Low Noise Preamplifier for Cryogenic Fourier Transform Ion Cyclotron Resonance Mass Spectrometry

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Modern instruments such as FTICRMS and Orbitrap-MS which are based on the principle of inductive detection allow longer observation times of the ions making these instruments suitable for high precision experiments. The induced current on the detection electrodes (in the order of pA's) must be amplified using a transimpedance amplifier prior to digitization and data processing. The capacitance of the detection plates (~20 pF) makes the task of designing a wide bandwidth, low noise amplifier non-trivial. In this presentation, 2 designs of such an amplifier circuit will be reported, the room temperature version and the cryogenic version.

The detection amplifiers have been designed with 2 stages: an in-vacuum preamplifier and an atmospheric pressure instrumentation amplifier. The primary purpose of the preamplifier is the impedance transformation of the signal (from high to low). The low impedance signal from the preamplifier is fed to a low noise instrumentation amplifier kept outside the vacuum. The detection of image current in the order of pA's requires minimization of leakage currents in the preamplifier input transistors. Both parameters, low noise and low leakage current, can be improved by cooling the amplifier circuit to cryogenic temperatures. Hence we have developed a low noise preamplifier which can be cooled to 4 Kelvin using GaAs MESFETs.

The room temperature preamplifier uses low noise and low leakage Si-JFETs and the cryogenic version has GaAs MESFETs at its input stage. The voltage gain of both the preamplifiers is set to ~10 with bandwidth of 2.81 MHz. 20 dB gain in the first stage ensures that the preamplifier noise dominates the total amplifier noise. The measured power dissipation in the room temperature design is 340 mW and that of the cryogenic preamplifier is 0.5 mW which is within the acceptable range.

Performance of the room temperature design was evaluated on a custom MALDI-FTICRMS. Mass spectra of C_{60} desorbed using a ND-YAG laser showed a reduction in noise by ~25 folds acquired using the room temperature amplifier, Fig.1.

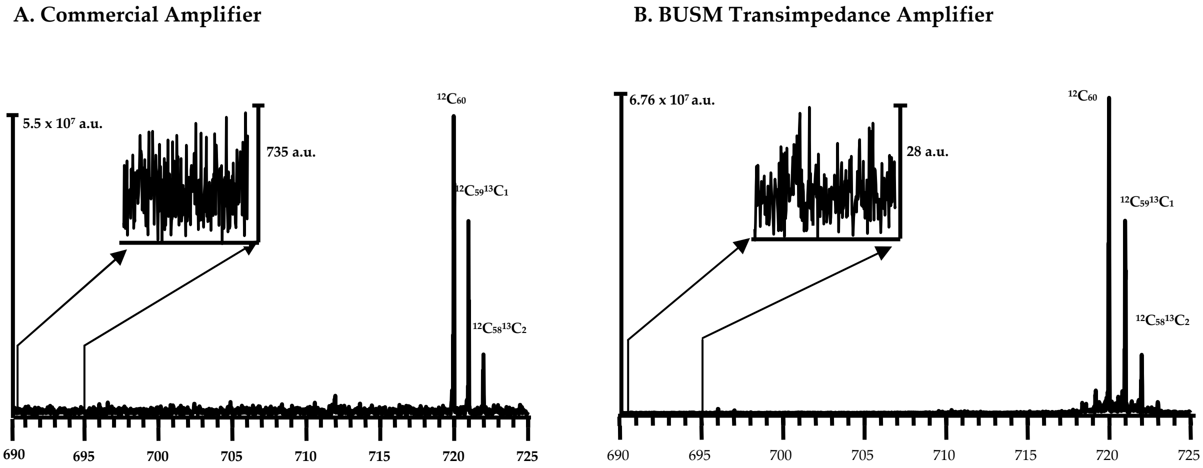

Fig.1. C_{60} MS obtained using a Commercial amplifier and the BUSM Transimpedance amplifier with identical instrument settings on a MALDI-FTMS.

