STATUS OF THE TEXAS A&M K500 SUPERCONDUCTING CYCLOTRON

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Summary

The Texas A&M K500 superconducting cyclotron is scheduled for completion in the spring of 1987. The field of the cyclotron magnet has been mapped twice. The first mapping in the summer of 1985 indicated that the first harmonic due to the steel is less than that of the NSCL K500 and that the first harmonic due to the coil is about the same as that of NSCL. Steel was added to the midplane of the yoke for the second mapping in the summer of 1986 with the consequence of significantly reducing the first harmonic due to the coil. Trim coil form factors were also mapped at that time. A number of RF system components including the dees, the RF liners, the RF anode, grid and screen power supplies, the RF control system, and the sliding shorts are complete or nearly so. The control system is being designed as a parallel processor system with networked IBM personal computers. Devices are interfaced through standard STD bus I/O cards and a parallel data highway which is mapped into the memory of the computer. The language for the system is FORTH. An axially injected electron cyclotron resonance (ECR) source is being designed with installation planned in 1988. The source will operate with a 14.5 GHz first stage and a 6.4 GHz second stage and will utilize an iron yoke to confine the solenoid field and to reduce power consumption. It will be a medium size source with a Sm Co hexapole surrounding the 13.7 cm. diameter second stage.

Introduction

Since the last report on the progress of this project,[1] funding has been obtained to construct an ECR ion source for the K500 cyclotron. With the addition of the ECR source, coupling the K500 and 224 cm cyclotrons provides little additional performance and has been abandoned. The K_b=500, K_f=160 cyclotron is expected to begin operation in the spring of 1987 using a PIG ion source. The ECR ion source will be assembled in the summer of 1987 and ECR beams will be available for axial injection and cyclotron acceleration in early 1988. Figure 1 shows the conceivable energy range of ion beams from such operation.

Magnet and Refrigerator

The cyclotron magnet was assembled in the cyclotron vault for the first time in May of 1985. Subsequently the lines necessary for transferring liquid helium from the refrigerator to the main coil cryostat were installed, and the cryostat was filled with LHe in June. The refrigerator at this time was producing at the rate of 46 l/hr which was improved by the time of the second mapping to 60 l/hr. Full field was achieved in early July, 1985. Balancing of the superconducting coil against the strong radial forces was achieved in a straight forward manner. The current was increased in both coils in increments while monitoring the forces on the radial links, and when the downward progress of these forces with increasing current was interrupted in one link, the magnet current was reduced and the coil was adjusted towards that link. Adjustments were in the range of .005 in.

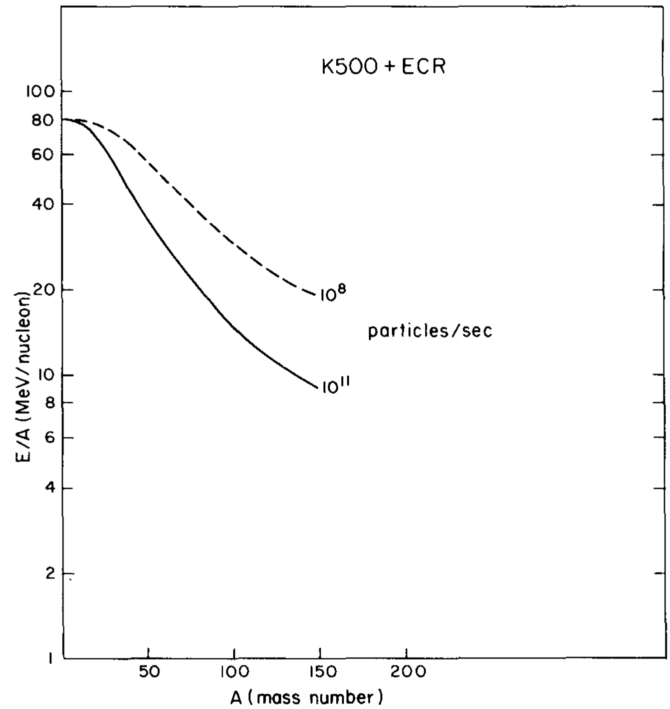

Fig. 1 Expected performance from the ECR+K500 combination.

