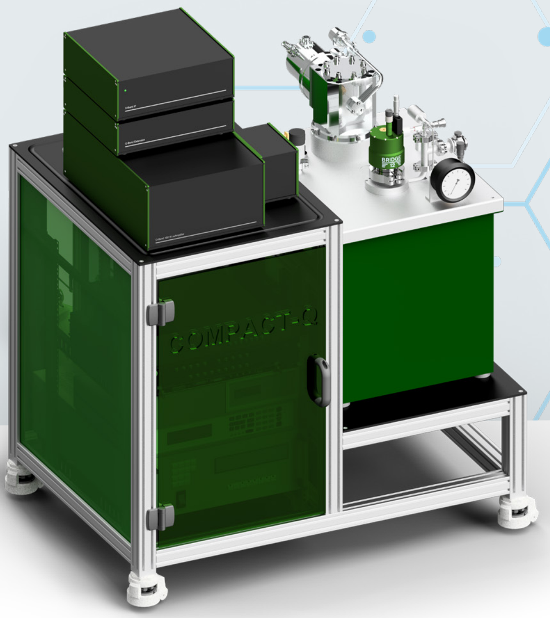


MAGNETIC RESONANCE

Compact-Q DEER

Tailored Precision. Advanced Pulsed EPR for Your Research.

Innovation with Integrity

Introduction

The Compact-Q™ DEER Spectrometer represents Bruker's commitment to making advanced EPR accessible, reliable, and impactful for research. By removing the need for liquid cryogens and offering a compact, lab-friendly design, it lowers barriers to entry and enables continuous, cost-effective operation. Its cutting-edge components deliver reproducible, high-quality data that researchers can trust for critical applications in structural biology, biophysics, materials research and quantum information science. Whether supporting multidisciplinary research environments or driving high-impact publications, the Compact-Q DEER is built to integrate effortlessly into workflows, helping scientists and lab managers push the boundaries of molecular understanding.

Benefits

- **Accessibility:** Compact and liquid cryogen-free design makes pulsed Q-Band EPR spectroscopy feasible for more labs.
- **Scientific Excellence:** High sensitivity and precision support cutting-edge research.
- **Operational Efficiency:** 24/7 availability and low maintenance reduce downtime and cost.
- **Workflow Compatibility:** Seamless integration into existing lab setups and data analysis tools.
- **Brand Integrity:** Embodies Bruker's "Innovation with Integrity" through trusted performance and user-centric design.

Compact-Q DEER is a high-performance pulsed EPR system operating at Q-band frequencies (34 GHz) tailored for modern applications in structural biology, materials research and quantum information science.

Compact size - unlimited opportunities

With only a 3′ x 4′ (0.9 m x 1.2 m) footprint, the Compact-Q DEER offers a versatile platform for pulsed EPR spectroscopy. It integrates a superconducting magnet and a cryostat both cooled by a cryogen-free system that does not require handling of liquid helium or nitrogen. The sample temperatures can be varied from 2 K to 325 K by a variable temperature insert.

Modern bridge architecture

The microwave bridge of the Compact-Q DEER system employs digital demodulation for detection of echo signals. The EPR signals are digitized at an intermediate frequency (IF) of 500 MHz, digitally demodulated and filtered using modern digital signal processing (DSP) techniques integrated into the acquisition software.

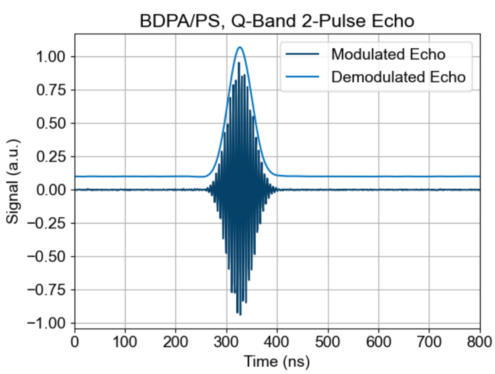


Figure 1: Raw and demodulated (real part) echo signals

This detection scheme provides enhanced performance characteristics:

- Elimination of baseline artefacts and DC offsets
- Variable detection bandwidth and multi-stage/variable gain video amplification
- Integration of DSP tools and non-uniform sampling (NUS)-based time schedules
- Large sensitivity and high detection fidelity

Excellent amplitude and phase balance

The spectrometer pulse generation architecture is centered around an arbitrary waveform generator (AWG) that also delivers clock signals across the spectrometer for superior synchronization. The pulses are generated by the AWG at an IF of 500 MHz followed by up/down conversion to/from Q-band frequencies using an IQ-mixer.

