Paramagnetic materials possess at least one unpaired electron, allowing them to have a small, positive susceptibility to magnetic fields. To study these materials, we designed and built probes for electron paramagnetic resonance (EPR). Because these probes must withstand relatively high magnetic fields and frequencies, challenges occur in the resonant cavity and waveguide design. The probes must be built for EPR experiments that may require fields of up to 100 T and frequencies ranging from 40 GHz to 4THz. Using an external magnetic field and fixed frequency, we can excite an electron from a lower energy level to an upper energy level. Higher frequencies, sometimes, require higher fields in order to detect the resonance condition, and this presents challenges. At the National High Magnetic Field Lab (NHMFL), the higher fields are accessed using bigger magnets that are powered by a water-cooled generator. Cooling system diagnostics is essential for knowing how much water is flowing through the filters. Because this water can be contaminated with copper, silica, dirt and cause the dumped water could have a negative impact on the environment. Thus, we must know how much water is flowing through the filters, and when the filters should be changed.

**EPR spectroscopy is employed to study elements/compounds, that possess unpaired electrons. When an electron is excited in the presence of an external magnetic field it will process about that magnetic field at a frequency called the Larmor Frequency (a). The spins can align either parallel or antiparallel to the external magnetic field creating an energy gap known as the Zeeman effect. When the applied energy, i.e. the microwave energy/frequency and applied magnetic field, scale with the Zeeman splitting (b), the electrons can absorb the microwave energy and move to a higher energy state. The energy is then given back when the electron relaxes back to its initial state. It is these excitations that give rise to the features that are observed in the EPR experiment (c). Furthermore, the electrons in some systems exhibit a preferred directional orientation (magnetic anisotropy) in the absence of an external magnetic field. ESR is an exceptional tool for probing the electronic structure and magnetic anisotropy in materials such as molecular quantum magnets and strongly correlated electron systems.**

**PROBE & CAVITY CALIBRATION**

Frequency vs. field map with calculated g-factor of 2. Map shows a positive, linear trend in frequency as field is swept, indicating that higher field is needed in conjunction with a higher frequency. Inset shows EPR spectra collected at 280 GHz and 1.8-2.2-diphenyl-1-picrylhydrazyl (DPPH), which has one unpaired electron and a simple energy level structure, is the sample that was used to test the probe.

If the water is not able to flow through the cooling system to cool the generator, the generator will not function properly—meaning no high fields can be accessed. Collecting data on the cooling system helps us to know how often water filters should be changed as determined by a low flow rate and large pressure drop across the filters. (a,b). The 1 mm filter has no water flowing through as a consequence of the 5 µm filter’s accumulation of debris. Filters should be changed after 40,000 – 50,000 gallons of water have flown through. (c,d) An increase in flow restriction can cause a water flow of 8 gal/min in both filters. In the 5 µm filter, this can cause the differential pressure to be as high as 16 – 23 psi. When the water flow is at least 10 gal/min, the differential pressure stays below 10 psi, according to the data. (e) About 1.86 x 10^9 grams of total suspended solids (TSS) accumulates in the 5 µm water filter after approximately every 50,000 gallons. Some filters were changed before or after 50,000 gallons of water went through the filters. The highest recorded differential pressure in the 5µm filter was 21 psi, the pressure at which the water flow was 8.50 gal/min. Therefore, after 50,000 gallons has flown through the system since the last change, staff should also check the water flow. If the water flow is no more than 9 gal/min, the filters should be changed.

**CONCLUSIONS**

EPR sheds light on the molecular and electronic properties of molecules. This is especially useful in the areas of telecommunications and the medical sciences. With the DPPH sample, we were about to see a perfect g=2 signal and observe the bandwidth of the single unpaired electron. Cooling system diagnostics of the generator reduces system downtime, allowing staff to spend less time on maintenance and decrease costs. The diagnostics will also help staff to know when the generator is not getting enough cooling water through the system, allowing the generator to function properly and assist magnets in producing high magnetic fields.