Field Mapping

The magnetic field was initially mapped in September and October of 1985. The search coil method was used, and the apparatus was similar to the design of the system used to map the field of the NSCL K800 cyclotron magnet.[2] The voltage from the search coil was input to a voltage-to-frequency converter[3] and the output scaled. The data were collected and the apparatus controlled with an IBM personal computer communicating with a CAMAC crate. The IBM-PC-to-CAMAC software was provided with the crate controller as FORTRAN callable subroutines. The PC was configured with a dot matrix printer plotter and 40 Mbytes of hard disk. Full 360 degree maps, taken in 1 degree azimuthal and 0.10 in. radial increments, required approximately 0.5 Mbytes of disk storage.

The mapping sequence consisted of two parts: (1) the measurement of the contribution of the uncentered steel coil tank to the first harmonic at outer radii and the use of this data to place the coil tank on center and (2) the mapping of K500 fields at various combinations of main coil currents. The former was achieved by making 360 degree maps with 10 degree or 3 degree increments with the coil tank moved to slightly different positions. When it was felt that this contribution was a minimum, the tank was marked for later pinning. The latter part consisted of full 360 degree 1 degree step and 0.10 in. increment maps at different field levels corresponding to the full operating range of the K500 cyclotron.

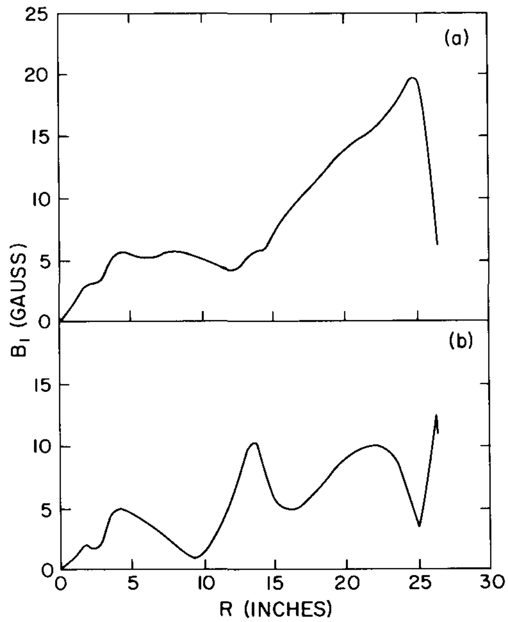

Fig. 2 First harmonic amplitude as a function of radius for I_α=687.5 A, I_β=150.0 A in first mapping, (a) measured and (b) after subtracting the calculated effect of moving the coil by 0.040 in.

Harmonic analysis of the field maps showed the similarity of the Texas A&M K500 to the NSCL K500 in that a large first harmonic component in the magnetic field could be attributed to an offset (.036 in. for NSCL[4] and 0.040 in. for Texas A&M) of the superconducting coil with respect to the center of the measuring apparatus. In both cases second harmonic data established an upper limit of less than .010 in. to the amount of off centering of the apparatus with respect to the pole tip steel so that the coil must have been off-center with respect to the pole tip geometry by more than .030 in. Since the off-centering is in the same general direction for both magnets, it was suspected to be due to the lack of symmetry in the yoke steel, caused by the penetrations through the median plane. Figure 2 shows the measured first harmonic as a function of radius for a typical field and the first harmonic left when the coil contribution is subtracted.

After mapping, the magnet was disassembled and the trim coils were installed on the pole tips. The field map data were examined using the trim coil fitting routine TCFIT, which was obtained from NSCL, and incorporating trim coil form factors from the NSCL K500. The field was determined to be very similar to the NSCL K500 field and suitable for acceleration of the full range of beams. After reassembly, a second mapping was begun in June of 1986. The goals of this mapping were to measure the contributions to the field due to the trim coils and to generate a set of maps to be used in predicting actual run fields. But since it had been shown at NSCL that the first harmonic contribution due to the coil made the extraction of certain beams more difficult,[5] it was decided that an effort would be made to center the coil.