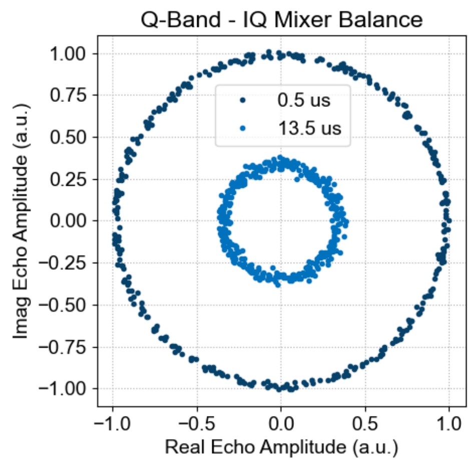


Figure 2: IQ balance measured from echo signals at two inter-pulse delays

This scheme has multiple advantages:

- Excellent carrier suppression
- High-fidelity pulse generation
- Perfect IQ amplitude and phase balance

AWG performance

With 12-bit or better amplitude resolution and a sampling rate exceeding 2 Gs/s, the AWG-based pulse forming unit is tailored for pulse shaping using WURST, HS, OCT and user specified waveforms.

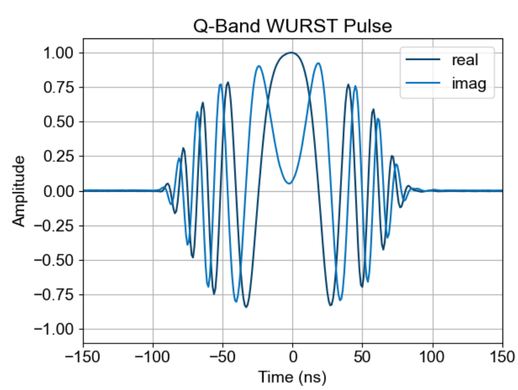


Figure 3: High power WURST pulse measured at Q-band

Compact-Q DEER is Your Turn-Key Solution

Compact-Q DEER is powered by SpecMan, a powerful software platform for instrument control and signal acquisition. SpecMan seamlessly integrates a wide range of hardware modules providing unmatched flexibility in experimental design and workflow automation.

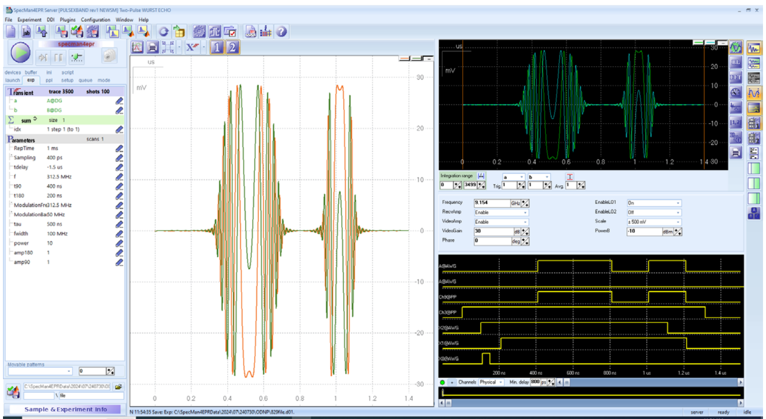


Figure 4: SpecMan user interface

Spectrometer control and data acquisition

Featuring an intuitive yet a powerful environment for users to acquire high-quality data, Compact-Q DEER offers:

- Resonator tuning with a chirp pulse and automated iris control
- Comprehensive library of ready-to-use experiments (including PELDOR/DEER, DQC, SIFTER, RIDME, ESEEM, HYSCORE, Inversion/Saturation recovery, FT-EPR)
- Easily programmable pulse sequences implementable on hardware (including phase cycle) to minimize overhead time
- Efficient signal averaging on hardware
- Preconfigured, parameterized pulse shapes (WURST, HS, Gaussian, etc.)
- Linear, logarithmic, and non-uniform sampling (NUS) customized for better efficiency in data acquisition
- Variables and parameters that can be used as axes for automated optimization of experimental settings

Workflow automation and high throughput

The Compact-Q DEER system is easy-to-use, and even non-expert users can easily create the most sophisticated pulse sequences. The acquisition software enables complete automation of the EPR experiments including resonator tuning, magnetic field adjustment, parameter optimization, and cryogenic sample ejection. The system is tailored to streamline the EPR workflows and increase the throughput of the instrument, ensuring precise and reproducible results.

