PRODUCT DATASHEET

263, 395 & 527 GHz Gyrotron Assemblies

The 263, 395 and 527 GHz gyrotrons are microwave sources for DNP in 400, 600 and 800 MHz solid-state NMR. Their high power and frequency stability allow ultrasensitive experiments from simple 1D to extended multidimensional studies. Each gyrotron system consists of:

1. cryogen-free (CF), persistent-mode gyrotron magnet, with coldhead and helium compressor,
2. the gyrotron tube,
3. power supply for CF magnet & NMR sweep,
4. ‘gun coil’ electromagnet and power supply,
5. DNP control system (single-bay), including
   - user interface, monitoring and logging,
   - high-voltage power supply, including integrated filament heater supply with power-stabilizing feedback loop,
   - Fast-Protection Unit (FPU) for robust safe and rapid shutdown upon fault detection,
   - high-voltage supply to vac-ion pump (integrated to tube)
6. dual-channel cavity/collector recirculating water-cooled chiller,
7. safety interlocks,
8. EMO/PDU (emergency-off power-distribution unit) to Gyrotron control, tube, and cavity/collector chiller, and
9. low-loss microwave transmission line (TL) with optimized taper coupling to Bruker DNP NMR probes.

Example of a 395 GHz gyrotron 600 MHz DNP NMR installation. The gyrotron (right) is equivalent in size/shape to those at 263 and 527 GHz for 400 and 800 MHz NMR. Included, but not shown: Helium compressor for CF magnet coldhead, power supply for use with CF magnet and NMR sweep, and the gyrotron’s cavity/ collector chiller and single-bay control system.

The gyrotron operates in second-harmonic mode, which enables operation at half the magnetic field of fundamental-mode gyrotrons. Microwaves are generated as the high-power electron beam traverses the resonant cavity of a high-vacuum tube. An internal launcher and mode-converter forms a Gaussian profile of the microwave output, which is optimal for low-loss transmission when the microwaves exit horizontally through a sealed window and into an enclosed waveguide tailored for the output frequency. The gyrotron tube is industrially sealed at the factory, and thus includes an integrated ion pump to maintain ultrahigh vacuum over its lifetime.

Microwave power monitoring is provided inline via a directional coupler included along the TL. Beneath the probe and NMR magnet, the microwave beam is redirected vertically, and focused using a low-loss taper element to match the final ID of the microwave waveguide in Bruker DNP probes.

The gyrotron system integrates seamlessly for operation along with the Bruker NMR spectrometer. Operational parameters of the CF magnet, the power supply, the helium compressor and the coldhead are monitored and logged by Bruker MICS accessible in TopSpin.

Safety interlocks are included to ensure microwaves are on only for cold sample conditions (for sample safety), with closed transmission line (for personal safety), and under appropriate operating conditions of the chiller, power supply and HV circuit within the gyrotron vacuum tube. For certain cases, an interlock bypass may be provided, e.g., to enable microwave operation for cases where DNP is effective with a warm sample.

Models:

263, 395 & 527 GHz Gyrotron Assemblies, BH4000W-400, 600 and 800, respectively.

Bruker BioSpin
info.brkr@bruker.com

bruker.com

DNP Efficiency:

DNP signal enhancement ≥ (180, 90 or 25) for 263, 395 or 527 GHz on 250 mM (U-^{13}C,^{15}N) proline in glycerol-d_8/D_2O/H_2O (60/30/10 by volume) with 12 mM of AMUPol biradical, as packed in 3.2 mm sapphire rotor with 25 µl sample volume and with a Bruker DNP probe.

Enhancement measured as microwave on/off ratio of {^1H}^{13}C CPMAS spectra collected at 8 kHz MAS frequency, ≤ 100 K sample temperature, with 8 scans, 2 dummy scans, and 10 s recycle delay.

DNP signal enhancements on other samples depend on experimental conditions, such as polarizing agent, sample preparation, spinning frequency, sample temperature, rotor material, and microwave power.

Specifications and Requirements:

Microwave source type	Gyrotron, 2nd harmonic mode
Mode of operation	Minimum 10-day continuous operation
Operation frequency	263, 395 or 527 GHz
Frequency stability	≤ (±10 ppm) over 12 h. The observed frequency stability may vary depending on environmental factors impacting HV power supply and temperature regulation by the cavity chiller.
Maximum output power	≥ (25, 20 or 15) W for 263, 395 or 527 GHz, respectively. The power specifications are for standard TL lengths and design noted below. Power may vary in cases of user-requested modifications to the TL.
Output power stability	± 0.5% over 12 hrs, achieved with feedback loop
Microwave output	Linearly polarized, gaussian beam/HE11 into overmoded circular waveguide, 19 mm ID at 263 GHz and 16 mm ID at 395 and 527 GHz.
Mode purity	≥ 90 % Gaussian beam purity at output of gyrotron
Microwave transmission line	Circular waveguide assembly with directional coupler to calorimeter for power measurements, terminating in a mode-preserving taper to mate with probe waveguide. Bore-to-bore distance of 2.4 m (or 2.7 m) between 263 and 395 GHz (or 527 GHz) gyrotron magnet and corresponding Ascend DNP NMR magnet.
Input power requirements	Three-phase, 208 V, 60 A, 60 Hz or 400 V, 50 A, 50 Hz, into provided EMO/PDU. (both cases, voltage L-L with Neutral and separate protective earth)
Chiller (gyrotron cavity collector)	Indoor, 2-channel water-cooled chiller, powered via EMO/PDU. Dimensions: 130 x 76 X 117 cm (H x W x D) (includes locking casters on H, filters on D)
Gyrotron magnet	Cryogen-free shielded 4.8, 7.2 or 9.7 T magnet (for 263, 395 or 527 GHz) with indoor, water-cooled compressor.
Power supply for gyrotron magnet and NMR sweep coil	Main supply for cryogen-free Gyrotron magnet with integrated supply to operate NMR sweep coil on Ascend DNP WB magnets. Remote control via ethernet to included laptop or to Bruker NMR console.
Site requirements	Customer must plan for backup water and electricity for gyrotron magnet helium compressor/cryocooler. Please inquire for detailed site planning requirements.
Autonomous facility recovery	In case of power failure or loss of cooling water to the compressor, the gyrotron magnet will quench. Recovery and magnet recharging may be accomplished by the customer with included magnet power supply.
System maintenance	Every 2 years for gyrotron magnet and yearly for high-voltage power supply safety checks. Bruker engineer required. See service plan details for variations in service required on the gyrotron magnet system at 2-, 4- and 8-year intervals.

Specifications are valid as of June 13, 2024. Technical data and specifications subject to change without notice.

bruker.com

Bruker BioSpin
info.brkr@bruker.com

bruker.com