Motivation
Chondrules are one of the primary components of chondritic meteorites. In carbonaceous chondrites, chondrules are commonly surrounded by fine-grained dust rims (FGRs) [1] as shown in Figure 1. Analysis of the physical characteristics of FGRs preserved in meteoritic samples [2] may be able to give insight into processes in the early solar nebula. We propose an experimental method to investigate rim growth to compare with previous experimental studies [3]. Fundamental processes affecting the formation of FGRs can be studied, allowing application of numerical models which show that porosity and thickness of FGRs collected in a protoplanetary nebula depend on relative velocity and charge of the dust grains [4, 5]. Comparison with rims observed in meteoritic samples may help elucidate the conditions and processes present in the solar nebula.

The IPG6-B Facility
Experiments will be conducted within the IPG6-B experimental facility at Baylor University [5]. The facility consists of a 1.2 m³ vacuum tank connected to a vacuum system capable of maintaining a base pressure of 0.2 Pa. This vacuum tank is connected to an inductively-heated plasma generator (IPG), shown in operation in Figure 2, which is capable of producing an inductively coupled discharge with electrical powers between 150 and 15000 W in various gases. A light gas gun can be used to shoot dust into the facility as well as to create gas-dynamic shocks with a wide range of velocities [6].

Experiment
Chondrule analogs are mounted on a sample holder within the vacuum chamber by using very thin needles. As shown in Figure 4, the vacuum chamber is aligned vertically with the gas and particle injector head on top of the chamber. Micrometer-sized divinite dust is injected into the vacuum chamber and directed onto the sample holder. The velocity v(x) of the dust at a distance x from the dust injection device can be calculated as velocity and temperature profiles of the gas flow are known (shown in Figure 3). The position of the sample holder is varied to achieve different velocities. For a dust particle with diameter d_p, density ρ_p and mass m_p = (π/6) d_p³ ρ_p, the equation of motion is

\[ m_p \frac{dv}{dt} = F_{\text{drag}} + F_{\text{gravity}}. \]

The resulting velocities for a particle with a diameter of 10 µm are shown in Figure 5. The dust flow and collisions with the chondrule analogs will be illuminated using a laser and tracked using particle image velocimetry (PIV). After dust rims are collected on the chondrule surface, the light gas gun can be used to induce gas-dynamic shocks which compact the dust. Samples of chondrules will be studied using optical and electron microscopy as well as computer tomography before and after treatment in the facility to observe differences in the collected dust rims.

Dust aggregation is studied for three different cases:
- **Low pressure**: In this condition, particles are dropped on the sample with no gas flow at very low pressure. The particles are not entrained in the gas and have very low-velocity collisions with the chondrule surface. This condition is similar to the environment in a minimum-mass solar nebula at a distance of 1 AU to the center of the nebula and serves also as a control condition for the two other cases.
- **Neutral dust in gas flow**: A small gas flow is introduced in the experimental chamber. This enables the influence of relative velocity between dust and gas on FGR growth to be investigated. Background gases used are Argon and Helium.
- **Charged dust in plasma flow**: A special focus of this study is to investigate the difference in aggregation between neutral grains and charged grains. For a high Knudsen number Knule, a low-power inductive discharge is ignited, ionizing the gas flow and charging the dust grains. Electron temperature and density are known from prior characterization of the plasma generator.

Scaling
The characteristic time for the gas to travel the distance L between nozzle and sample holder is \( t_{\text{travel}} = L/v \). As shown in Figure 2, the stopping time is \( t_{\text{stop}} \leq 10^{-4} \text{s} \) for the pressure regime of the facility, while the ratio \( t_{\text{travel}}/t_{\text{stop}} \leq 1 \), leading to the conclusion that the particles reach gas velocity before interacting with the chondrules.

References