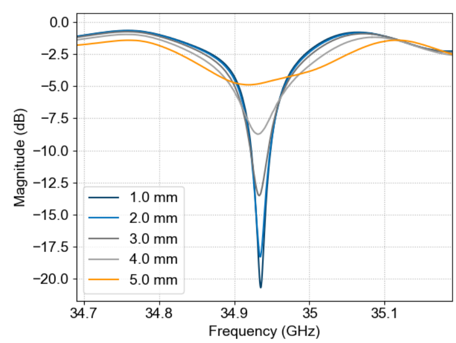


Figure 5: Remotely controlled resonator coupling

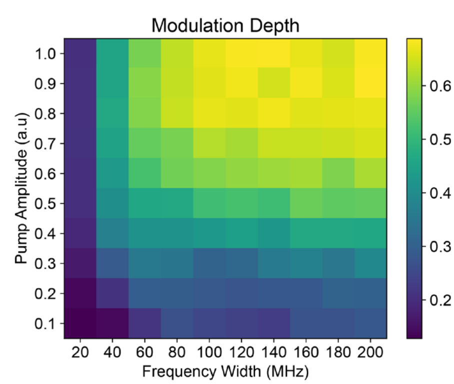
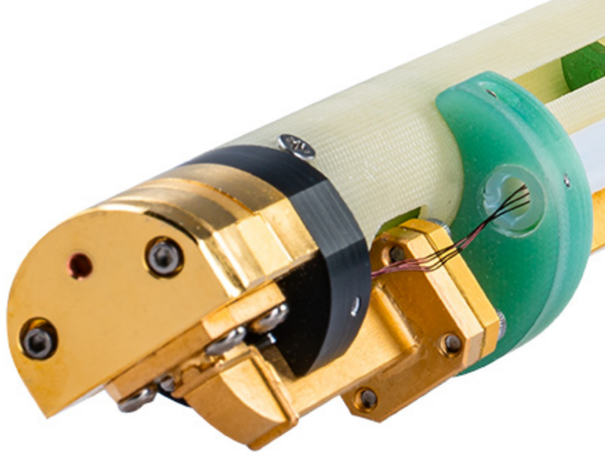


Figure 6: Optimization of parameters for WURST pump pulse for best modulation depth in DEER measurements

Focus on what matters most

The SpecMan platform and Compact-Q DEER architecture are aimed to reduce the barrier for new users, shifting the focus from parameter optimization to data acquisition and analysis.

Q-band Loop-Gap Probes



Q-band loop-gap probes (QLP) are optimized for a large excitation bandwidth and strong B_1 fields. The probes reveal high B_1 homogeneity and are ideal for nanometer distance measurements using PELDOR/DEER, DQC, SIFTER, and RIDME techniques.

QLP probes are well-suited for applications, employing broadband or selective shaped and OCT pulses, such as quantum information science and spin-based quantum technologies. In addition, they are equipped with an optical window, enabling Transient EPR experiments involving photoexcited spin states.

QLP probes are available in two versions, QLP-1.6 and QLP-2.5, distinguished by the sample tube outer diameters of 1.6 mm and 2.5 mm, respectively. Due to up to 4 times larger sample volume, QLP-2.5 offers higher concentration sensitivity for pulsed EPR.

