ECE Senior Design Project:
Resonant Cavity Field Profiler

2022 SPRING SEMESTER
About Us…

**Starfire Industries LLC located in Champaign, IL USA** (near *University of Illinois*)

- ~35 employees, including 6 PhDs
- 14,000 ft\(^2\) engineering, lab/test and production space
- Complete vertical integration from R&D, manufacturing, applications testing and support
- Making neutron generators and pulsed plasma sources for 10+ years!

**Products:**

- nGen\(^\circledast\) portable neutron generators
- Centurion\(^\circledast\) transportable MeV particle accelerators
- IMPULSE\(^\circledast\) pulsed power modules for sputtering
- RADION\(^\text{TM}\) plasma sources for PECVD & Etching

**Internship/Co-Op Program:**

- M.S. & M.Eng. Program + Ph.D. (planned)
Project Background

**RF accelerator systems use a resonant cavity**
- Shaped cavity interior converts oscillating fields into directed particle acceleration
- Operation requires precisely controlled EM field profile

**Tuning the cavity field is an iterative process**
- Measure field profile → adjust tuning slugs if needed → repeat

**Field profile is inferred via a ‘bead-pull’ technique**
- A metal bead on a nylon wire is pulled through the cavity
- The bead causes a shift in the resonant frequency of the cavity based on the magnetic field strength at the bead’s location

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**Starfire’s prototype, compact 4 MeV D+ RFQ cavity**

A close-up view of the tuning slugs used for field shaping.

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\begin{align*}
|\vec{E}| & \quad \text{Tuning slugs} \\
TE_{210} & \\
|\vec{H}| &
\end{align*}
\]
A functional block diagram for the proposed project is shown at right
- The RF circuitry, RF cavity, and bead-pull hardware will be provided by Starfire

RF circuitry accepts control signals for controlling frequency and phase shift
- Feedback output is proportional to \( \omega_{\text{res}} - \omega \)

The proposed project is to design & build a system capable of:
1. Supplying drive signals to a stepper motor to step the metal bead through the 4 quadrants of the RFQ cavity
2. Maintain a drive frequency that is equal to the resonant frequency
3. Record the frequency shift as a function of the metal bead’s position
4. Interface with a PC to allow the user to set operating conditions and to transfer/save data for subsequent analysis

A block diagram of the proposed system. The RF electronics, beadpull hardware, and RFQ cavity all exist at Starfire. Their design and construction are outside of the scope of this project.