Resonant Cavity Field Profiler

ECE 445 Project Proposal

Team 31
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1. Introduction

1.1 Problem

This project proposal was submitted by Starfire for designing a device to tune Resonant Cavity Particle Accelerators.

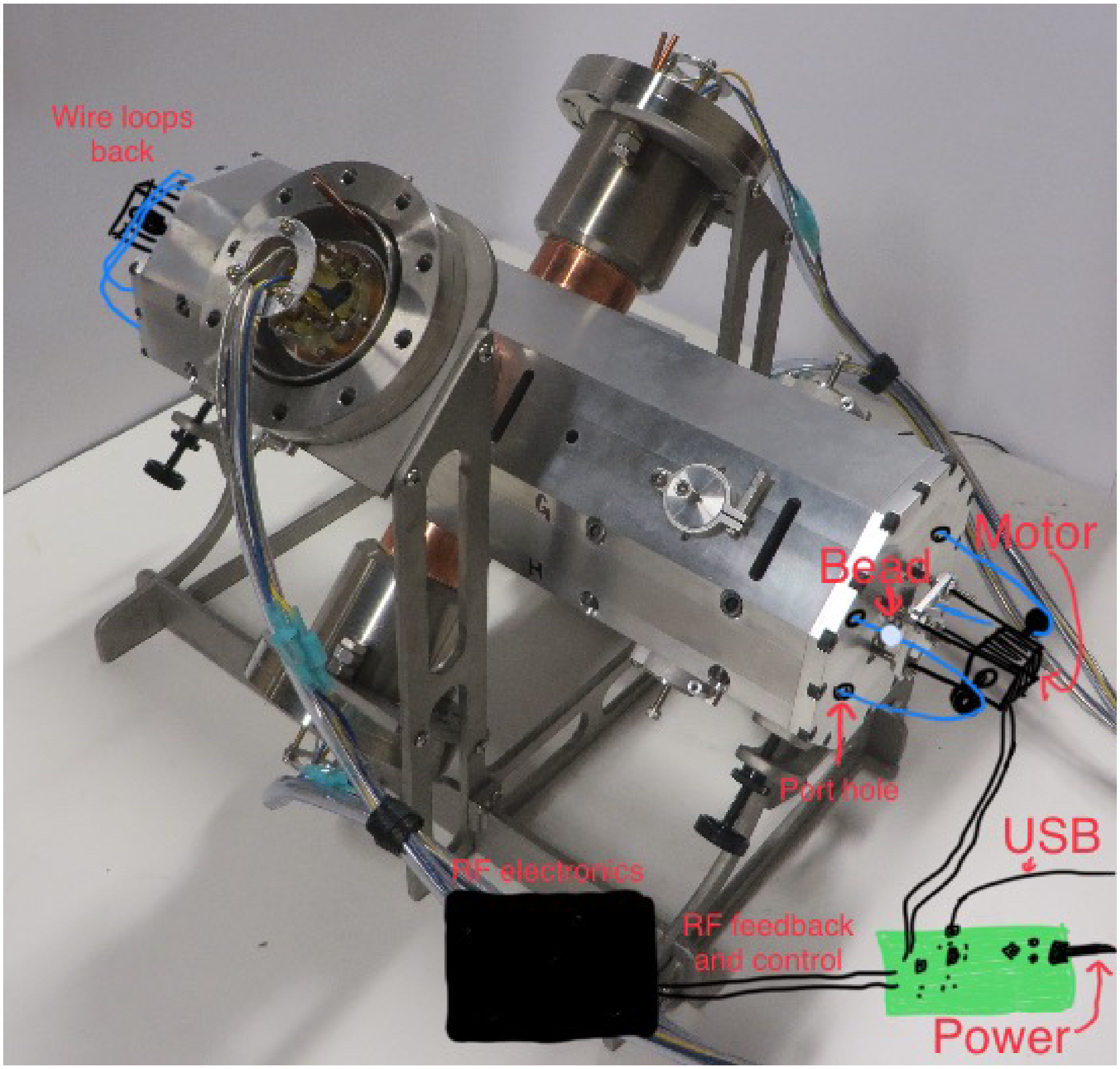
The design process of Resonant Cavity Particle Accelerators requires fine characterization of their electric field for design verification. This is typically accomplished by pushing a metal bead through the cavity where the magnetic field is the strongest. This results in a small, but measurable change in the resonant frequency of the internal cavity. This frequency offset gives the operator an indication of the strength of the magnetic field displaced by the bead. This is then used to estimate the electric field strength and uniformity. This is typically done manually, with a user making small changes to the position of the bead and measuring the resulting frequency shift. This process can be very time consuming and take a single user up to two days to accomplish.