	QLP-1.6	QLP-2.5
Sample access (OD)	1.6 mm	2.5 mm
Resonator length	4 mm	
Active sample volume	3.8 µL	15.2 µL
Typical B_1-bandwidth	400 MHz*	
Typical B_1-strength	60 MHz**	40 MHz**
Typical π-pulse length	8 ns**	14 ns**
High-sensitivity mode	Absolute	Concentrate
Optical window diameter	1.5 mm	
Auto sample exchange	Cryogenic sample ejection system	
Special feature	Remote B_1-bandwidth control	

Table 1: Probes specifications

* Probes are moderately over-coupled

** Compact-Q DEER is equipped with a 100 W solid-state amplifier

Nanometer Distance Measurements

Pulsed EPR dipolar spectroscopy is a powerful technique to measure distances between paramagnetic centers in a range of 2 to 16 nm. Q-band PELDOR/DEER utilizing nitroxide spin labels has been the gold standard for EPR-based distance determination for structural biology applications. Recently, Q-band DQC has demonstrated superior performance in terms of larger sensitivity and improved precision due to minimized background contribution at low sample concentrations.[1] Compact-Q DEER equipped with QLP probes is optimized for both DEER and DQC techniques.

Increased sensitivity of DEER measurements

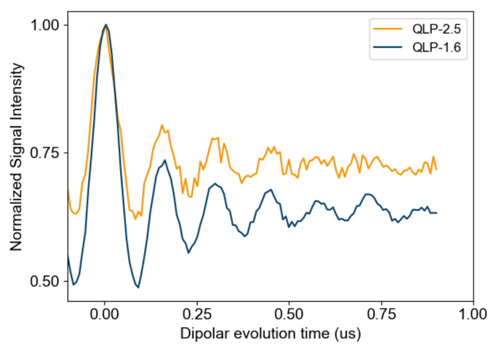


Figure 7: Single-shot DEER time traces obtained with QLP-1.6 and QLP-2.5 Probes at 50 K on a model bis-nitroxide system with an inter-spin distance of about 2 nm

	Modulation Depth	Pump Pulse	MNR
QLP-1.6	36 %	12 ns	78*
QLP-2.5	28 %	16 ns	148**

Table 2: DEER performance

* Modulation depth per Noise Ratio (MNR) obtained from single-scan single-shot 16-step phase-cycled time traces (5 s acquisition)

** MNR was scaled to 4 times larger sample volume of QLP-2.5

Outstanding performance of DEER measurements using the Compact-Q DEER system can be further enhanced by incorporating refocusing pulses (CPMG-like sequence) into the detection pulse scheme. By adding 9 refocusing pulses and summing over 10 refocused Hahn echoes, the sensitivity is increased by 60 %.

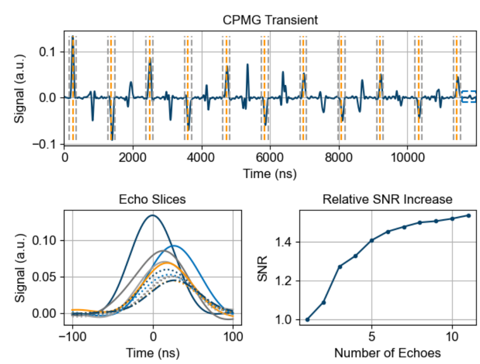


Figure 8: CPMG echoes generated by DEER sequence with additional refocusing pulses

Double Quantum Coherence (DQC) measurements

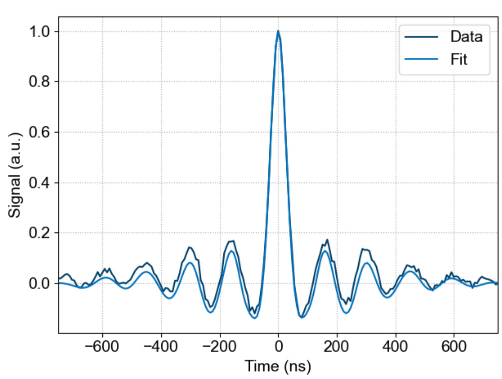


Figure 9: DQC time trace obtained with QLP-1.6 Probe at 50 K

Due to the large B_1-bandwidth, high B_1-homogeneity and conversion factor of the QLP-1.6 probe, Q-band DQC measurements using nitroxide spin-labels achieve a modulation depth of 100% using 8 ns rectangular pulses. DQC can provide greater sensitivity than the gold standard DEER technique.

