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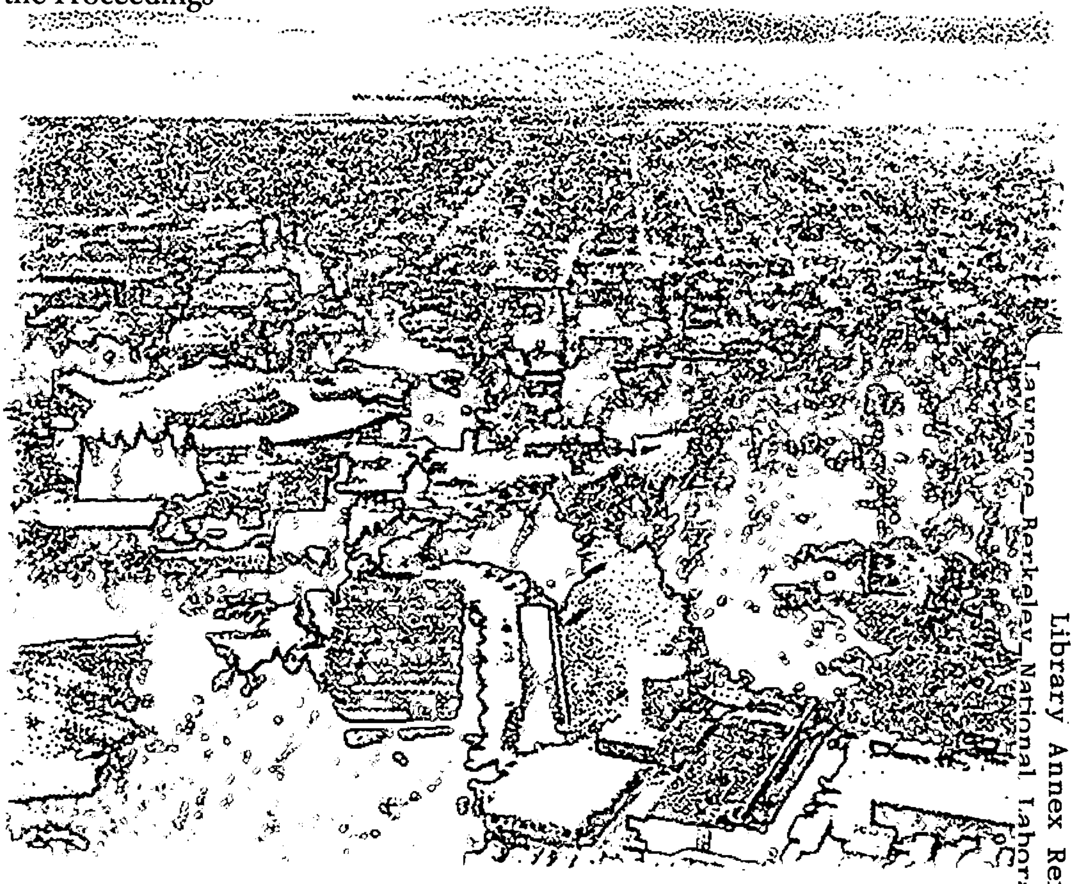

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PROGRESS REPORT ON VENUS

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Abstract

The construction of VENUS, a next generation superconducting Electron Cyclotron Resonance ion source designed to operate at 28 GHz, is complete. The cryostat including the superconducting magnet assembly was delivered in September 2001. During acceptance tests, the superconducting magnets produced an axial magnetic field strength of 4T at injection, 3T at extraction, and a radial field strength of 2T at the plasma chamber wall without any quenches. These fields are sufficient for optimum operation at 28 GHz.

The cryogenic system for VENUS has been designed to operate at 4.2° K with two cryocoolers each providing up to 45 W of cooling at 50° K and 1.5 W at 4° K in a closed loop mode without further helium transfers. However, during the acceptance tests an excessive heat leak of about 3W was measured. In addition, the liquid helium heat exchanger did not work properly and had to be redesigned. The cryogenic system modifications will be described. In addition, an update on the installation of the ion source and its beam line components will be given.

1 VENUS ECR ION SOURCE

Figure 1 shows the main components of the ECR ion source. The mechanical design has been optimized for maximum ion source performance as well as easy serviceability for operational use.

