IBM Quantum Teach-the-Researcher series:

Variational Quantum Eigensolver Deep Dive

This document contains all of the material presented at the IBM Q Network Teach-the-Researcher VQE Deepdive courses taught in Yorktown Heights (January 28th-30th, 2020) and Tokyo (February 18th-20th, 2020). Please note that the section numbering may differ from those in the original course agenda. Sections 0-4 are introductory VQE material, 5-6 are introductory IBM Quantum hardware material, and sections 8-10 build on the content covered in sections 0-7. There is also an "extra" slide that discusses a longer term perspective on hybrid quantum algorithms but does not have an associated video.

All Power Point Slides can be viewed here.

0. VQE Overview — Going from cost functions to a Hamiltonian and computational complexity of short depth circuits
    a. Video
    b. Suggested Readings: Chemistry VQE Overview, Broad VQE Overview
1. Optimizers —VQE-Aqua flow and empirical study of optimizers
    a. Video
    b. Suggested Readings: Papers for each optimizer found in relevant code base.
    c. Jupyter notebooks: Callback Function for VQE iteration tracking
2. Hamiltonian Mapping Basics — From qubit measurements to observables, introduction to second quantization & different mapping overview
    a. Video
    b. Suggested Readings: First Quantization Encoding, Introduction to Second Quantization, Bosonic Encoding – Cat States
3. Hamiltonian Mapping & Reduction — Understanding different mapping's benefits, & reduction methods
    a. Video
    b. Suggested Readings: Section 2b of VQE Overview
    c. Jupyter notebooks: Hamiltonian Mappings
4. Initial States + Variational Forms— Understanding the Circuit Unitary
    a. Video
    b. Suggested Readings: Barren Plateaus, Adapt-VQE, Generalized UCCSD

    c. Jupyter notebooks: Variational Circuits
5. Hardware Introduction — Understanding circuit QED, superconducting qubits, and their limitations
    a. Video
    b. Suggested Readings: Engineer's Guide to Superconducting Qubits
    c. Jupyter notebooks: Readout Calibration
6. Dealing with real hardware — Understanding sources noise
    a. Video
    b. Suggested Readings: Dynamical Decoupling, Number Conserving Gates
    c. Jupyter notebooks: Measurement Error Mitigation, Backend Noise Simulation
7. Hardware Control — Introduction to 1&2 qubit gates
    a. Video
    b. Jupyter notebook: Qiskit OpenPulse Intro, Accessing Higher Energy States, Two Photon Excitation
8. Error Mitigation Techniques — Richardson Extrapolation at pulse level and "above"
    a. Video
    b. Suggested Readings: Richardson Extrapolation Theory Proposal & Experimental Realization
    c. Jupyter Notebooks: Simulating T1 Noise for VQE
9. Neural Network Estimators — Improving Sampling Errors with the use of Neural Networks
    a. Video
    b. Suggested Readings: Neural Network Estimators
10. Building on top of VQE — Overview of methods to study excited state dynamics (VQE-QSE) and qEOM), protein folding, QVector, VQE-cVAR and QAOA
    a. Video
    b. Suggested Readings: VQE-cVaR, qEOM, Protein Folding, QVector, QAOA
    c. Jupyter notebooks: qEOM
11. Extra — Explicit discussion for scaling issues of VQE.