Development of a Broadband LN2 Cooling Cryogenic Preamplifier for FTICR MS

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News
1. A novel broadband cryogenic-detection system has been developed to improve the signal-to-noise ratio (S/N) of FT-ICR mass spectrometry at liquid nitrogen (LN2) temperature.
2. Recent results show significant improvement of the FT-ICR signal originating from liquid nitrogen cooling.

Goal
Operating a preamplifier of a FT-ICR MS setup at cryogenic temperatures has potentially two main advantages: First, better vacuum conditions are achieved. Second, a larger signal may be obtained since the preamplifier is installed very close to the ICR trap and at the same time is cooled, thus reducing noise. The act resulting higher electrical signal to noise (SN) ratio guarantees greatly improved sensitivity.

1. Implementation
The novel aspects of the developed FT-ICR MS detection setup are a partially cryogenically vacuumed setup in conjunction with cryogenic preamplifiers. The system was developed by the KBIS Korea Basic Science Institute in close collaboration with Stahl-Electronics, Germany, providing cryogenic amplifier technology. The broadband preamplifier can be operated over a very wide temperature range from room temperature to low temperature environments (T ~ 4.2 K, 77 K).

A cooling system inside the FT-ICR 9.4 T setup has been designed, which uses circulation of LN2 (liquid nitrogen, 77K) or LH (liquid helium, 4.2K) to cool down a cold finger including cryo preamplifier and FT-ICR cell to 80 K or to 16 K. In contrast to other ways to improve the sensitivity of FT-ICR MS, such as higher transmission efficiency, a linear excitation trap and various ion optics devices, the cooling of crucial parts (trap and electronics) represents a more fundamental approach. A conventional trap (Open Cylinder trap) has been modified and its signals are processed by a low noise cryogenic amplifier, being located in close proximity to the trap inside vacuum. The cryogenic amplifier is followed by a new 2nd amplifier (Stahl-Electronics) which amplifies the signal subsequently after the cryopreamplifier.

2. Diagram of cryogenic preamplifier setup

3. COOLING SYSTEM FOR PREAMPLIFIER AND TRAP
- Liquid (LN2, LH) Circulation System
  - Liquid circulates in the tube-in-tube setup in order to reduce heat leakage from the flange
  - Portable and compact cooling unit

![Fig. 2 Liquid Circulation Unit](image)

4. Cryo-PREAMPLIFIER for FTICR MS

Semiconductors at low temperatures
- Problem: Standard silicon-based components fail to work at low temperatures (~60 K) and have difficulties to work at high magnetic fields (Hall effect).
- Solution: GaAs-based components can operate at low-T and high-B but show increased noise at low frequencies (1/f-noise)

5. Experimental Results

Mass Spectrometer: 7T KBSI FTICR
Sample: Agilent tune mix, (022 Da, 922 Da), 1521.9 Da)

As shown in Fig.12 (b), signal peaks increase with LN2 cooling, which means that the gain (operation point) of the cryo preamplifier circuit changed with temperature. This can be explained by changes of internal circuit components (B, C, FETS).

![Fig.12: Agilent tune mix. Signal @ 300K, @ 80 K](image)

The increase in signal level and decrease in noise both contribute to improve the signal to noise ratio (S/N) by using the LN2 cooling. The S/N ratio is in total improved by more than 200%.

Conclusion
A combination of a cryo-cooling system and cryogenic amplifiers has been developed in order to improve the ICR signal sensitivity. As shown above, the noise level decreases and the Signal-to-Noise (S/N) ratio improves at 80 K by cooling the trap and detection circuit with a LN2 circulation.

Work in Progress
In order to improve the cryo-detection system, a modified circulation system is being redesigned to control the final cooling temperature. Furthermore, the cryopreamplifier is being modified to maintain its gain at low temperatures (80K, 4K).

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