Mechanical Engineering Design Portfolio

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1 Overview

This portfolio showcases my proficiency in Autodesk Inventor and mechanical engineering design, including 3D CAD models and detailed engineering drawings. Designed and simulated a compact modular Merritt coil system to replace Helmholtz coils, reducing the size by 6x while doubling the longitudinal field gradient and increasing the uniform field range by 33%. Over the years, I have devised and upgraded several instruments and devices suitable for various experimental applications in thermal control system and optical measurements. All of which are achieved through close collaboration with our departmental machine shop teams and engineers.

2 Merritt coil system

In the neutron scattering experiment, electron beam passes through a hybrid high-pressure spin-exchange optical pumping (SEOP) cell consists of a spherical pumping cell on the top, a cylindrical target cell at the bottom, connected by a thin transfer tube, containing helium-3, rubidium, potassium, and nitrogen gases. Though the pumping laser is directed onto the pumping cell, the electron beam is propagating through the target cell. The cell is usually covered by a red home-built cuboid plastic shielding, with openings located at designated locations for SEOP and probe beam path. Helium-3 nuclear spins are modulated using nuclear magnetic resonance (NMR) in the presence of a longitudinal magnetic holding field, generated by a pair of Helmholtz coils with radius 65.5” (166.6 cm).

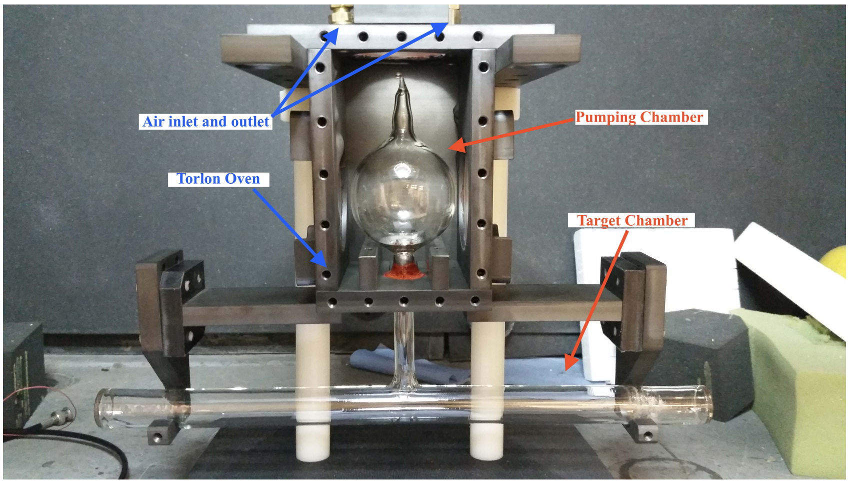

Figure 1: Side view of cell Vivian install in a torlon used in the Faraday lab.

Due to the bulk size and unshielded nature of Helmholtz coils, our experiments suffered several systematics associated sourced by the magnetic field gradients and fringe field effects. It is well understood that larger field gradients lead to longer spin relaxation times and increase depolarized per spin flip. And many of the experimental setup surrounded the cell Vivian are magnetized due to fringe field effect, thus causing undesirable results, most notably the optical benches, posts, and mirror mounts.

Figure 2: Assembled Merritt Coil System Assembly.

The Merritt coil system, provides a robust and flexible solution designed specifically to be adapted with the cell Vivian and its associated experiments. Since the two outer coils are connected in series and run a higher current than the inner coils, the side length difference of the frames must be taken into account to make sure that the center of the cross section of each coil lies on the same horizontal plane. The square shaped coil frame maximized the rigidity and sturdiness while maintaining enough symmetry for magnetic field generation; mostly importantly, they are easy to machine and assemble.

During the design, the minimum bending radii for single-conductor wire rated for our experiment are also considered. For this purpose, four smooth fillet corners made with cylinder tubes and sandwiched by two side flanges connect the rest of the aluminum extrusions. Also, note that every half-coil frame is securely connected by four Ultem 1000 flange pieces mounted at the central top and bottom locations; they are needed to effectively break the induced current potentially caused by NMR coils; these materials have very high tensile strength ($> 15200\,\mathrm{psi}$) and very low coefficient of linear thermal expansion ($< 3.1\,\mathrm{in/in/^\circ F} \times 10^{-5}$). In principle, the screws included in this assembly are made of brass, aluminum, or titanium; however, in practice, we have found that 316 stainless steel screws introduced negligible effects on the overall magnetic field distribution.

Two anodized aluminum extrusions (Vention ST-EXT-001-1125) are installed on the plywood project panels, with each coil mounted to the extrusions through two cutom-made aluminum mounts and profile sliders (Vention MO-LM-008-0002), the sliders can be fixed at optimal intercoil spacing using T-nuts with screws. The coil mounts were carefully designed to center and level all four coils.

