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# Development of an RF resonator for a double junction ion trap

Semester Project

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**Abstract**

This paper shows complete process of modeling, designing and testing an RF helical resonator suitable for supporting a double-junction ion trap in a cryogenic environment.

# Contents

Chapter 1

# Introduction

Quantum computing is an exciting and rapidly evolving field of a modern science. One of the popular implementations of a quantum computer is based on an ability to control and measure systems of trapped ions. Those ions are typically confined in Paul [4] traps by applying static and high voltage RF signals to trap's electrodes, which on average generates a corresponding stabilizing electric potential.

## 1.1 Why do we need resonators?

One could potentially couple a radio frequency source directly to an ions' trap. However it imposes the following challenges:

- noise from a source may contribute to heating of trapped ions [5]
- in order to maintain efficient cryostat cooling all internal connections must be manufactured out of materials with low thermal conductivity. Unfortunately following the Wiedemann-Franz law [1] it leads to low electrical conductivity thus resulting in high dissipation of power
- impedance mismatch between source and trap leads to an additional dissipation of RF power

These issues can be avoided by placing an amplifier close to Paul trap, which would filter incoming signal and output it with voltage suitable for operating the trap. Two available options are active and passive amplifiers. Active amplifiers perform better in terms of voltage gain at room temperatures, but cryogenic temperatures do not allow underlying semiconductor technology to function, which leaves us with passive amplifiers (resonators).

## 1.2 Context of a project

This semester project aims to be a part of an attempt to create a scalable quantum computing architecture by Chiara Decaroli. It provides the following benefits compared to existing solutions:

- using subtractive laser writing to manufacture wafers eliminates misalignment effects
- double junction ion trap was designed for parallel operations, Decoherence Free Subspace (DFS) ion transport across the junctions, and manipulation of long chains of ions
- integrated laser delivery through optical lensed fibers eliminates the need for bulky optics and custom objectives which limit scalability

[TRAP PICTURE HERE]

## 1.3 Kinds of resonators

Required frequency range limits our selection to the following types of resonators: helical [3] or, for higher frequencies, coaxial, RLC [2], and crystal oscillators.

### 1.3.1 Helical

Helical resonators are the most widely used type of resonators.

### 1.3.2 RLC

RLC resonators provide

### 1.3.3 Crystal

Unlike helical and RLC resonators crystal oscillators do not store energy just in electric field. This type utilizes piezoelectric effect to transform applied harmonic voltage into surface mechanical modes and vice versa.

Narrow excitation spectrum is provided by physical dimensions imposing hard constrains on vibrational oscillations and could have made such device an ideal filtering solution for ions traps. Unfortunately, there are some major downsides that seriously limit its applicability:

- after fabrication resonant frequency can not be widely tuned
- limited stability of the crystal does not allow high voltages

### 1.3.4 Choosing the right one

Chapter 2

# Theory

## 2.1 Helical resonator models

## 2.2 Comparing Macalpine's vs Hensinger's

Chapter 3

# Design

Chapter 4

# Validation

Chapter 5

# External circuits & additional features

# Bibliography


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