1.2 Solution

A stepper motor will move the bead through the cavity while a microcontroller will correct for any resonant frequency offset and log the current position. This device will move the bead through all 4 cavities of the accelerator while simultaneously making measurements to estimate the current field conditions in response to the bead. The frequency offset will be controlled by the MCU and the setting time of the control loop will be the limiting factor in the time it takes to perform a complete characterization. This will help technicians properly tune and characterize cavities to obtain optimum performance.

We will work with Tom Houlahan, the engineer responsible for the project, and will meet with him regularly to discuss the project. Starfire will be providing a test cavity for the purposes of design verification and testing. Tom would like the characterization to take roughly the amount of time to get a cup of coffee or roughly 5 minutes at minimum.

1.3 Visual Aid



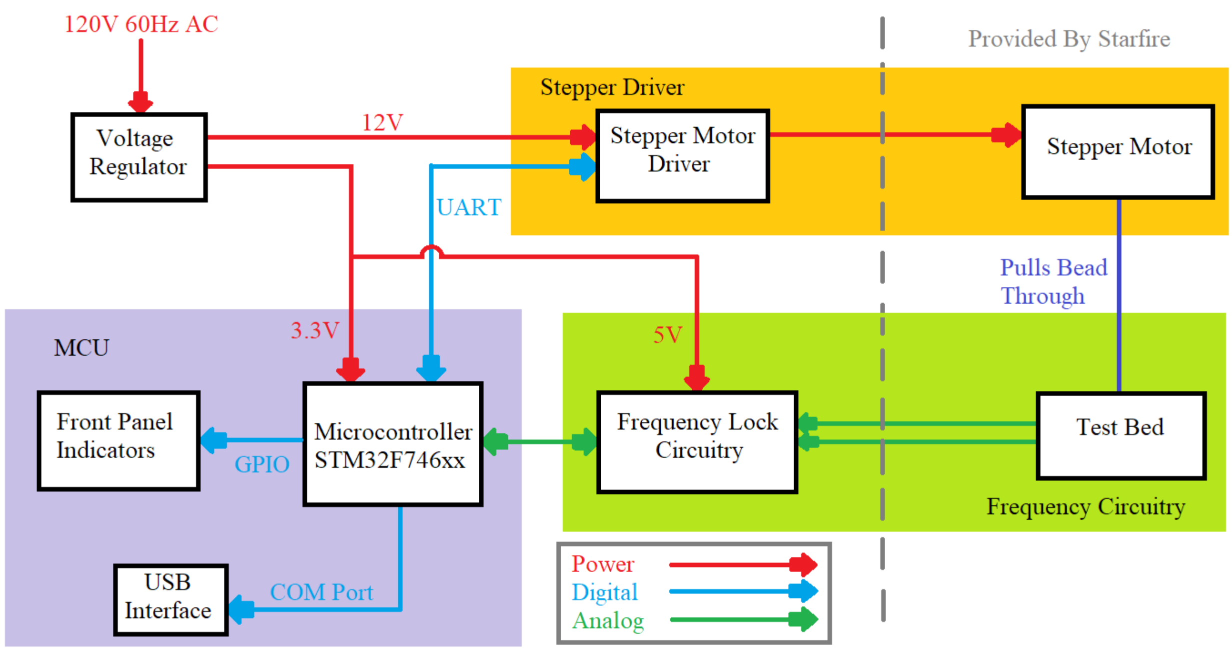
Basic setup with the test cavity. Our board is shown in green while all other materials are to be provided by Starfire