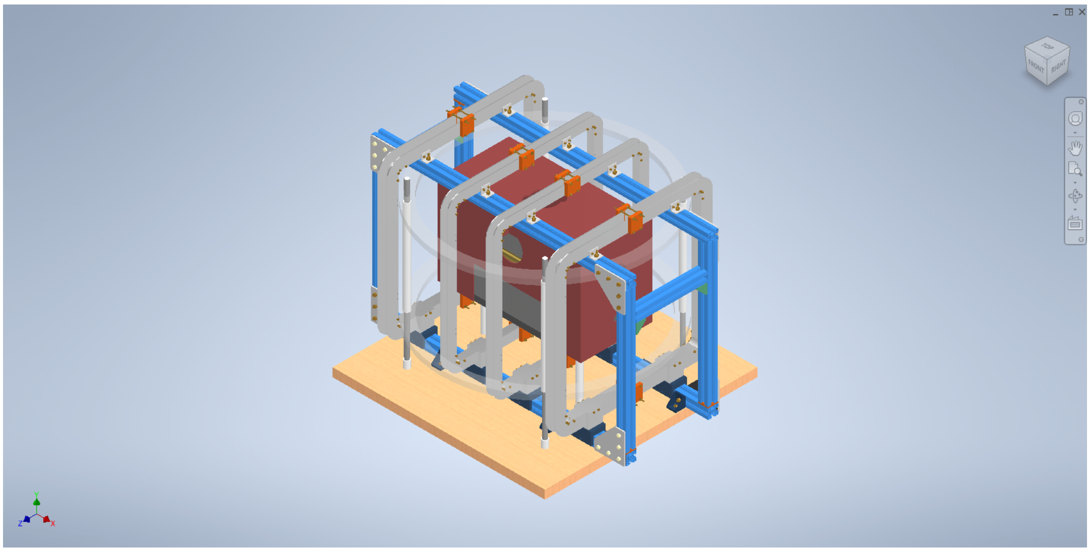

Figure 3: Rendered 3D model of the Merritt coil system assembly

Additional designs include electrical connection panels, breakup pillars, and system stabilization supports. But they are not shown in Fig. (2), only in the rendered 3D model Fig. (3).

The following figures present detailed mechanical drawings of the components:

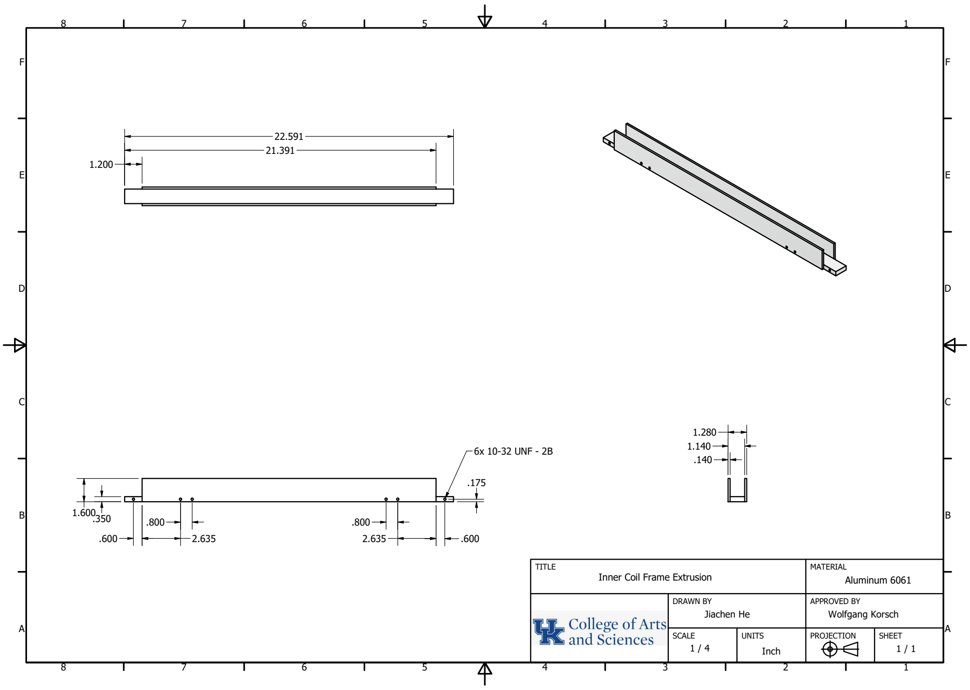

Figure 4: Inner Coil Frame Extrusion (Material: Aluminum 6061)