The plasma chamber has been designed to be able to handle 15 kW of CW RF power. It is made out of aluminum with 18 gun-drilled water-cooling channels. 6 of the channels were further opened up with a EDM wire cut at the magnetic poles of the sextupole. The plasma chamber is not round. As shown in figure 2, it has six cutouts at the magnetic poles in order to match the plasma shape. Therefore, the chamber geometry provides for additional volume where the ECR plasma is protruding outward. In addition, this shape allows maximum utilization of the magnetic sextupole field. In between the plasma flutes, where the plasma radius is significantly smaller, the chamber becomes thicker in order to provide structural rigidity. Aluminum was chosen because of its favorable secondary electron emission properties and its resistance to plasma etching.

Only metal vacuum seals were used in the ion source and beam line to ensure the cleanest vacuum condition. Up to three off-axis wave guides and two high

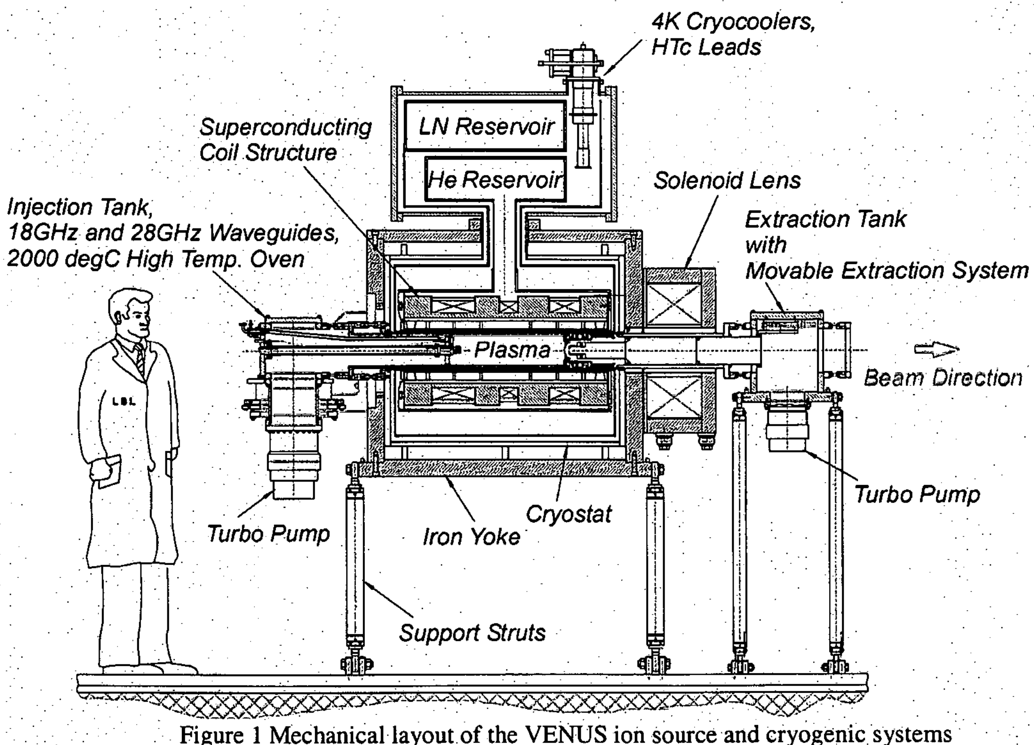

Figure 1 Mechanical layout of the VENUS ion source and cryogenic systems

temperature ovens can be inserted from the injection tank (see Fig.1). A water-cooled aluminum biased disk terminates the plasma in the axial direction at the injection end. Its shape has been optimized to allow maximum pumping through the injection end. The complete injection assembly can be wheeled out conveniently for service on a rigid support system, which guaranties alignment of the more than 1 m long injection assembly with the plasma chamber during service [1].

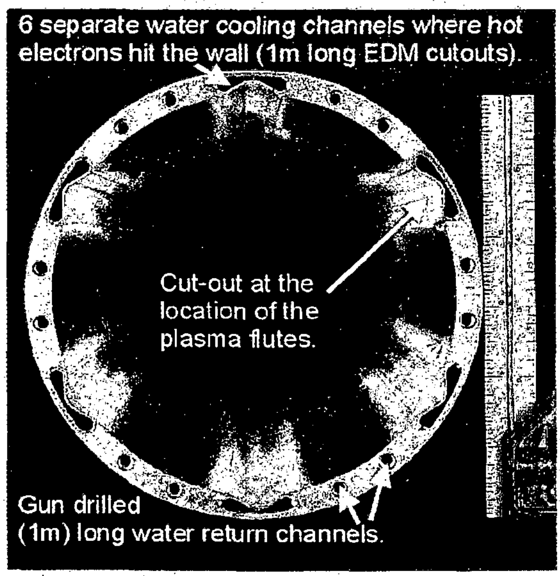

Figure 2 Picture of the VENUS plasma chamber before welding.

