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Rapid Scan ESR as a Versatile Tool for High-Frequency Spin Dynamics and Quantum Technologies

ABSTRACT

The development of pulsed Electron Spin Resonance (ESR) spectroscopy at microwave frequencies above 100 GHz remains a challenging and costly task, primarily due to the limited output power of modern high-frequency solid-state electronics. Nonetheless, a range of critical scientific problems—such as dynamic nuclear polarization (DNP) enhancement of NMR and quantum computing applications involving electron spins—necessitate spin relaxation measurements at THz frequencies.

An alternative to pulsed ESR that circumvents the need for high microwave power is rapid scan ESR, which still enables the extraction of spin relaxation times. This method involves fast sweeps of the excitation microwave frequency across the ESR line. When the sweep rate exceeds a certain threshold, characteristic oscillations—often referred to as "wiggles"—emerge in the ESR spectrum [1–3]. As demonstrated by Josef Dadok in NMR [4], it is possible to recover the undistorted, slow-scan spectrum through Fourier Transform analysis.

Importantly, these oscillations also encode valuable information about the electron spin–spin relaxation time (T_2), which can be extracted by fitting the rapid scan spectrum using modified Bloch equations. This approach enables measurement of spin–spin relaxation times on the nanosecond scale. Moreover, the specific design of modern high-frequency ESR spectrometers supports multifrequency operation, allowing spin relaxation measurements across an exceptionally broad range of magnetic fields—all using a single spectrometer (see Fig.1).

Finally, we will outline the future steps required to establish THz rapid scan ESR as a convenient, accessible tool for a wide range of scientific fields—from quantum information science to clinical diagnostics.

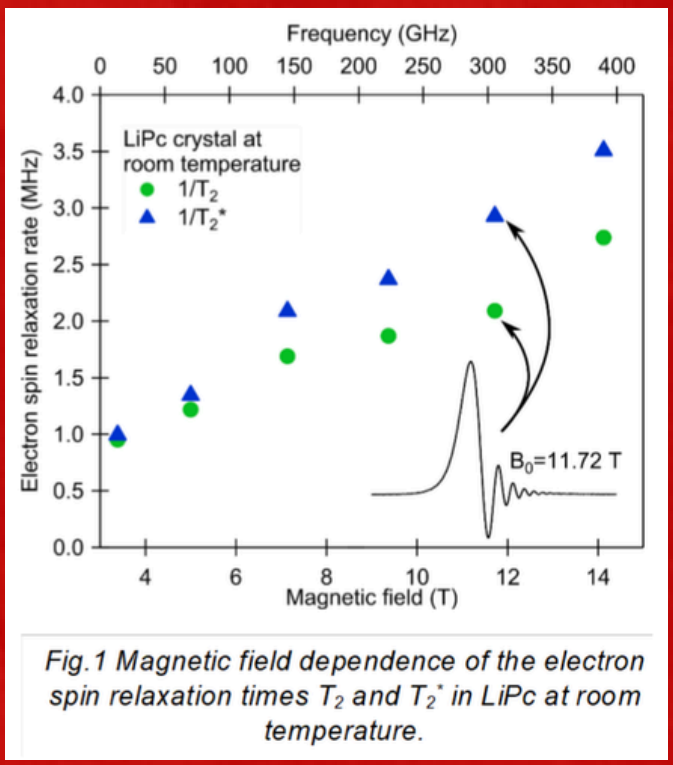

Fig.1 Magnetic field dependence of the electron spin relaxation times T_2 and T_2^* in LiPc at room temperature.

References:
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