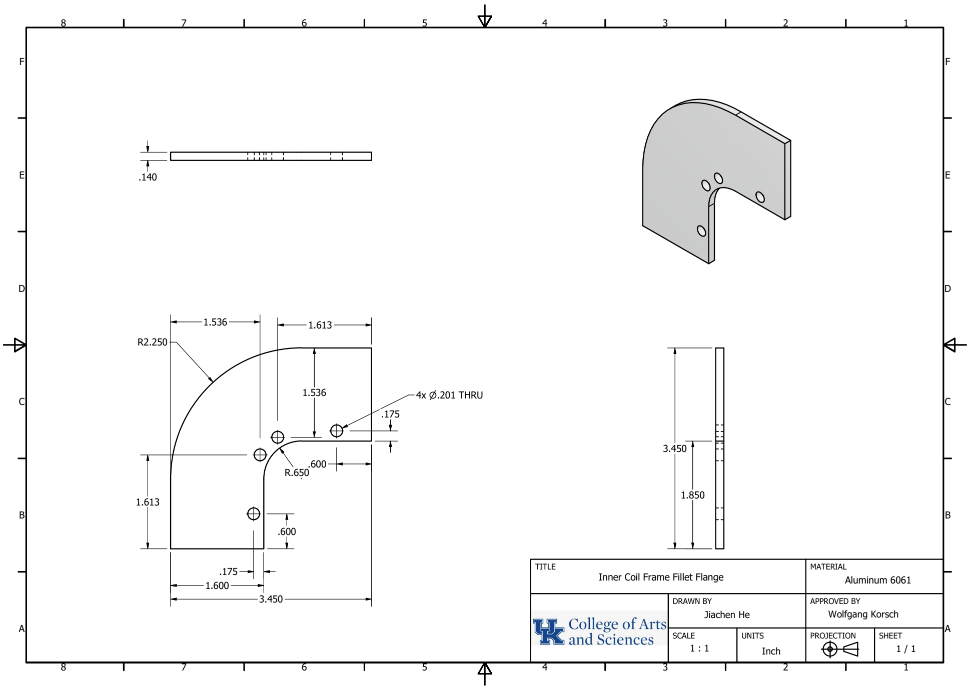

Figure 5: Inner Coil Frame Fillet Flange (Material: Aluminum 6061)

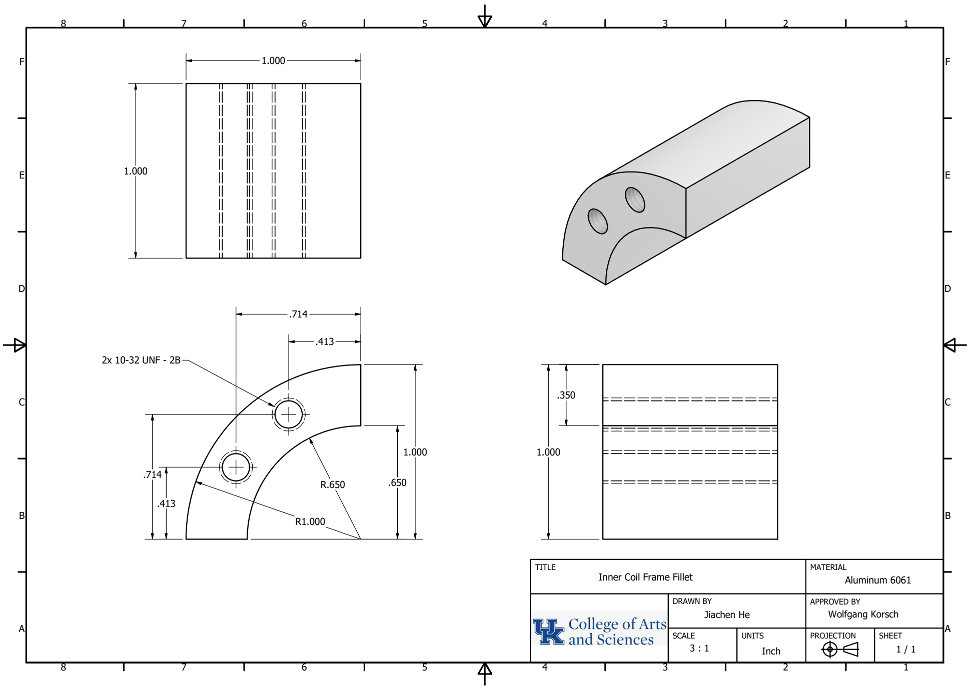

Figure 6: Inner Coil Frame Fillet (Material: Aluminum 6061)