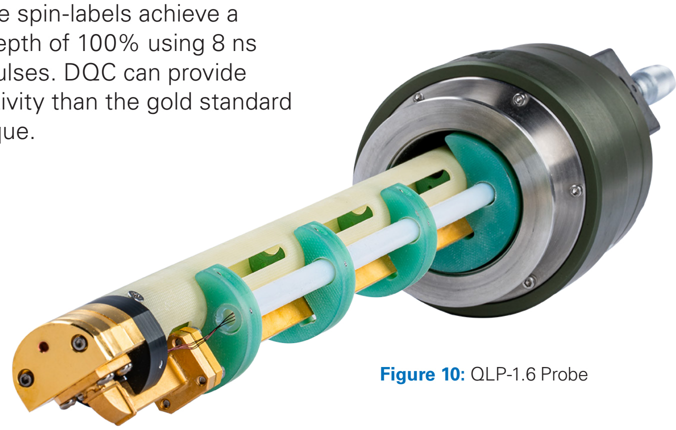


Figure 10: QLP-1.6 Probe

[1] Mandato et al, *J. Phys. Chem. B*, 2025, 129, 7108

Compact-Q: Q stands for Quantum

Quantum computing and quantum sensing are redefining industry standards and provide devices with greater performances as compared to their classical counterparts. The Compact-Q DEER system can aid in advancement of novel quantum devices and enables efficient characterization of their properties. Furthermore, with its excellent synchronization, high-resolution AWG, large detection bandwidth and modern digital electronics, Compact-Q serves as a robust platform for development and validation of coherent quantum control algorithms.

Probing long-lived states

As demonstrated for E′ centers in a quartz glass system at 12 K:

- Sequences with a length of 20 s or longer can be generated without losing coherence between pulses
- Shot repetition times of exceeding 20 s can be generated to support long pulse sequences

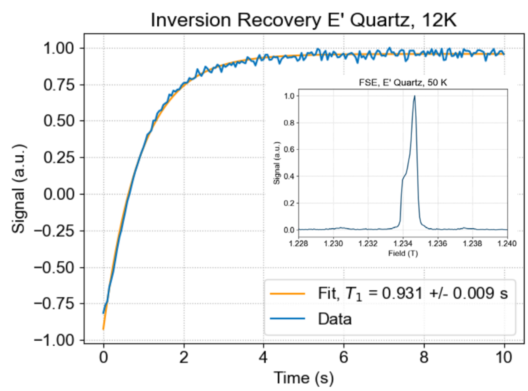


Figure 11: Inversion recovery time trace for E′ centers in quartz at 12 K and corresponding echo-detected field-swept EPR spectrum (insert)

Probing phase memory time

Using WURST pulses with a bandwidth exceeding 300 MHz, a broadband echo encoding the entire EPR spectrum can be effectively probed.

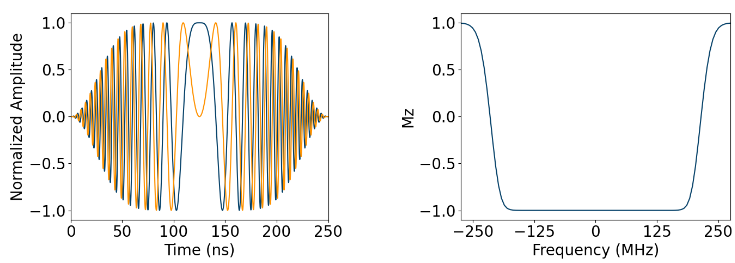


Figure 12: Simulated WURST π-pulse in time and frequency domains

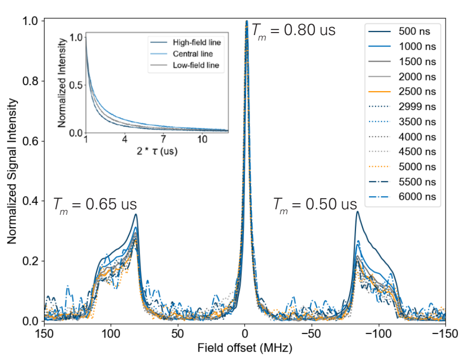


Figure 13: P1 centers-based broadband echo in frequency domain as a function of τ at 250 K and integrated echo decays at three positions across the spectrum (insert)

As demonstrated for P1 centers in diamond powders at 250 K, the anisotropic phase memory time across the spectrum can be efficiently probed by using a broadband echo sequence with incrementing inter-pulse delay time (τ).