The effort at NSCL to eliminate the first harmonic of the geometric form factor of the penetrations of the K800 steel yoke[6] and the success they had in centering the K800 coil[7] suggested that altering the

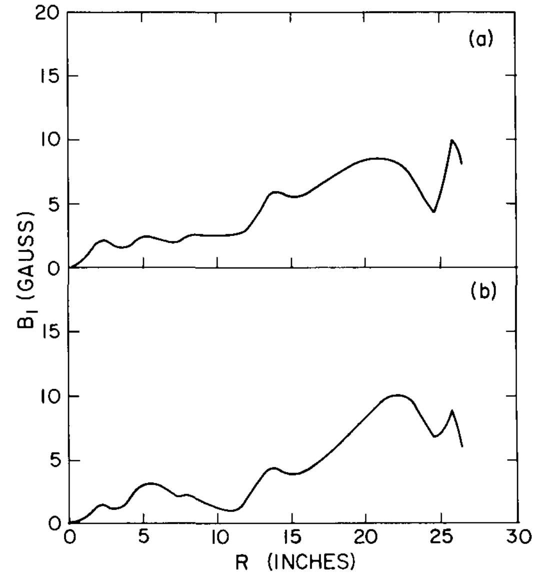

Fig. 3 First harmonic amplitude as a function of radius for I_α=687.5 A, I_β=150.0 A, in second mapping, (a) measured and (b) after subtracting the calculated effect of moving the coil by 0.019 in.

holes of the K500 might have some effect. Before the steel was altered the field was mapped at several coil currents to remeasure the first harmonic and verify the off-center amount. Then approximately 80 lbs. of steel were placed in the 8.5 in. high yoke penetrations at 93 degrees symmetric with respect to the median plane, and leaving a 3.0 in. high gap. The result was a significant reduction in the tension on the radial link at 96.5 degrees at high current. The coil had to be moved away from this link (and toward the center of the measuring apparatus) by approximately .005 in. in order to rebalance the radial forces. Another 356 lbs. of steel were now added in the same manner in this penetration and in the 8.5 in. high penetration at 106 degrees reducing its height to 3.5 in. The rebalancing of the coil moved it to a position approximately .019 in. off center of the measuring apparatus. Addition of the steel considerably reduced the first harmonic as can be seen by comparing Fig.3, where the final measurements of the first harmonic and the first harmonic left when the coil contribution is subtracted are shown, and Fig.2 which shows the same things before the addition of the steel.

RF System

The anode, screen grid and control grid power supplies have been constructed and tested. The transmission line to dee coupling capacitor has been redesigned to match 50 ohm transmission line as well as to minimize electric field gradients so that less conditioning of the electrodes should be required. The lower trimming capacitors, which NSCL does not move in controlling the resonator frequency, have been redesigned to be fixed in place, attached to a bracket on the rf liner. This leaves three 3.5 in. diameter holes in the lower pole cap which can now be used for pumping. The sliding short has been redesigned around a new type of rf contact finger developed at NSCL. One of the shorts, which requires no pneumatic locking devices, has been constructed. The lower rf liner has been constructed and leak tested, and fabrication of the upper liner is almost complete. The copper dee shells have been formed and will soon be welded to the

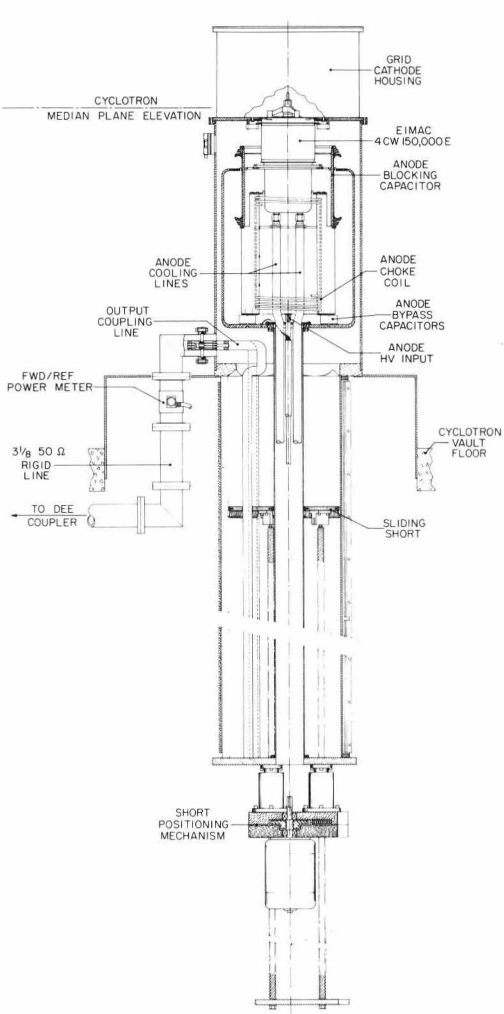

Fig. 4 Section of final amplifier.