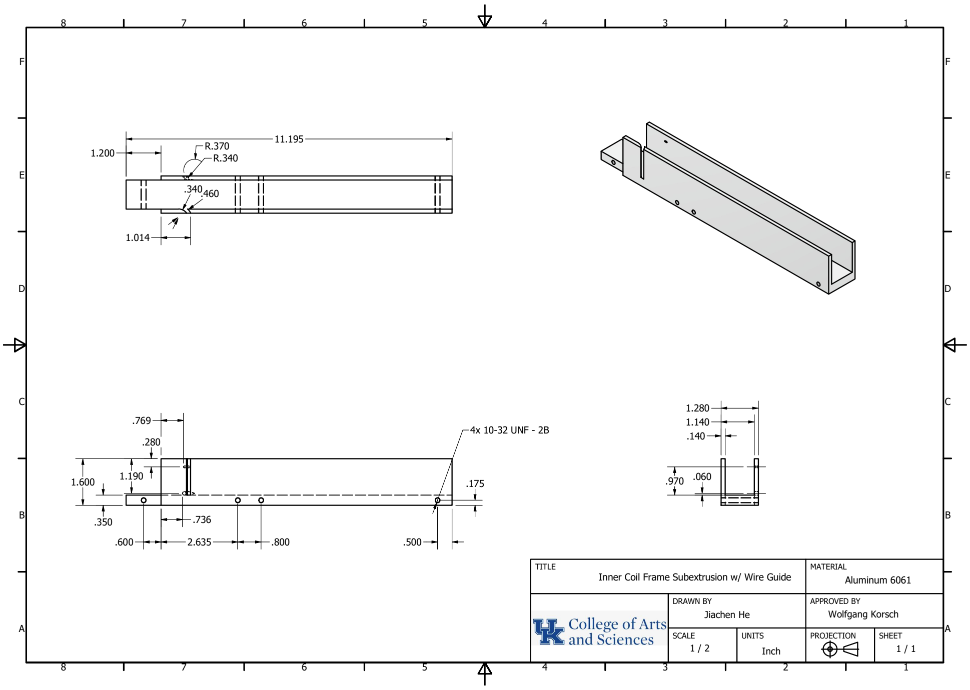

Figure 7: Inner Coil Frame Subextrusion with Wire Guide (Material: Aluminum 6061)

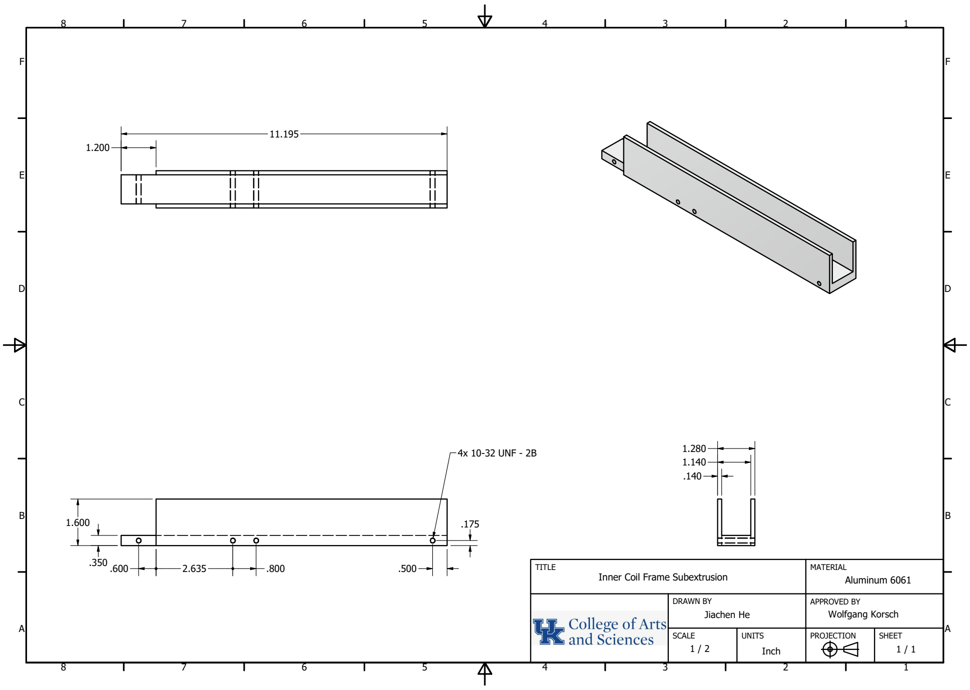

Figure 8: Inner Coil Frame Subextrusion (Material: Aluminum 6061)