1.4 High-level requirements list

1. Pull a bead through the cavity and record the responding resonating frequency. It will continue and calculate the bead position for an optimal resonating frequency.
2. Characterization will complete in a matter of minutes (five minutes was requested). The entire characterization process will not require any input from a user. Once complete, it would then notify the user of its completion.
3. Data will be logged on a PC for later use so users can refer to it later. The data should include the position of the bead and its corresponding field characterization.

2. Design

2.1 Block Diagram



2.2 Subsystem Overview

2.2.1 MCU

Supplies drive signals to a stepper motor to move the metal bead through the 4 quadrants of the RF cavity. Controls a front panel to indicate the current state of the system. Communicates to an external computer to allow the user to set operating conditions and to log position and frequency correction data for further analysis. Samples feedback signals from RF front end and issues corrections to the PLL circuitry through the DACs. We chose the STM32F746 due to availability. This microcontroller is highly capable and notably has 2 12bit DACs, 3 12bit ADCs, 4 UARTs, 320kb onboard SRAM, and USB 2.0 FS support. These will fully satisfy our requirements for a microcontroller.

2.2.2 Frequency Circuitry

Maintains a drive frequency that is equal to the resonant frequency. A series of op-amps form a control loop from output signals from the RF front end. They will also filter the feedback signals before sampling by the ADCs. The LM324 is a good option for this as it supports up to 32V and is available in a quad package.

2.2.3 Stepper Driver

We will be using a Trinamic TMC2202 stepper motor driver IC. The TMC2202 can supply up to 1.2A RMS and up to 256 micro steps offering high positional performance and smooth operation. This IC can be easily interfaced with a UART port from the MCU. Over UART, you can issue speed and distance commands and read back the current positional data. A small momentary contact switch will be used to "home" the bead to ensure the same starting location before each profiling pass.

2.3 Subsystem Requirements

2.3.1 MCU

1. Communicate with a PC over USB for data logging
2. Communicate with Frequency-Lock Circuitry to receive data from RF cavity
3. Control the front panel indicators

2.3.2 Frequency Circuitry

1. Regulate inputs from test bed/RF cavity and output resultant frequency to MCU

2.3.3 Stepper Driver

1. Precisely control a Stepper motor (provided by Starfire) to move a bead through the RF cavity
2. Communicate with MCU on the current position of the bead and reset it to a given position if needed.

2.4 Tolerance Analysis

To meet the requested five minute acquisition requirements, the bead must be able to traverse the cavity four times (once for each quadrant) in roughly 300 seconds. The cavity is one meter long so this equates to a required traversal speed of 1.33 cm/s. We would like to make a measurement of the beads' field displacement roughly every

1mm which represents an ADC sampling rate of around 14Hz. This is well within the capabilities of our microcontroller's maximum conversion rate of 2.4MSPS.

3. Ethics and Safety

We will be working with potentially high power RF circuits operating at around 600Mhz. Leakage from the cavity could represent a serious source of interference to communications in the UHF band. This is mitigated by the design of the RF cavity and is outside the scope of our work. This still should be taken into account and the test cavity should not be operated without the tuning port holes open.

A fully operational particle accelerator of this class is capable of accelerating particles to energies capable of damaging tissues. This will not be an issue as the cavity will not be under vacuum and therefore not capable of accelerating particles.

We will be working with voltages above 100V which have the potential for dangerous discharges. Capacitors can hold dangerous amounts of charge for extended periods of time after being disconnected from a power source. For this reason caution should be taken around PCB areas that were energized and should not be touched.

We do not consider any major ethical concerns as the device is not meant to be actively interfaced with or to anyone or any living organism.