machined dee lips. The tapered inner conductors of the resonators, the outer conductor spinnings and the dee stem insulators, described in an earlier report as products of SUPERFISH calculations[8] have been received in the past year. Cooling lines have been added to the copper panels of the hexagonal outer conductors in a pattern determined by SUPERFISH calculations of the power loss along the resonator. The final-amplifier design is shown in Fig. 4. The resonance characteristics of the anode tuner and the fields around the inductive-coupling loop were studied using SUPERFISH. Assembly and testing of these amplifiers are awaiting arrival of the mechanical parts.

ECR Ion Source

A project to construct an ECR ion source at Texas A&M and inject its beam into the K500 cyclotron has been funded. After observing several of the ECR sources now operating around the world, a source is being designed which incorporates successful features of several of them. Among these is a cylindrical steel return yoke like that used at NSCL. The yoke decreases power consumption and provides shielding for both magnetic field and X-rays, and the field due to coils and yoke is easily calculable with POISSON. Access for pumping on the second stage is also provided so that the higher pumping speed to this stage allows some

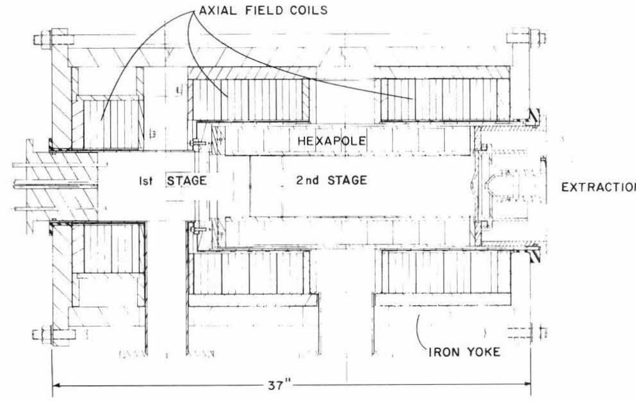

Fig. 5 Cross-section of ECR ion source.

control of the neutral density. A high neutral density can degrade the production of high-charge-state heavy ions through charge exchange. The first- and second-stage plasmas will be excited by a 2.0 kW, 14.5 GHz microwave transmitter and a 3.25 kW, 6.4 GHz microwave transmitter, respectively. Figure 5 illustrates this design. In addition, since there is the possibility of significantly increasing the high-charge-state output by increasing the second-stage microwave frequency, the design provides for enough axial field capability to accomodate a 14.5 GHz second stage with a stronger second-stage hexapole.

For axial injection we will rely to a large extent on the design of the NSCL K500 axial injection line and inflector. However, several changes will be required to accommodate differing requirements. In addition to transporting heavy ion beams from the ECR source a portion of the line must also serve for transporting the beam from our polarized deuteron source into the cyclotron. Our source will be placed on roof planks above the cyclotron, rather than below as at MSU, and both horizontal and vertical distances the beam must travel are different. The beam-line section leading up to the axial line must be decoupled each time the K500 upper pole cap is lifted, but since this section is farther from the K500 than the corresponding section at NSCL it should be easier to shield magnetically. Figure 6 illustrates the planned layout of the two sources and their injection into the cyclotron.

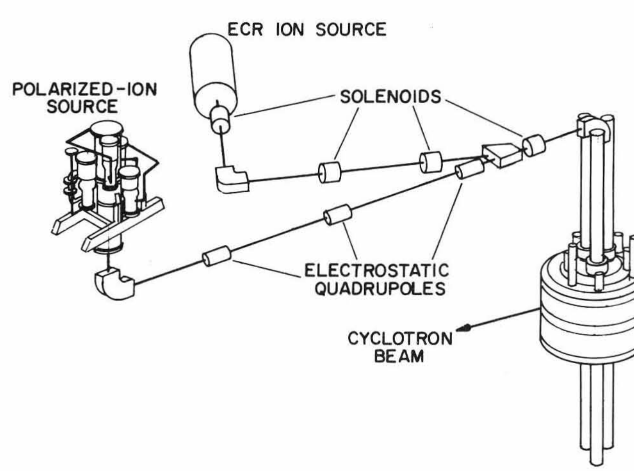

Fig. 6 Layout of the ECR and polarized ion source, with associated injection lines.

