Ultra-High Field NMR: Bruker's Gigahertz-Class Spectrometers

For years, high-resolution NMR was limited to a magnetic field of 23.5 Tesla, equivalent to a proton resonance frequency of 1.0 GHz, due to the physical properties of metallic, Low-Temperature Superconductors (LTS). Bruker pioneered the use of High-Temperature Superconductors (HTS) in NMR magnets, leading to the commercial availability of 1.1 and 1.2 GHz NMR spectrometers in the early 2020s.

Improved Resolution and Sensitivity

The strength of the magnetic field is one of the most important properties of an NMR spectrometer. The **improved dispersion** of Ultra High Field (UHF) spectra and the **improved mass-sensitivity** of UHF spectrometers make GHz-class NMR an invaluable tool for structure determination. Examples for the improved resolution of UHF spectrometers are shown in Figures 1 and 2. The most important benefits are the following:

- Rare and limited samples benefit from UHF NMR since it typically requires only small amounts.
- Unprecedented resolution
- GHz-class NMR provides solution-state information, revealing biomolecule behavior in near-native conditions.

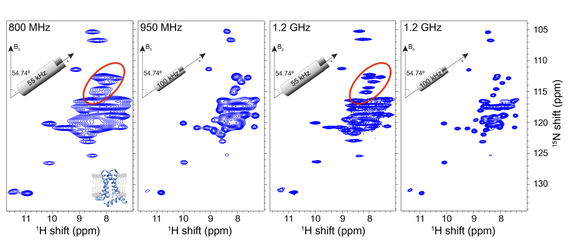

Fig. 1: ^{15}N resolution improvement with magnetic field in an Influenza A M2$_{18-60}$ sample. Courtesy of Dr. Loren Andreas, Max Plank Institute for Multidisciplinary Sciences, Göttingen, Germany.

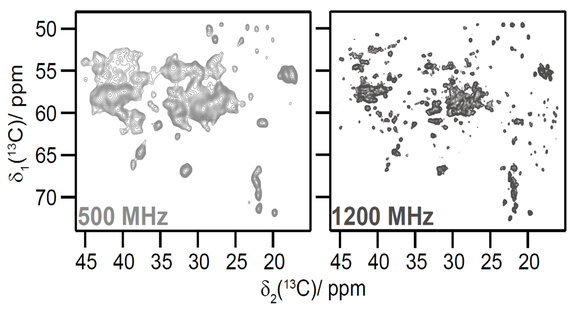

Fig. 2: 20 ms DARR spectra of the DnaB helicase from Helicobacter pylori, recorded at 500 MHz and at 1.2 GHz. Adapted from Callon et al., bioRxiv 2021.03.31.437892.

UHF NMR Probes

Bruker offers a wide range of NMR probes for their GHz-class spectrometers, such as CryoProbes for solution-state NMR and fast-spinning MAS solid-state NMR probes. The most popular probes for GHz-class NMR spectrometers are:

Liquids Probes:

- TCI ("inverse") triple-resonance CryoProbes with dedicated H, C, N and ^{2}H channels and cold preamplifiers. These TCI solution-state probes are optimized for proton detection.
- TXO ("observe") triple-resonance CryoProbes with dedicated H, C, N and ^{2}H channels and cold preamplifiers. The TXO probes are optimized for X-detection.
- TXI triple-resonance room-temperature probes (H, C, N and a ^{2}H lock channel).
- BBI dual-resonance room-temperature probes have a proton channel, a broadband channel, a deuterium lock channel, and a gradient coil. They make solution-state GHz-class spectrometers particularly versatile, as the broadband channel expands the range of accessible nuclei considerably.

Solids Probes:

The advantages of GHz-class spectrometers are particularly pronounced in solid-state NMR. Bruker offers an extensive range of CPMAS probes. For GHz-class spectrometers, probes with the fastest spinning speeds (i.e. probes for and 42, 67 and 111 kHz rotation) are typically employed (HCN, HX or HXY), with 160 kHz MAS probes soon becoming available.

MicroImaging

Bruker's renowned magnetic resonance (MR) microscopy probes are also available for GHz-class spectrometers. With GHz-class spectrometers, unprecedented resolution can be achieved in imaging applications.

Please contact us to discuss your research plans. Bruker provides UHF spectrometers with customized probes for your specific science program.

Magnet Technology

Bruker's 1.0 GHz Ascend Evo, and 1.1 and 1.2 GHz Ascend magnets, shown in Figure 3, utilize a sophisticated hybrid design with High-Temperature Superconductor (HTS) in the inner sections and Low-Temperature Superconductor (LTS) in the outer sections of the magnet, as illustrated in Figure 4. These magnets feature a 54 mm room-temperature bore ("standard bore") and have exquisite homogeneity and field stability compatible with the demanding requirements of high-resolution NMR.