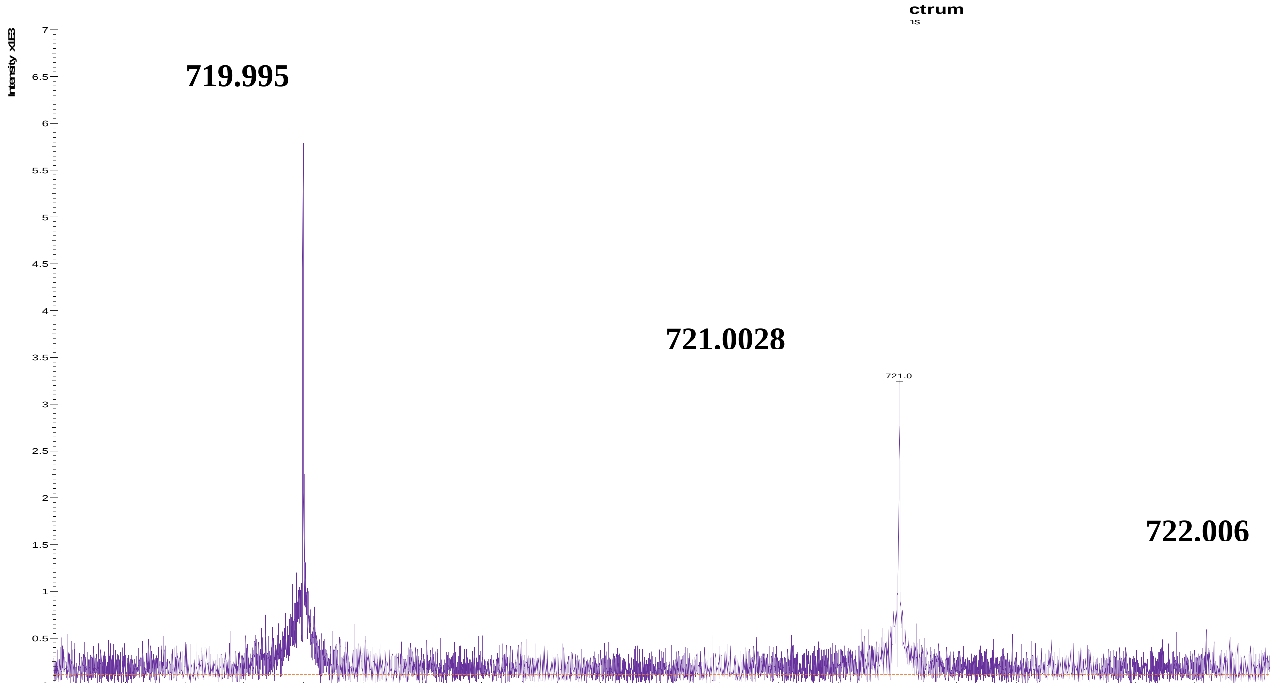

Fig.2. C_{60} MS obtained on the 14 Tesla Cryogenic FTMS. The Broadband detection using a room temperature amplifier yielded a resolving power of ~ 431k.

The cryogenic preamplifier positions the input GaAs MESFETs at 4 Kelvin. The output signal from the drain of the input MESFETs is fed to a Si JFET cascode pair which sits outside the vacuum system via a ~1 m long cable. The capacitance of this cable would normally form a high frequency pole with the resistance at its terminating end which would limit the bandwidth of the design, however the use of cascode configuration ensures that the terminating resistance looking into the source of the JFET is low – hence pushing this pole to higher frequency. Experiments to detect the ICR signal using the cryogenic amplifier are being performed on the cryogenic FTICRMS.

A room temperature instrumentation amplifier was used to detect the ICR signal generated by C_{60} ions at 14 T on the Cryogenic-FTMS. The high resolution MS obtained by broadband detection for 12.6 sec shows a resolving power of 431k, Fig.2.

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