Commissioning the Extended Interaction Oscillator (EIO) Tube For a 5T Dynamic Polarization System

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Introduction

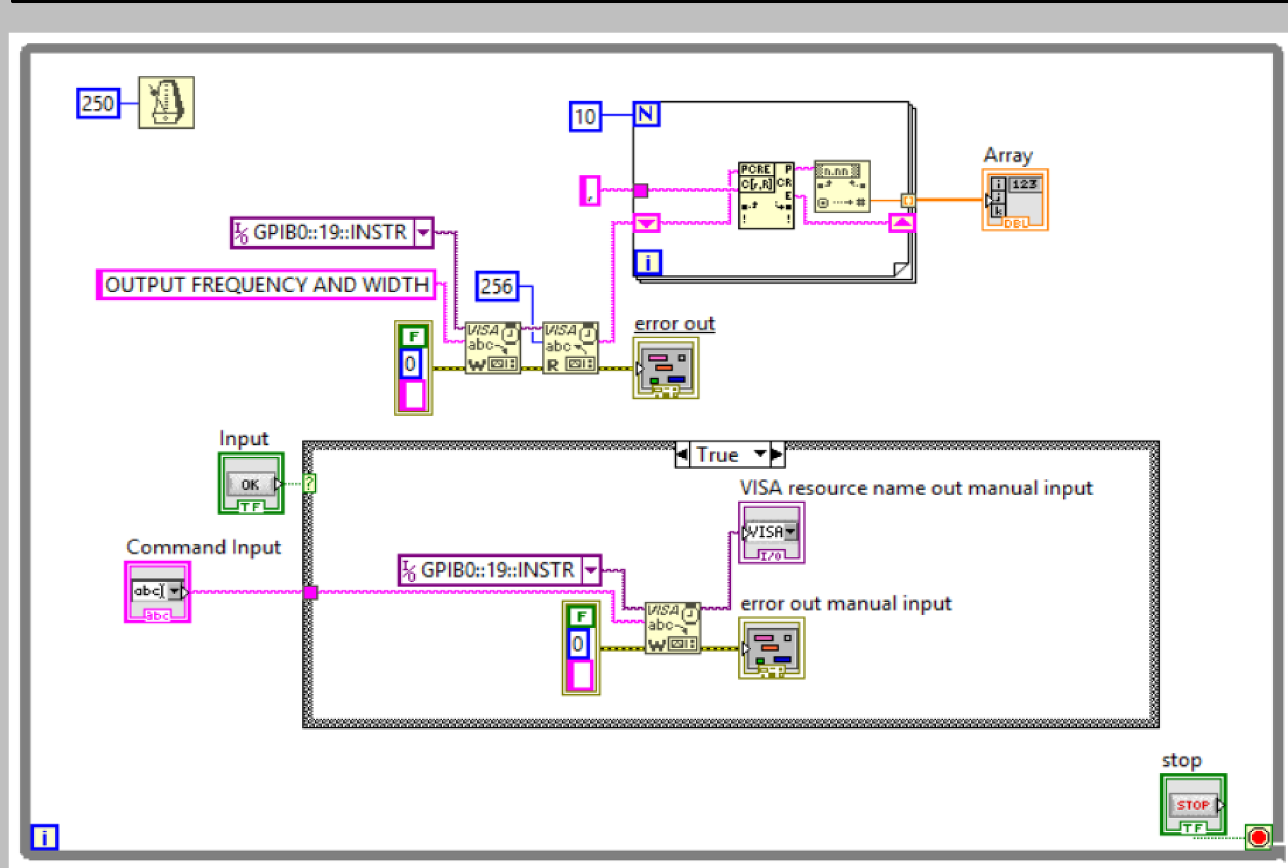
The VKT 2438P Series CW Extended Interaction Oscillator (EIO) is a high-power microwave source designed for continuous wave operation in the millimeter-wave frequency range. We plan to utilize this microwave equipment for Dynamic Nuclear Polarization (DNP), a technique that employs microwaves to transfer polarization between electrons and the target sample.

Goal

Utilize the VKT 2438P Series CW EIO to transfer the polarization obtained from a large electric field ($\geq 5T$, see Matthew Bretton's poster) from electrons to the nucleons of the target material.