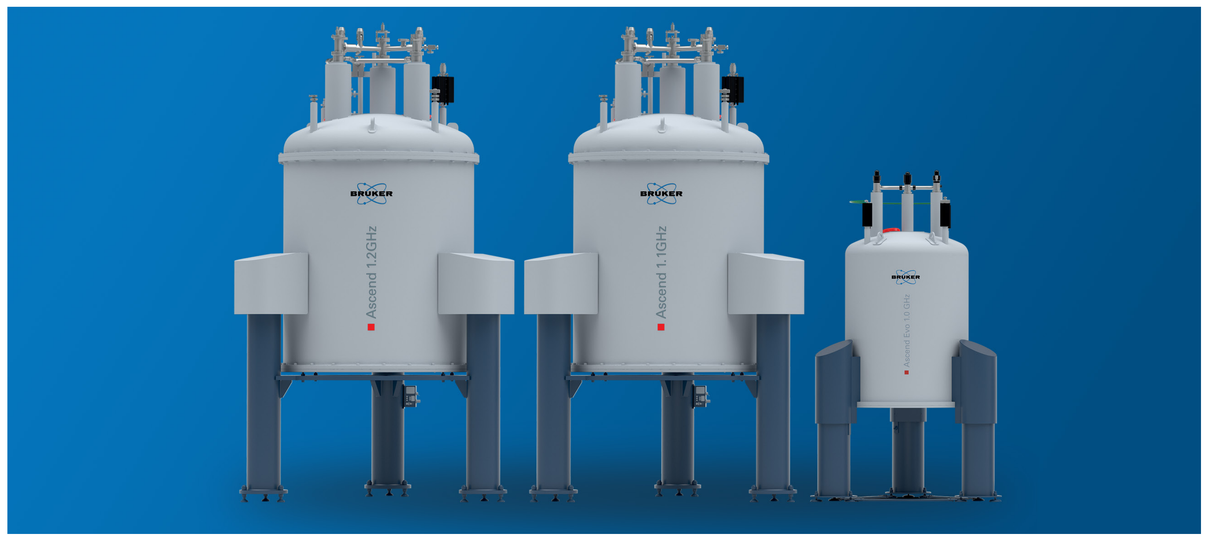

Fig. 3: Bruker's Ascend 1.1 and 1.2 GHz magnets are the highest-field commercial NMR magnets. The Ascend Evo 1.0 GHz magnet is easier to site in a standard 1-story laboratory and has an impressively low helium consumption, making GHz-class NMR available to a larger group of researchers.

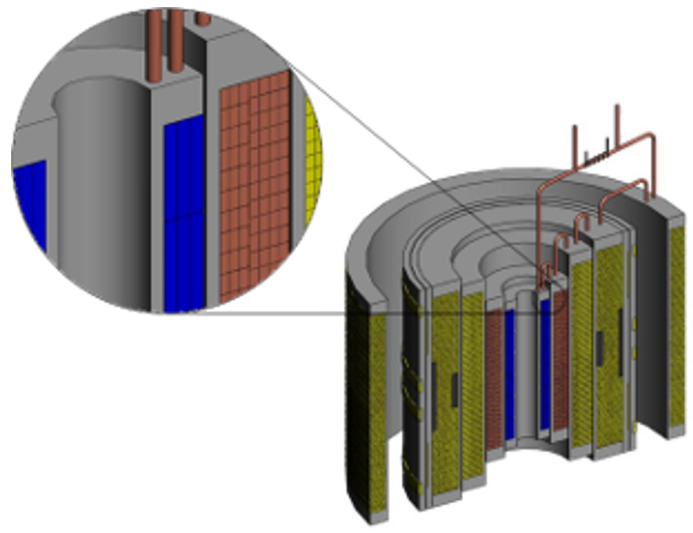

Fig. 4: NbTi (yellow) is used in the outermost sections of the magnet, Nb_3Sn (red) in the mid-field region, and high-temperature superconductors (blue) in the central section.

Installed Base

The field population of GHz-class NMR spectrometers is steadily growing. Figures 5 and 6 show the locations of installed commercial GHz-class spectrometers worldwide and in Europe, respectively. Several additional deliveries are still pending. **Current lead times are between 24 and 36 months. Please contact our experts to discuss how Bruker can support you with your grant proposal.**

Fig. 5: Installed UHF NMRs (Worldwide)

Fig. 6: Installed UHF NMRs (Europe)

Conclusion

- GHz-class NMR enables unprecedented resolution and mass-sensitivity.
- Bruker has extensive experience with numerous successfully completed GHz installations worldwide.
- Bruker's range of standard UHF probes is complemented by custom probes, allowing you to tailor your UHF project.