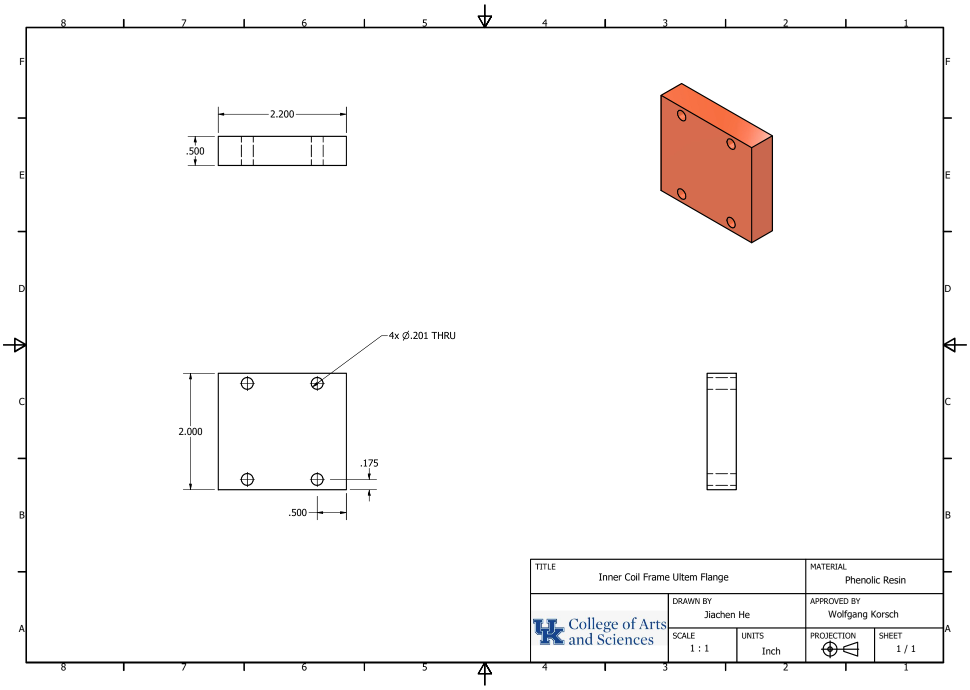

Figure 9: Inner Coil Frame Ultem Flange (Material: Ultem 1000)

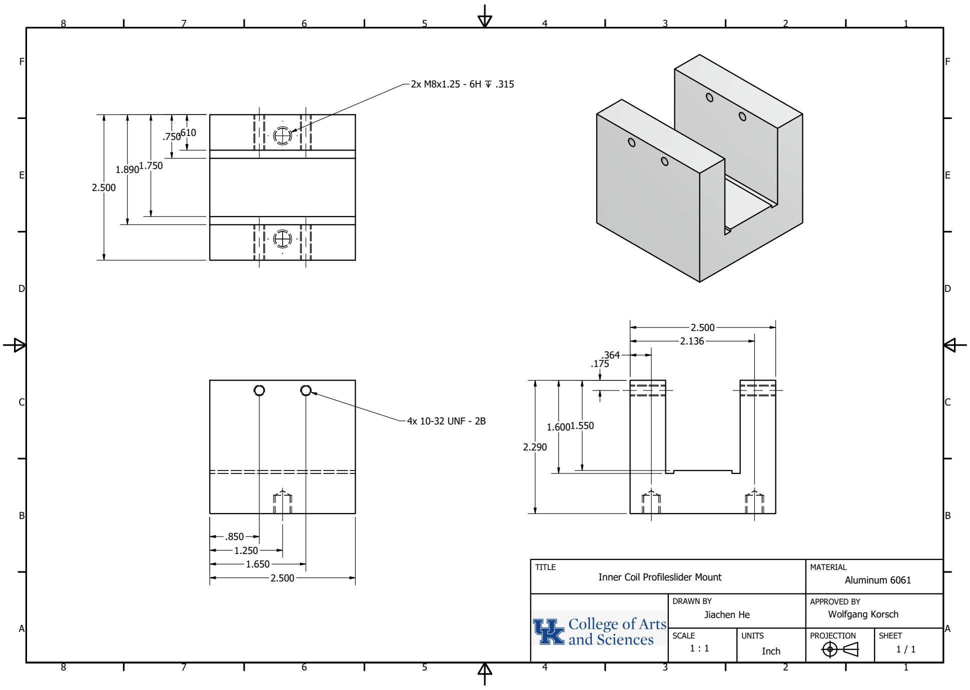

Figure 10: Inner Coil Profile Slider Mount (Material: Aluminum 6061)

3 Home-built vapor cell mount

Another import focus amongst my Ph.D. projects is the experimental realization of a sensitive optical magnetometer using the resonant Faraday effect using potassium vapor atoms. The setup aims specifically to monitor the change of magnetic field associated with the helium-3 spin flips, typically about tens of mG in a 25 G holding field. The system was first investigated on a potassium vapor cell instead of the helium-3 cell Vivian, thus a home-built nonmagnetic vapor cell mount was designed.

