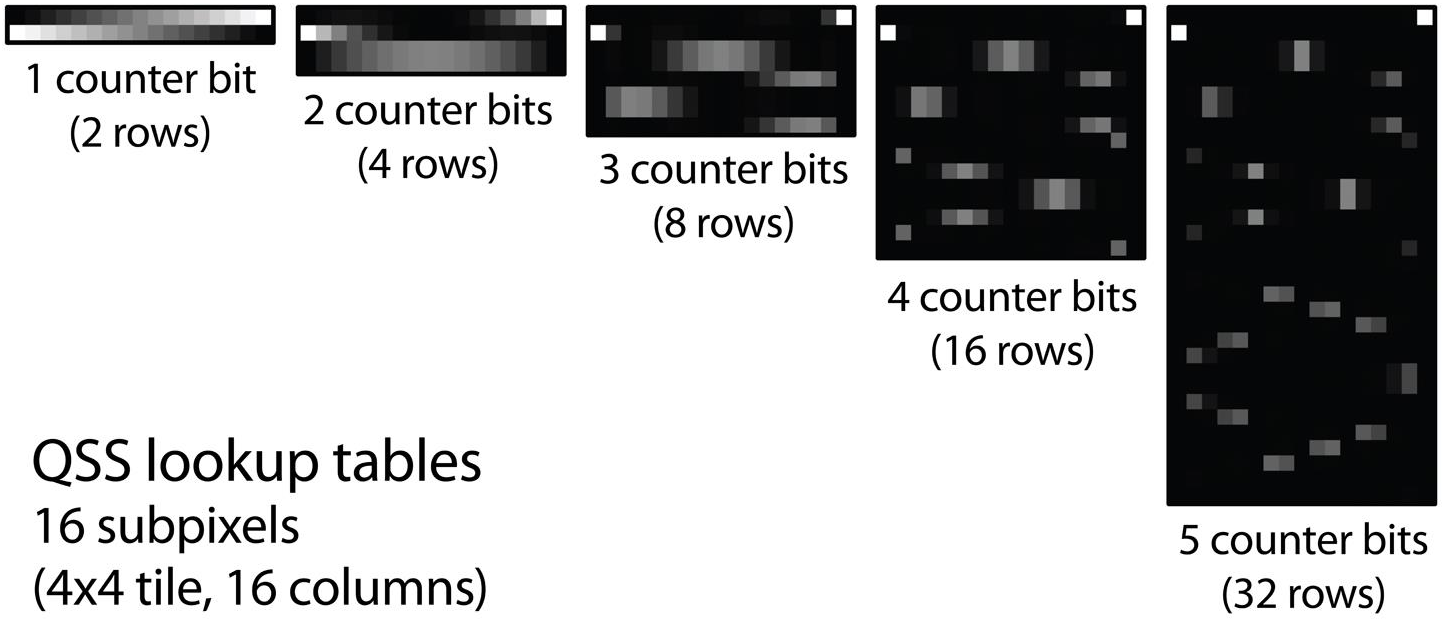
QSS lookup tables
4 counter qubits
(16 rows)



4 subpixels
(2x2 tile, 5 columns)

16 subpixels
(4x4 tile, 17 columns)

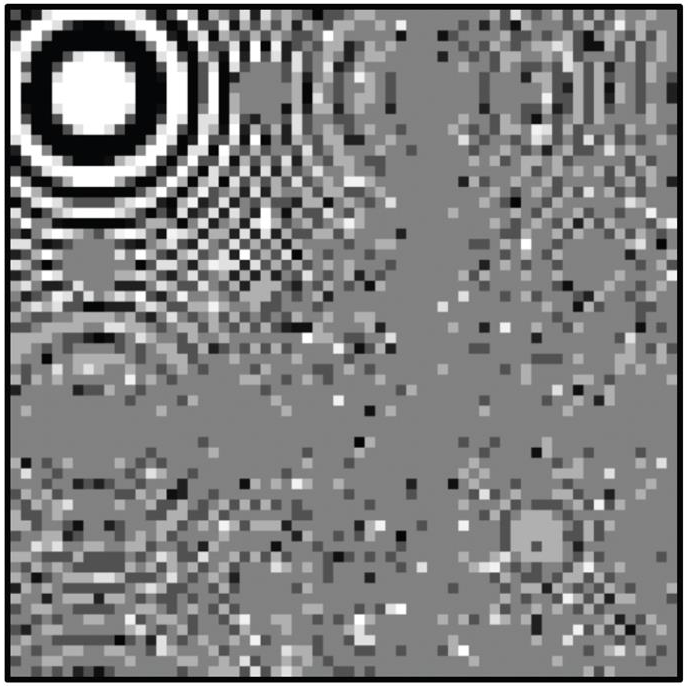
64 subpixels
(8x8 tile, 65 columns)



