Design of the Cryogenic Fourier Transform Mass Spectrometer

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Fourier Transform Mass Spectrometry is limited in its base performance characteristics (resolution, sensitivity, mass accuracy, etcetera) by three fundamental instrumental limitations, pressure, magnetic-field strength, and preamplifier noise. The need for low pressure implies need for a large bore for large conductance to the pumps, but the need for high field with high homogeneity implies the need for low bore diameter to simplify magnet design. Designing an FTMS for operation in the cold bore of a superconducting magnet eliminates this contradiction as the bore itself becomes a cryopump. Because the cold bore acts as a cryopump, the ion transfer vacuum chamber can be made substantially narrower than normal, allowing use of narrower bore magnets than are normally used in FTMS while still achieving the needed <1e-9 mbar pressures. The cold surfaces can also be used to chill a preamplifier to cryogenic temperatures for improved signal/noise performance.[1]

A specially designed magnet has been built to couple with a standard external source MALDI FTMS design. The FTMS consists of an external MALDI source, an accumulation hexapole, a transfer hexapole, and a capacitively coupled open cylindrical cell, pumped by two ~200 l/sec turbomolecular pumps. The titanium in-bore vacuum tube is designed to have high radiative heat coupling to the interior of the magnet chamber, but low radiative heat transfer down the tube. Furthermore, the tube walls are as thin as possible to decrease conductive heat transfer to the 4K region. The data system is a modular FTMS data system based on National Instruments boards.

The complete design for the system is finished and a screenshot of the Autocad file is shown in figure 1. The magnet is designed to hold ~100 l of liquid helium, which will be shielded from direct radiative exposure to room temperature by an aluminum radiation baffle which will be held at ~50k. Both temperatures will be generated using a two stage cryorefrigerator which can cool ~1.5W at 4K and >60W at 50K. Due to the narrower 3" bore, the magnet will be designed as a 15 Tesla magnet which will achieve acceptance specifications at 14 Tesla. The bore is designed with two copper mounting brackets which will function as thermal anchors for the inner FTMS vacuum chamber. However, due to the large surface areas involved, the primary heat transfer will be due to direct radial radiative heat transfer, which will allow most of the heat flowing down the vacuum chamber walls to be transferred to the 50K shield before it reaches the 4K region. Thermal analysis shows that it is possible to build a vacuum chamber which can transmit less than 0.5W of heat from the source to the cell. The instrument is currently being constructed, and is currently waiting on the installation of the magnet. The magnet has met field (14T) and homogeneity specifications (10 ppm over a 40 mm long by 40 mm diameter cylinder) and is currently being vacuum tested in the final dewar.

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References:
(1)O'Connor, P. B. Considerations for the design of a fourier transform mass spectrometer in the 4.2k cold bore of a superconducting magnet *Rapid Commun Mass Spectrom* **2002**, *16*, 1160-1167.

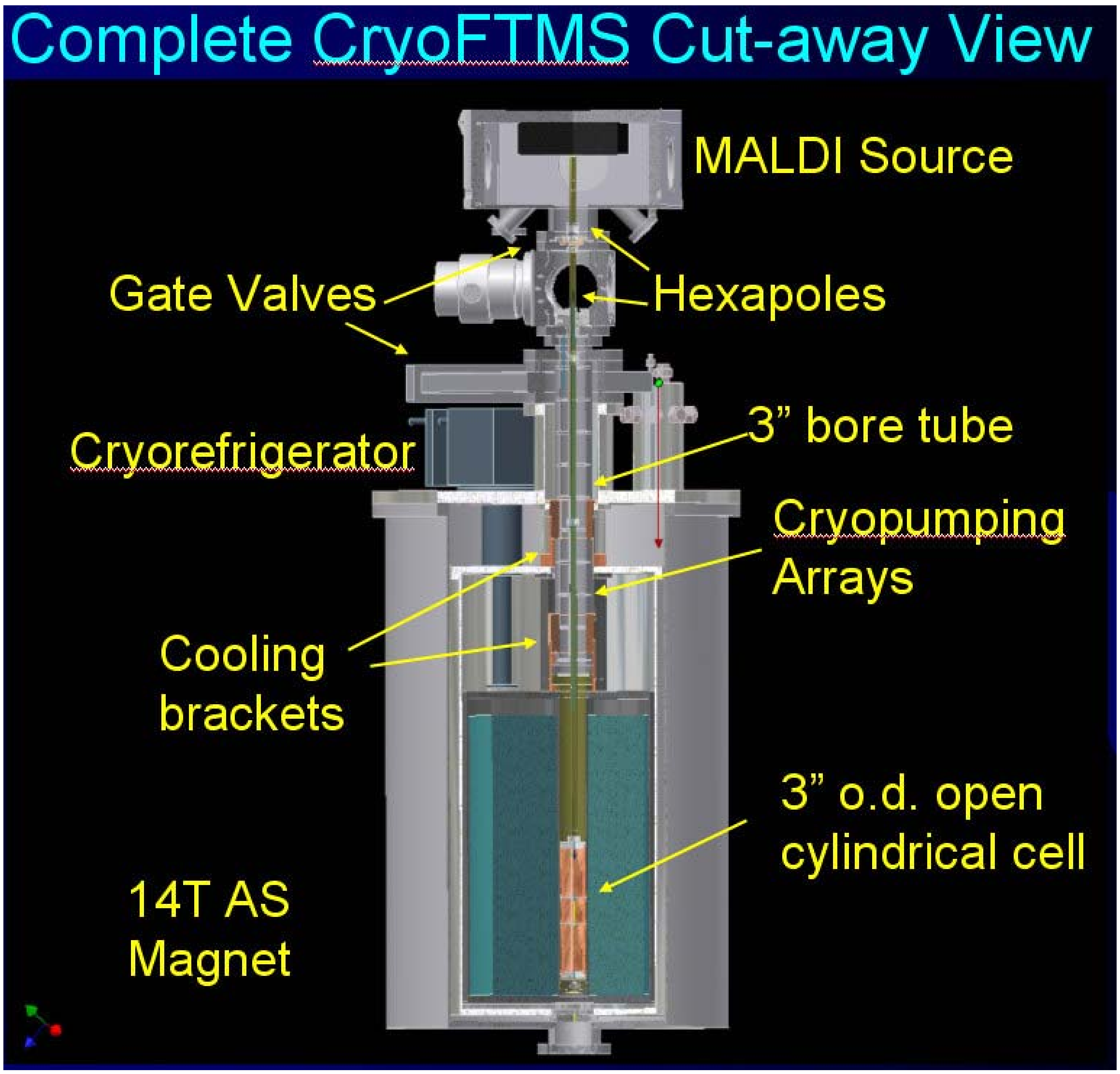

Figure 1. A screenshot of the CAD assembly for the Cryogenic FTMS