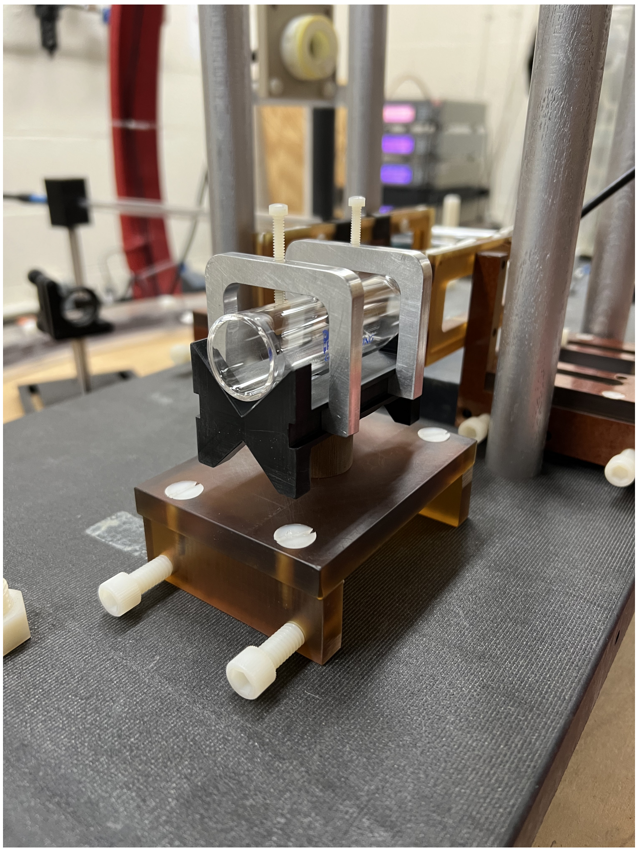

Figure 11: Master view of potassium vapor cell mounted on the home-built nonmagnetic cell mount assembly.

The base plate and connected tilt plates are made from Ultem-1000 material with minimal coefficient of thermal expansion, two nylon screws are used in the front for fine adjustment of tilting angles. The post holder is made of phenolic and the post is made of LCP plastic, both designed with a similar idea to that of the industry standard optical post and post holders. During the experiment, we also need to study the effect of optical aberration when the beam propagates through the side of the vapor cell instead of front to end, hence I designed several U clamps with the specific geometry of the cell mount in order to maximize the possible incident angles.