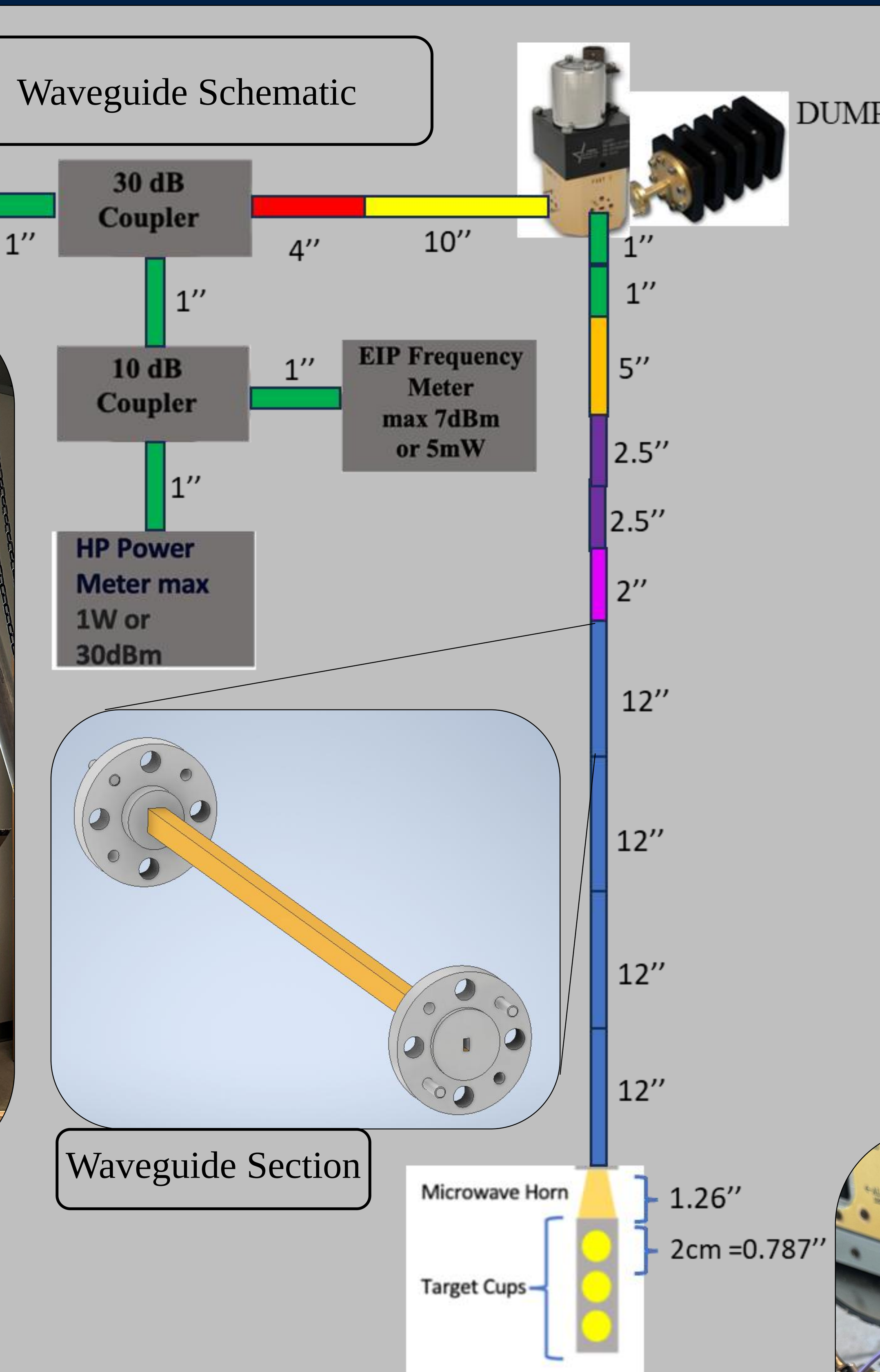
Background

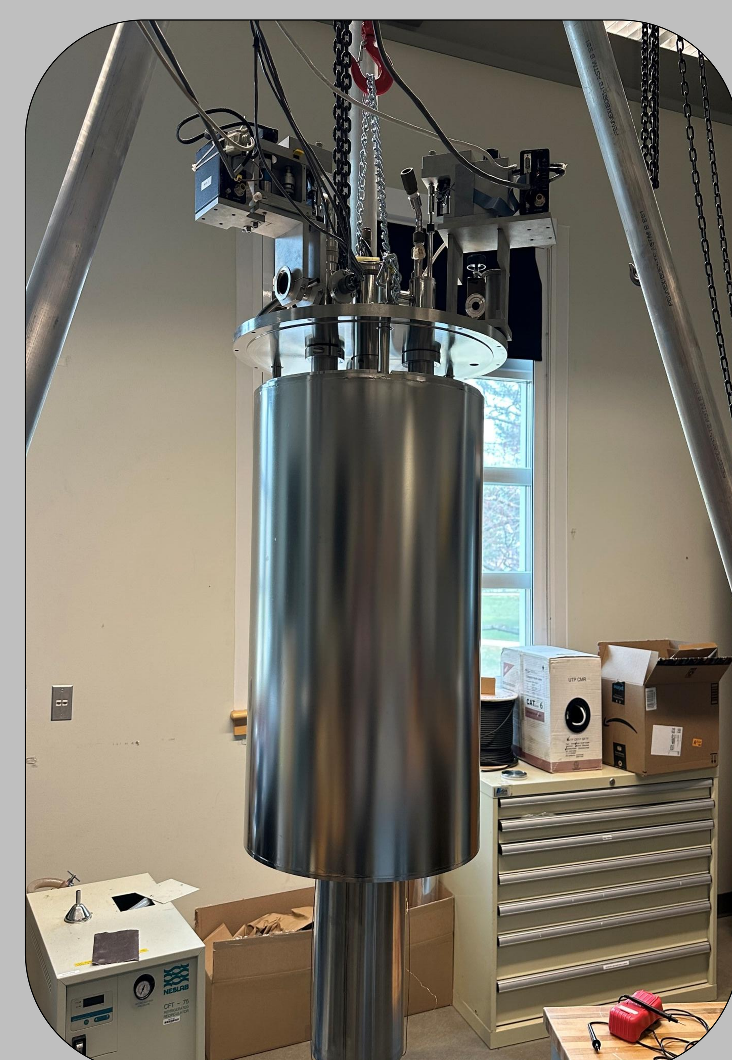
- **Hyperfine Interactions:**
  - An unpaired electron's and nucleon's spin couple i.e, if one spin flips, the other does too
  - Microwaves that match the Larmor frequency provide energy that induces these flips
- **Why we need Hyperfine Interactions:**
  - We rely on these interactions because polarization is proportional to the particle's gyromagnetic ratio, $\gamma \sim \frac{1}{m}$;~660 times as easy to polarize



LabView Code for Power/Frequency meter

Waveguide Schematic





Full cryostat

Waveguide Section

Future Work

- Have working LabView code for all measurement devices