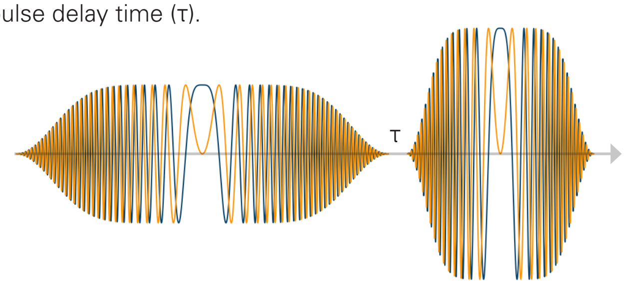
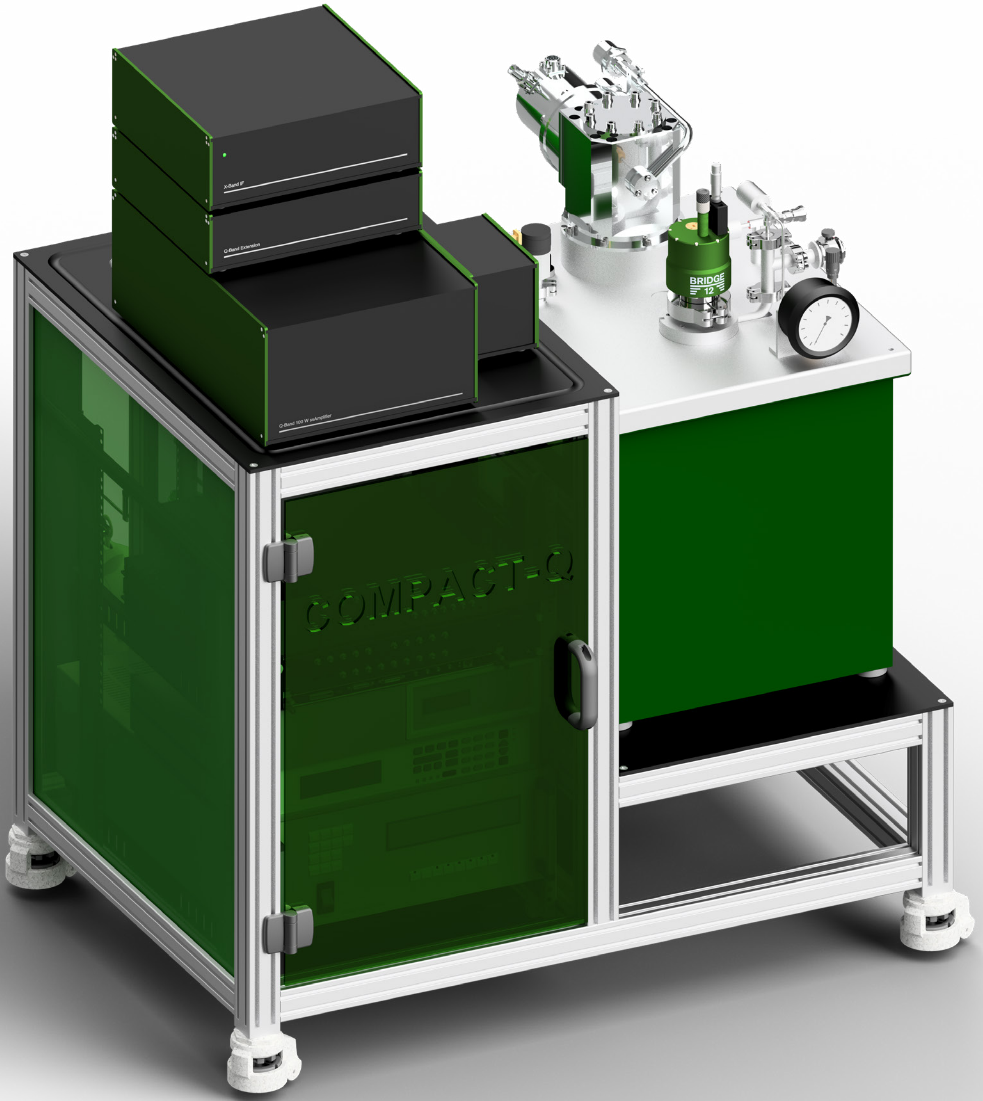


Figure 14: Broadband pulse sequence for probing anisotropic T_2



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Customer Support

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