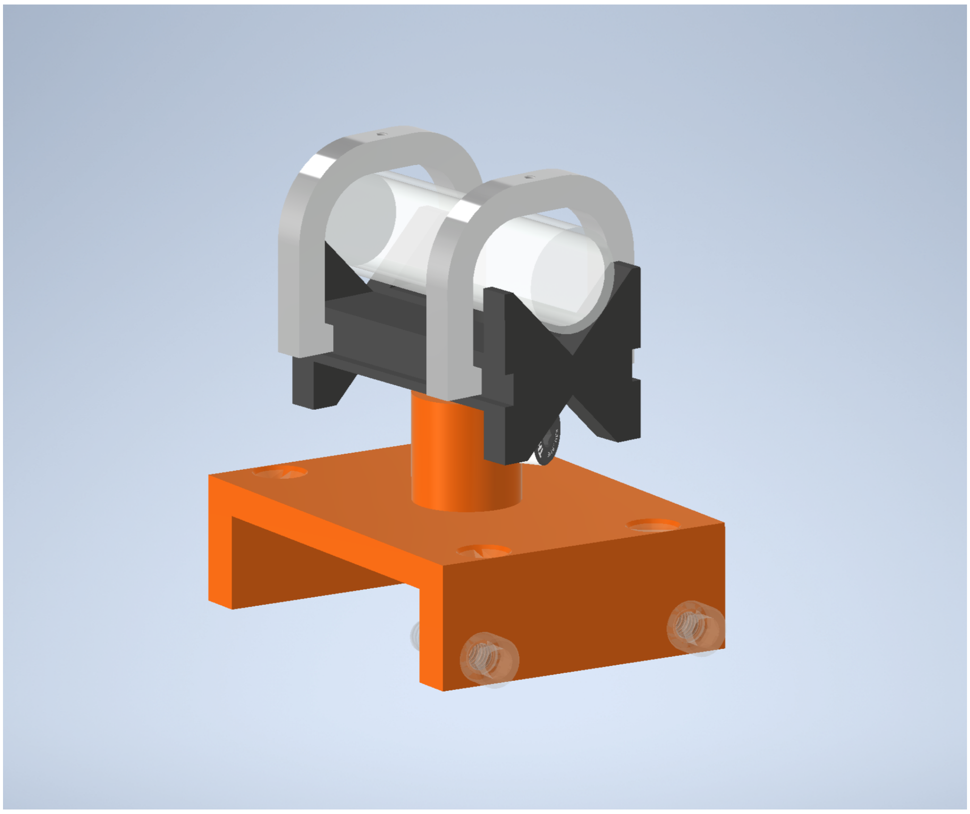

Figure 12: Rendered 3D model of home-built vapor cell mount assembly

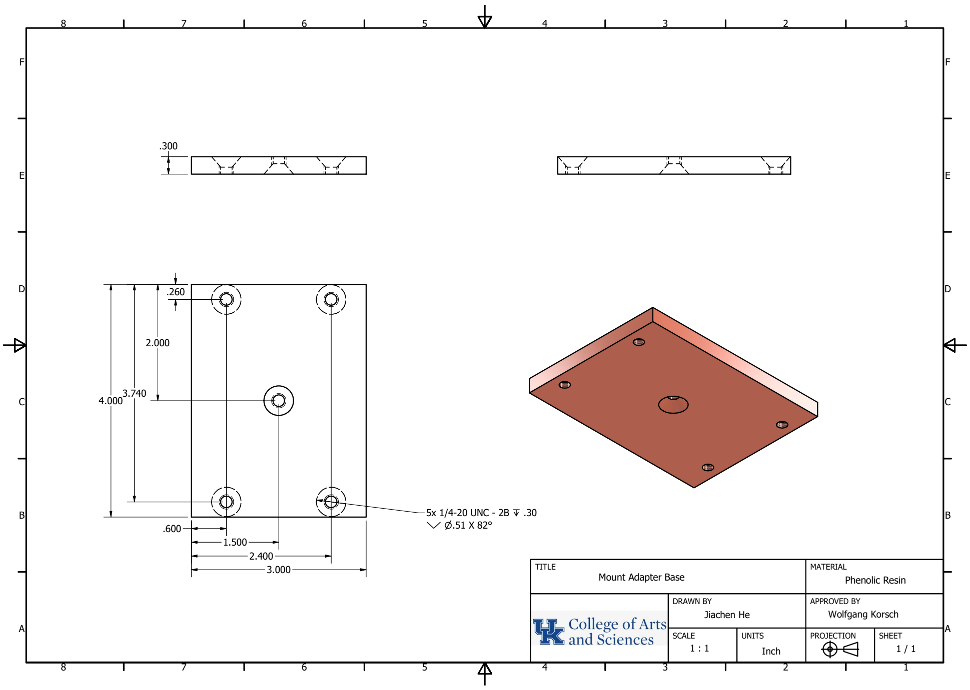

Figure 13: Mount Adapter Plate (Material: Ultem 1000)

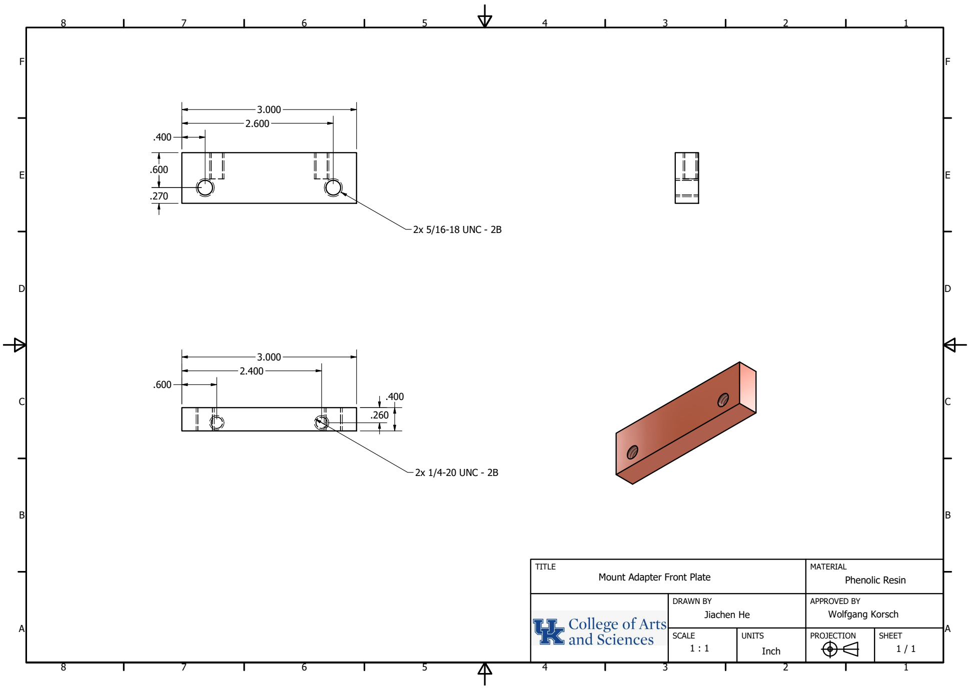

Figure 14: Mount Adapter Front Plate (Material: Ultem 1000)

