Design of Material Insert for Dynamic Nuclear Polarization

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Introduction

Breakthroughs in nuclear physics experiments have led to advancements in medical imaging and particle physics. Dynamic nuclear polarization (DNP) is a method that uses microwave irradiation to transfer the polarization of electron spins to nearby nuclei, boosting Nuclear Magnetic Resonance (NMR) signals. This process requires a strong magnetic field (5T) and very low temperatures (below 100K). I present the design of a material insert that aims to refine existing models to further the progress of these experiments.

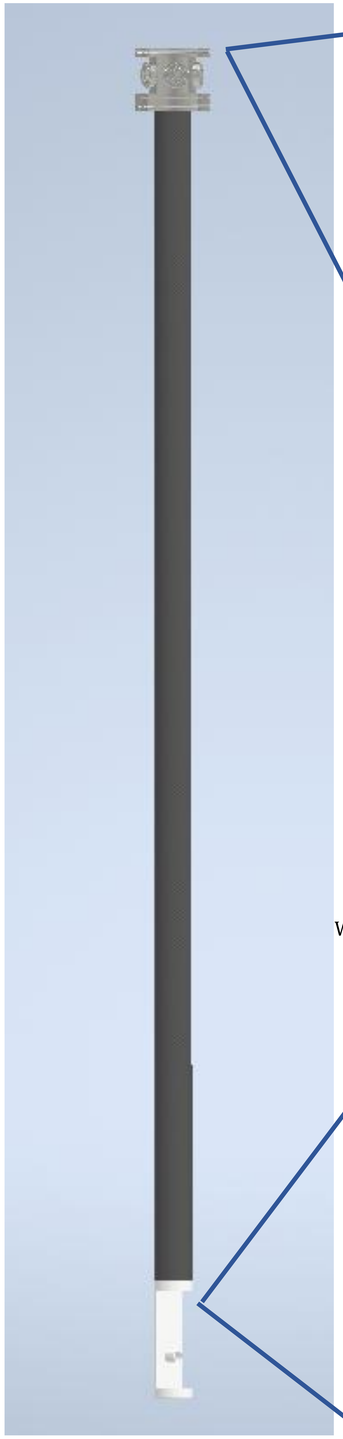
Design Requirements

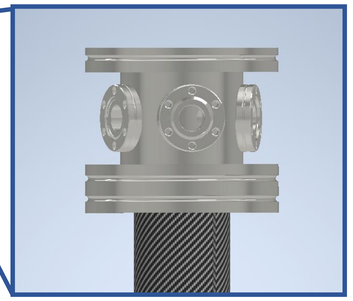
- Material that can withstand cryogenic temperatures ~ 1K
- Resistance to radiation damage
- Waveguide connections running through from the top piece down to the ladder
- Maximum microwave transmission from waveguides to sample
- Improved vacuum seals
- Smart and adaptable design allowing usage in different labs and experiments

Design Process

- Create 3D model of each component of insert
- 3D print parts to test different prototypes
- Revise and improve

Current 3D Model of Insert





"UFO"

- Thermometry
- Waveguide connection
- 2 ISO-63 SS flanges
- 5 CF-16 SS flanges

Waveguide

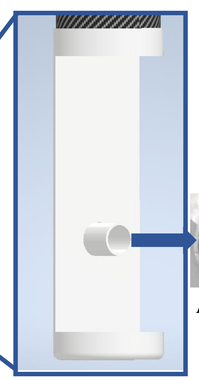
Carbon Fiber Stick

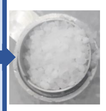
- ~ 2 meters
- Waveguides
- Cernox temperature sensors
- Vapor pressure measurements

Cernox sensors

Cryostat set-up in lab

NMR coils

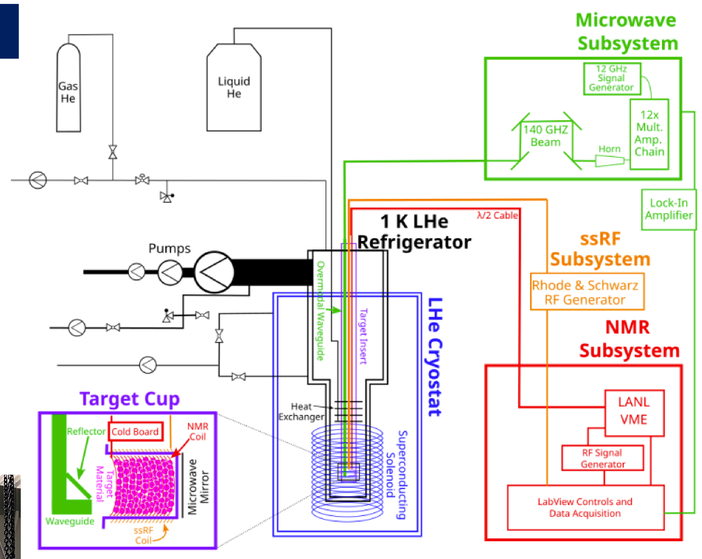




Ammonia beads

Ladder

- Holds target cup containing target material
- Replaceable and removable target cup
- Cernox thermometry
- NMR and EPR coils
- PEEK plastic



Schematic of cryostat showing various subsystems

Future Work

- Test different designs for waveguide vacuum seal
- Finalize detailed design of target ladder
- Construct target insert and perform tests
- Optimize design to enhance NMR sensitivity, enabling real-time, faster metabolic imaging in future medical applications

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References

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