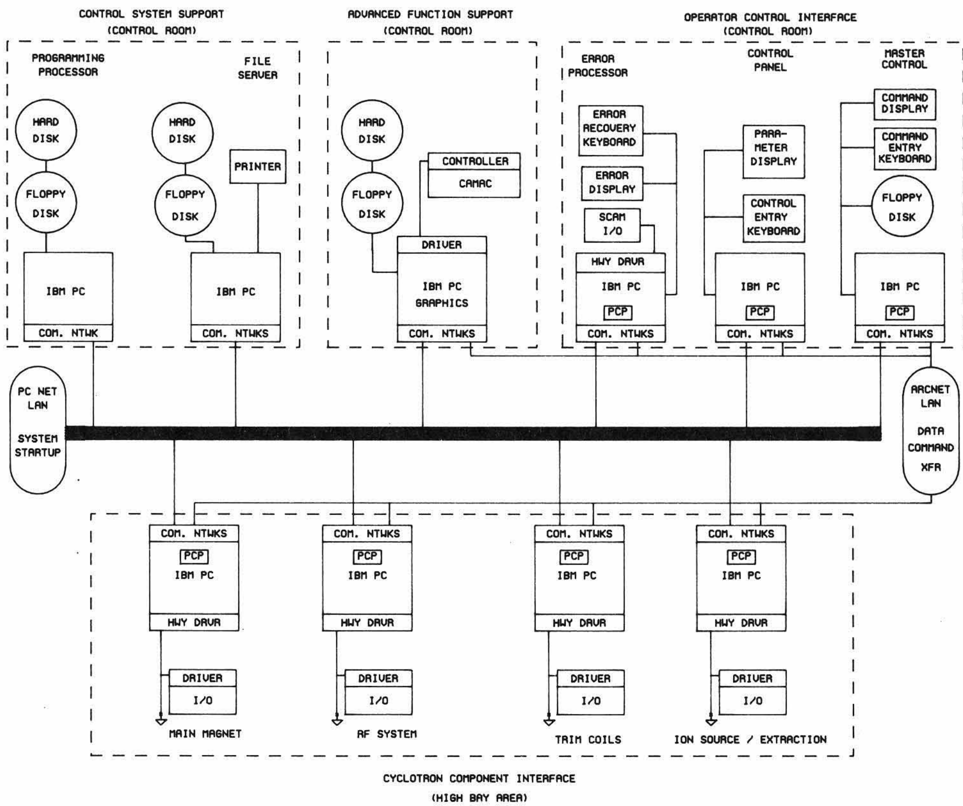

Fig. 7 Schematic of the cyclotron control system showing the computers and the local area networks.

Computer Control System

Figure 7 gives an overview of the cyclotron control system. Computer control for the K500 has been designed as a parallel processor control system consisting of ten IBM Personal Computers. The system interfaces to the cyclotron hardware via a memory mapped, tristate-parallel data bus and IEEE-696 (STD bus) I/O cards. Thus, as an example, a trim coil power supply looks like a number of addresses in memory to its control computer. The computers communicate via ARCNET a commercially obtained local area network, with another LAN, IBM-PC Network, supporting the start up of the diskless, operatorless computers. The STD bus cages are commercially available as are various I/O boards. A total of five kinds of cards have been designed especially for the system: (1) the STD bus crate controller card, (2) the highway controller cards for the control computers, (3) optical isolators for analog output, (4) optical isolators for BCD input, and (5) multipurpose DAC cards.

Much of the control software will be written in FORTH, a threaded interpretative language. A more detailed description will be available in the literature.[9] The latest tests of the system have been between the master control computer in the control room and the trim coil control computer on the high bay above the K500 via ARCNET and between the trim coil control computer and the STD bus in a trim coil power supply via the parallel highway. The system has been run error free for 150 hours and for 20 million operations using multiple trim coil subsystems.

References

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