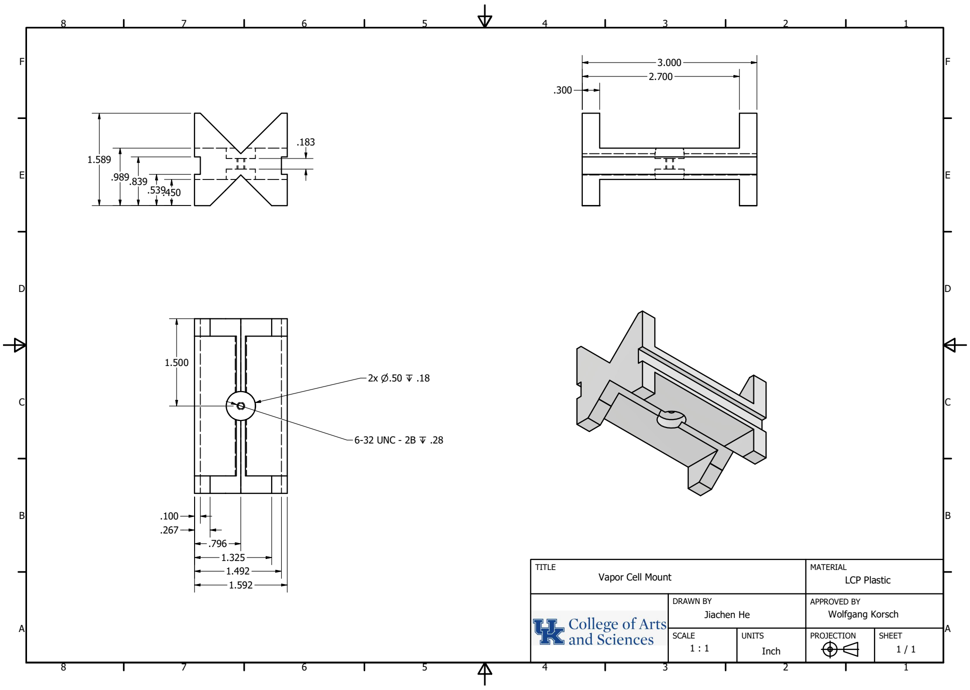

Figure 15: Vapor Cell Mount (Material: LCP Plastic)

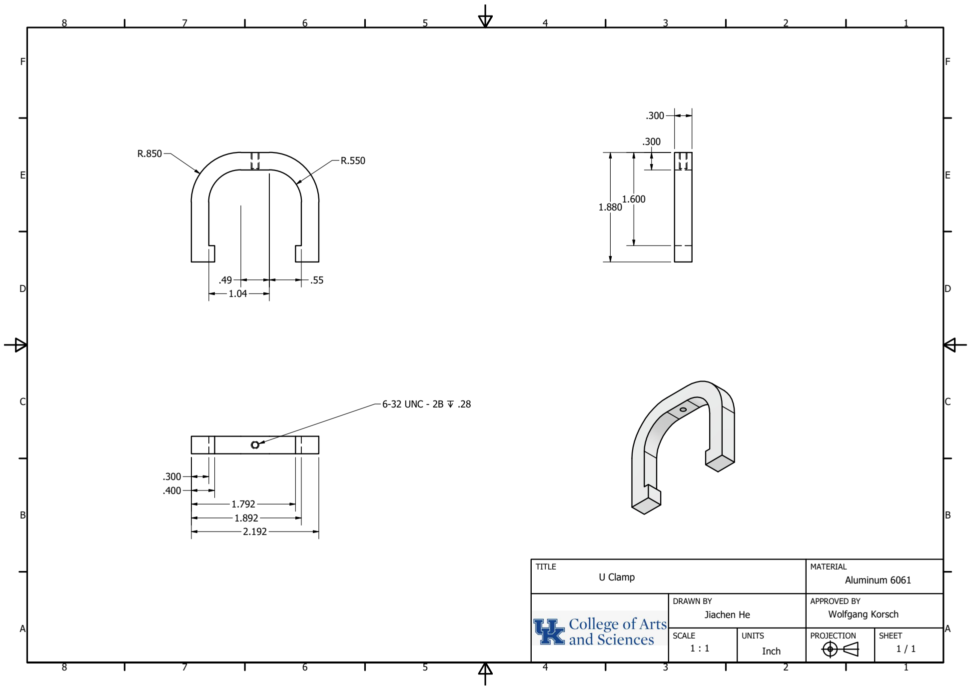

Figure 16: U Clamp (Material: Aluminum 6061)

4 Conclusion

The presented designs demonstrate a solid foundation in the principles of CAD modeling and mechanical engineering design. The use of Autodesk Inventor for parametric modeling and detailed engineering drawings highlights my technical proficiency and ability to translate conceptual designs into manufacturable components.