2 SUPERCONDUCTING MAGNETS

The design and construction of the superconducting magnets have been described in detail elsewhere [2]. The nominal design fields of the axial magnets are 4T at injection and 3T at extraction; the nominal radial design field strength at the plasma chamber wall is 2T.

The superconducting magnets and the cryostat have been constructed at WANG NMR Inc. in Livermore, CA. During the acceptance tests in September of 2001, the design fields were reached without quenches, with the sextupole reaching a field of 2.4 T at the plasma chamber wall (The magnets have already been trained in a test cryostat in 2000 as described in [2]).

The cryostat (see Fig.3) has been designed to work in a closed loop mode without LHe transfer. After the initial liquid helium filling and cool down, two cryocoolers should provide sufficient cooling power to keep the system at 4.2 K. However, during the acceptance tests in September 2001 the cryostat failed to meet two major design specifications: The heat leak exceeded the design goal of 1.5 W and was measured to be about 3 W (which is at the limit of the two croycoolers' capacity at 4.2 K). Furthermore, the heat exchanger, which couples the LHe reservoir to the two 1.5 W cryocoolers, did not function properly. As a result, it was necessary to regularly refill liquid He into the reservoir during the acceptance tests to compensate for the He loss through evaporation. Therefore, we decided to attempt to repair the cryostat at LBNL after the acceptance tests and before the final installation on the 88-Inch Cyclotron vault roof.

3 CRYOSTAT REPAIR

A thorough analyses of the original heat exchanger design (Fig.4) showed, that the thermal resistance of the flexible copper link was too high to provide sufficient heat flow from the He reservoir to the cryocoolers. Therefore, a new design approach had to be found.

In the new heat exchanger design, we replaced the copper link with a small He – recondensing unit [3], which is attached to each cryocooler as shown in Fig. 5. He gas from the He-reservoir enters the unit and condenses at the high purity copper fins. Then the liquid He flows back to the reservoir. The copper fins are bolted to the cryocooler with a mechanical indium joint. The unit relies on the operation with He-gas since the heat transfer through condensation is the most efficient cooling process. Furthermore, the pressure head produced by the liquid helium flowing back into the reservoir establishes the "pump" like mechanism.

Four holes were carefully drilled into the He reservoir to connect the two heat exchanger units to the He reservoir. Care was taken to avoid introducing any