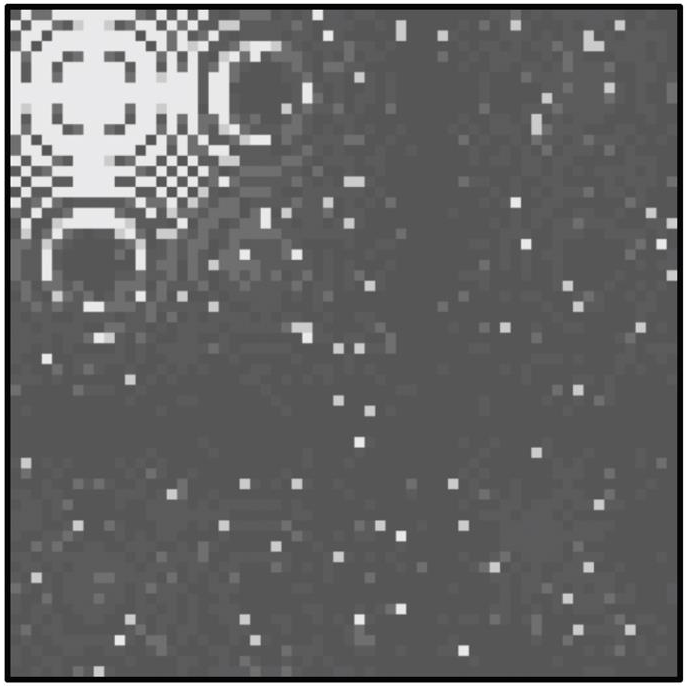
QSS lookup tables

16 subpixels

(4x4 tile, 16 columns)

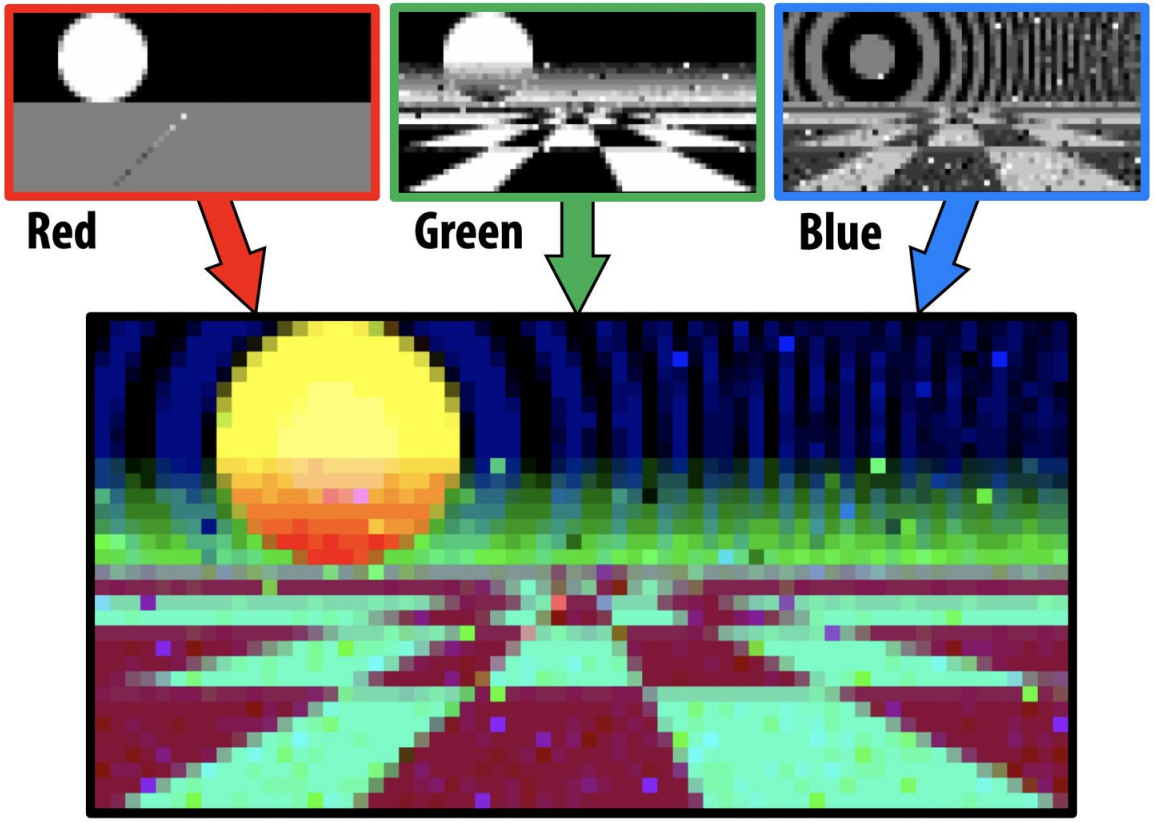


QSS result



Per-pixel confidence map

Adding Color



Discussion

Q & A

Next Lecture Appetizer!

- In next lecture (isA):
  - Quantum Cryptography.
    - Shor's Algorithm.
  - Reading Ch.12 before next class is a MUST.

Course Webpage

http://eng.staff.alexu.edu.eg/staff/moez/teaching/pqc-f19

- Where you can:
  - Download lecture slides (incl. exercises and homework).
  - Check links to other useful material.

Thank You