- Power test the EIO
- Experimentally get values for effective volume, spin-lattice relaxation time, and efficiency factor
- Run a full cool down and transfer the polarization

References

Albannay, et al. *Optimized Microwave Delivery in dDNP*, Journal of Magnetic Resonance, 2019, https://www.sciencedirect.com/science/article/pii/S1090780719301119?via%3Dihub. Accessed 2025.

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Considerations

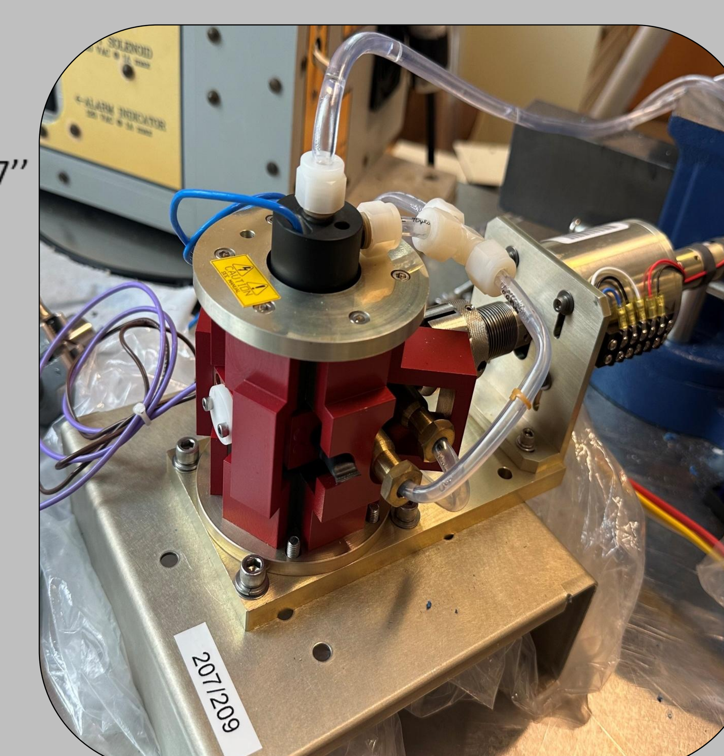
Circular vs Rectangular Waveguide:
Due to their straight walls, rectangular waveguides lose less power than their circular counterparts. The cutoff frequency is typically higher, but is not an issue:

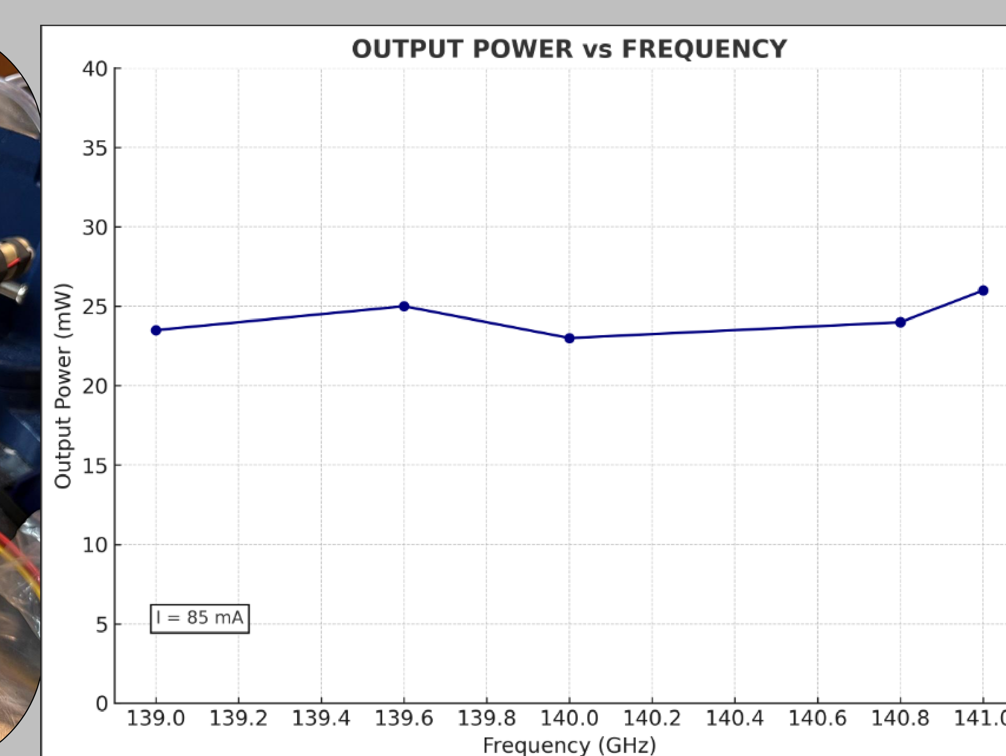
$$f_c = \frac{c}{2}\sqrt{\left(\frac{n}{a}\right)^2 + \left(\frac{m}{b}\right)^2}$$

Input Frequency:
To induce the exchange of polarization, we need our microwaves to match the electrons' Larmor frequency modeled by:

$$f_e = \gamma_e B_0 = 140 \text{ Ghz}$$

Given γ_e, the electron's gyromagnetic ratio, 28 Ghz, and B_0 is the exterior magnetic field, 5T.





Input Power:
With a waveguide system, the traveling waves will lose power as they travel due to attenuation and coupling. To find the minimum power needed, I derived the equation:

$$P_{min} \geq \frac{V_{eff}}{2\nu\mu_0 T_{2e}} * \left(\frac{1}{\gamma_e T_{2e}}\right)^2 * e^{2\alpha_c L}$$

Given, α_c is the attenuation constant, L is the length of the waveguide, T_{2e} is the spin-lattice relaxation time, ν is the efficiency factor, V_{eff} is the volume the induced magnetic field covers, and μ_0 is the permeability of free space.