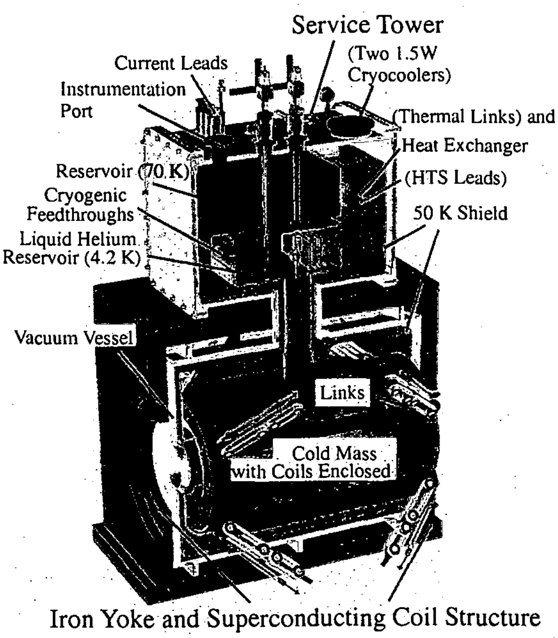

Figure 3: VENUS Cryostat and Superconducting Coil Structure

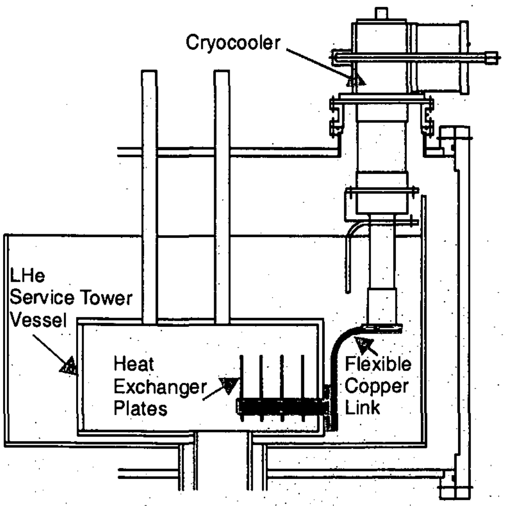

Figure 4 Original Heat Exchanger Design

metallic chips into the reservoir during this process.

The repair work began in February and took about 4 months. Operation of the cryostat was resumed at the end of May. Now the heat exchangers are able to remove 3 W and allow the system to operate in a closed loop (no He fills are required).

Unfortunately, the heat leak could not be decreased and remains about 3W. We suspect that the 50 K shield touches the 4 K vacuum vessel at the narrow connection neck to the service tower. Since this area is not accessible without a major rebuild of the cryostat, the best option will be to add another cryocooler unit in the near future.

For 18 GHz operation (and lower magnetic fields), the cooling power of the cryostat is sufficient for closed loop operation at 4.3 K. For the 28 GHz operation (expected to begin in 2004), another cryocooler will have to be added, which will increase the total cooling power to 4.5 W. This will be sufficient cooling to operate the superconducting coils at 4.2 K, which is required for maximum coil current.

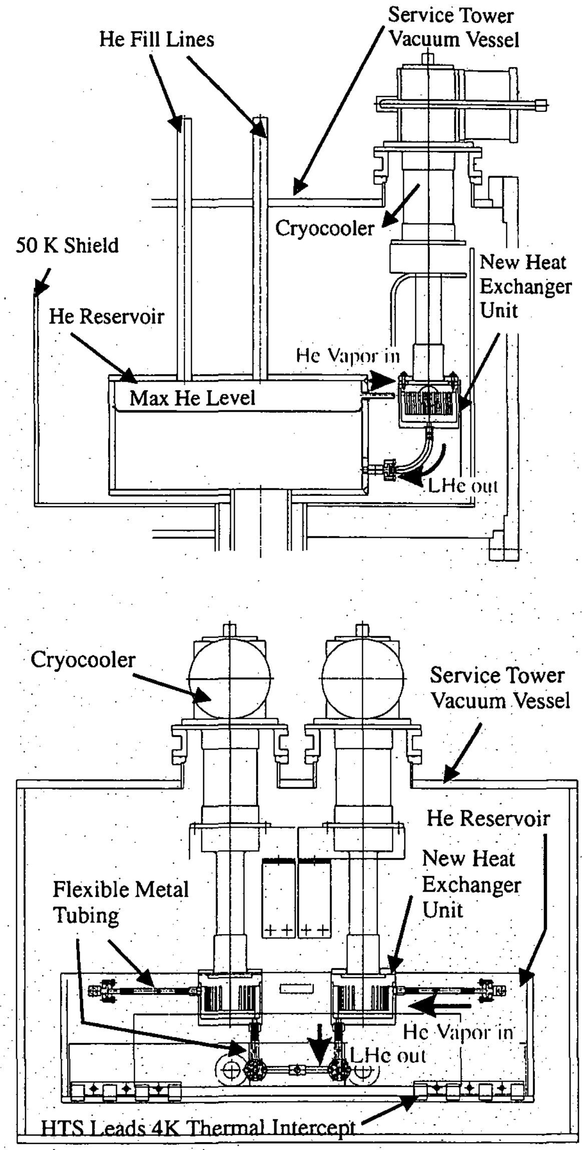

Figure 5 Side and front view of the new heat exchanger concept for the VENUS cryostat. In this design, the helium vapour transports the heat directly to the cryocoolers.

4 STATUS OF THE ION SOURCE

The ion source and analyzing magnet [4] have been assembled and installed on the vault roof of the 88-Inch Cyclotron. First plasma operation was achieved early June with 18 GHz microwave operation. During the summer assembly of the extraction system and electrical installation will be completed. First analyzed beam is expected in fall of 2002.

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