DELFT UNIVERSITY OF TECHNOLOGY

MASTER THESIS

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INTRODUCTION

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Deep-reactive ion etched resonators

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2.1 Introduction

At this moment circuit QED is at the stage where multi-qubit experiments are being realized.

2.2 Muxmon chip architecture

Topics that should be explained in this section:

- The Muxmon0 and Muxmon1 chip are designed with two purposes
  1. Testing multiplexing using the Duplexer
  2. Explore qubit frequency re-use
- Explain similarities of chips
  - Three qubits per chip
  - All three qubits have individual flux tuning
  - Air bridges are used, not only for connect the ground planes, but also such that the feedline can pass over other coplanar waveguides without contact
- Explain differences between Muxmon0 and Muxmon1.
  - The Muxmon0 chip has a driving line connected to each of the qubits.
    It has two resonator buses at 4.9 GHz and 5.0 GHz

    Advantage Able to fully control each qubit individually, even when multiple qubits share the same frequency.

    Advantage Less coupling between data qubits.

    Disadvantage Requires more driving lines.

    Disadvantage Adds extra source of dissipation for the qubits.

- The Muxmon1 chip has two driving lines, each capacitively coupled to one of the two data qubits, and to the Ancilla qubit.

  Advantage Less driving lines required

  Advantage Less dissipation due to capacitive coupling

  Disadvantage Cannot individually control data qubit and ancilla qubit when they share the same frequency

  Disadvantage More coupling between qubits

- Explain concepts of cross-coupling and readout cross-talk

  Cross-coupling The coupling between qubits.
  Cross-coupling leads to transfer of excitation.
  An associated coupling strength **g** can be associated to cross-coupling.
  Can be determined by driving one qubit extremely hard, and measuring signal from other qubit.
  TODO: Show values of cross-coupling found, or do this in characterization section
  TODO: Leads to coherent errors?
  TODO: Two types of cross-coupling? Direct leakage of pulse pulse, and transfer of excitation? cross-driving?

  Readout cross-talk Coupling between a qubit and a resonator that are not directly coupled.
  A part of the signal measured from one resonator is then due to the state of another qubit
  TODO: Understand more behind readout cross-talk

Left to think about:

- Should I already include items such as coherence times, the fact that Muxmon0 performs better than Muxmon 1?
- Where should I include coherence times versus frequency?
- Should the part on cross-coupling and readout cross-talk not be in characterization section?

Figures that need to be included:

- Muxmon0 and Muxmon1 chip
- SEM image of air-bridges such that coplanar wave-guides cross without intersecting
- schematic of cross-coupling and readout cross-talk
  It could be good to create this using the actual Muxmon chip as background, with arrows indicating how the different effects operate

2.3 QUBIT CHARACTERIZATION AND INITIAL TUNE-UP

2.4 CALIBRATION ROUTINES

2.5 RANDOMIZED BENCHMARKING