Preliminary Results of the JAERI FEL Superconducting Accelerator Modules and their Cryogenic System

E.J.Minehara, N.Kikuzawa*, R.Nagai, R.Kato, M.Sawamura, M.Takao, M. Sugimoto, M. Ohkubo, J. Sasabe**, Y. Suzuki and Y.Kawarasaki**

Free Electron Laser Laboratory, Tokai Research Establishment,
Japan Atomic Energy Research Institute
2-4 Shirakata-shirane, Tokai-mura, Naka-gun, Ibaraki-ken, 319-11 JAPAN
*Department of Nuclear Engineering, Kyushu University
6-10-1 Hakozaki, Higashi-ku, Fukuoka-shi, Fukuoka-ken, 812 JAPAN
**Hamamatsu Photonics Co., Research Center
Hamakita-shi, Shizuoka-ken, 434 JAPAN

ABSTRACT

We have developed, and constructed a prototype for a quasi-cw, and high-average power free electron laser driven by a 15 MeV superconducting rf linac at Tokai, JAERI. In 1992 Japanese fiscal year(April 1992 - March 1993), we have successfully demonstrated expected cryogenic(stand-by loss<3~3.5W at 4.5K) and accelerating fields' performances(Eacc~7MV/m and Q ~2 $x10^{+9}$) of four JAERI superconducting accelerator modules. Each module of the JAERI FEL superconducting accelerator is composed of a 500 MHz Nb cavity, double heat shields, slow and fast tuners, 3 higher order mode couplers, an adjustable main coupler, a shield cooler, a compact 4K He recondenser, their related peripherals and electronic instrumentations. All of the four modules were already installed in the JAERI FEL accelerator vault this January. Commissioning of the modules and cryogenic system including the rf tests in the manufacture's factory and JAERI site at Tokai is described.

1. Introduction

A developmental program[1,2] of the free electron laser(FEL) system for a far-infrared region from the wavelength of 20 μm to 50 μm or longer has been undertaken at Japan Atomic Energy Research Institute(JAERI), Tokai. The purpose of the present JAERI FEL program lies in constructing a very long pulse or quasi-continuous wave(cw) superconducting rf linac electron accelerator, and demonstrating a high-average power FEL in the far-infrared wavelength region.

Because wall losses and required rf power become minimal in the superconducting accelerator cavity, we may realize a quasi-cw and high-current rf linac driver, and hence a high-average power laser. Each major part of the program including future plans has been reported in other papers[3-8] in detail. Here, we report our commissioning of the superconducting accelerator modules and cryogenic system.

2. Superconducting rf Linac

As shown in figs. 1, 2 and 3, the JAERI superconducting rf linac consists of two pre-accelerator modules of the single-cell cavity type and two main modules of the 5-cell cavity type. The resonant frequency of the cavities is 499.8MHz which is exactly the same with the buncher, and the sixth harmonic of SHB in the injector.

We decided to choose a so-called DESY concept of the cavity geometry and fabrication technology refined by Siemens Energieerzeugung KWU for the JAERI FEL superconducting linear accelerator. Design values of the accelerating field strength and Q-value for the cavities are 5MV/m, and 2×10^9, respectively. In 1992 and 1993 Japanese fiscal year, we have successfully demonstrated expected cryogenic(stand-by loss<3~3.5W at 4.5K) and accelerating fields' performances(Eacc~7MV/m and Qo~$2 \times 10^{+9}$) of four JAERI superconducting accelerator modules, and installed them in the FEL accelerator vault.

As a main coupler was designed to have a variable coupling coefficient over 3 and half decades, we could inject not only low current but also high current electron beams into the accelerator module. Typical peak RF power for the coupler was measured up to ~40kW without trouble. The coefficient was designed to be adjusted by inserting a center conductor into the cavity.

Three sets of the higher mode couplers were designed, and fabricated to suppress unwanted and harmful TE and TM modes having a higher resonance frequency. A monitor coupler was designed, and fabricated to use in monitoring and phase detecting in the feedback loop of a fast tuner. Slow and fast tuners were designed, and fabricated to tune a resonance frequency of the cavity in the module. The slow tuner consists of a stepping motor driver and an interface from the control system. The fast tuner consists of a piezo-electric actuator, a high voltage power supply, a feedback loop, and an interface from the phase detector and the control system.

3. Cryostats and Refrigerators

We have newly developed a multi-refrigerators system[5] integrated into the superconducting accelerator module cryostat to realize a highly-efficient cryogenic system without any liquid coolant for the JAERI FEL. A finite element method(FEM) calculation code[9] has been used to evaluate temperature distribution of heat shields, and other major components of the cryostat. Thermal design for the cryostat is performed to optimize heat loads to the major components of the cryostat by utilizing the calculated and experimental results. A 4K closed-cycle He gas refrigerator mounted just above a liquid-He supply tower of the module was adopted to cool down and to recondense cold vapor of liquid He around a heat exchanger in the liquid He container. A 40K/80K two-stage closed-cycle He gas refrigerator, which was mounted in a vacuum vessel of the module was adopted to cool down the 40K and 80K heat shields and other major components of the cryostat. These two kinds of the refrigerators are available commercially in Japan and other countries. The 4K refrigerator suspended in a stainless-steel frame can be winched up and down to remove the heat exchanger out of the liquid He container, and to insert the exchanger into the container. Cooling capacity of the 4K refrigerator is 11W at 4.5K and 60Hz.

The 40K and 80K heat shields are used to prevent heat invasion from outside into the liquid He container. In order to minimize heat loads to the container, the heat shields work as a thermal anchor, and make the return route having a temperature higher than 4K for all heat bridges from the outside. The 40K/80K refrigerator used here provides two cooling stages with a typical pair of temperature of 40K and 80K and heat load capacities of 40W and 120W , respectively.

4. Summary

In 1992 Japanese fiscal year, we have successfully demonstrated expected cryogenic(stand-by loss < 3~3.5W at 4.5K) and accelerating fields' performances(Eacc ~7MV/m and Qo ~ 2 x 10^{+9}) of four JAERI superconducting accelerator modules, and liquid He refrigerators, and installed them in the FEL accelerator vault.

Acknowledgment

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Figure captions

Fig. 1 Layout of the JAERI FEL Facility.

Fig. 2 Crossectional drawing of the 5-cell cavity superconducting accelerator module.

Fig. 3 Crossectional drawing of the single-cell cavity superconducting accelerator module.

References

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Fig. 1

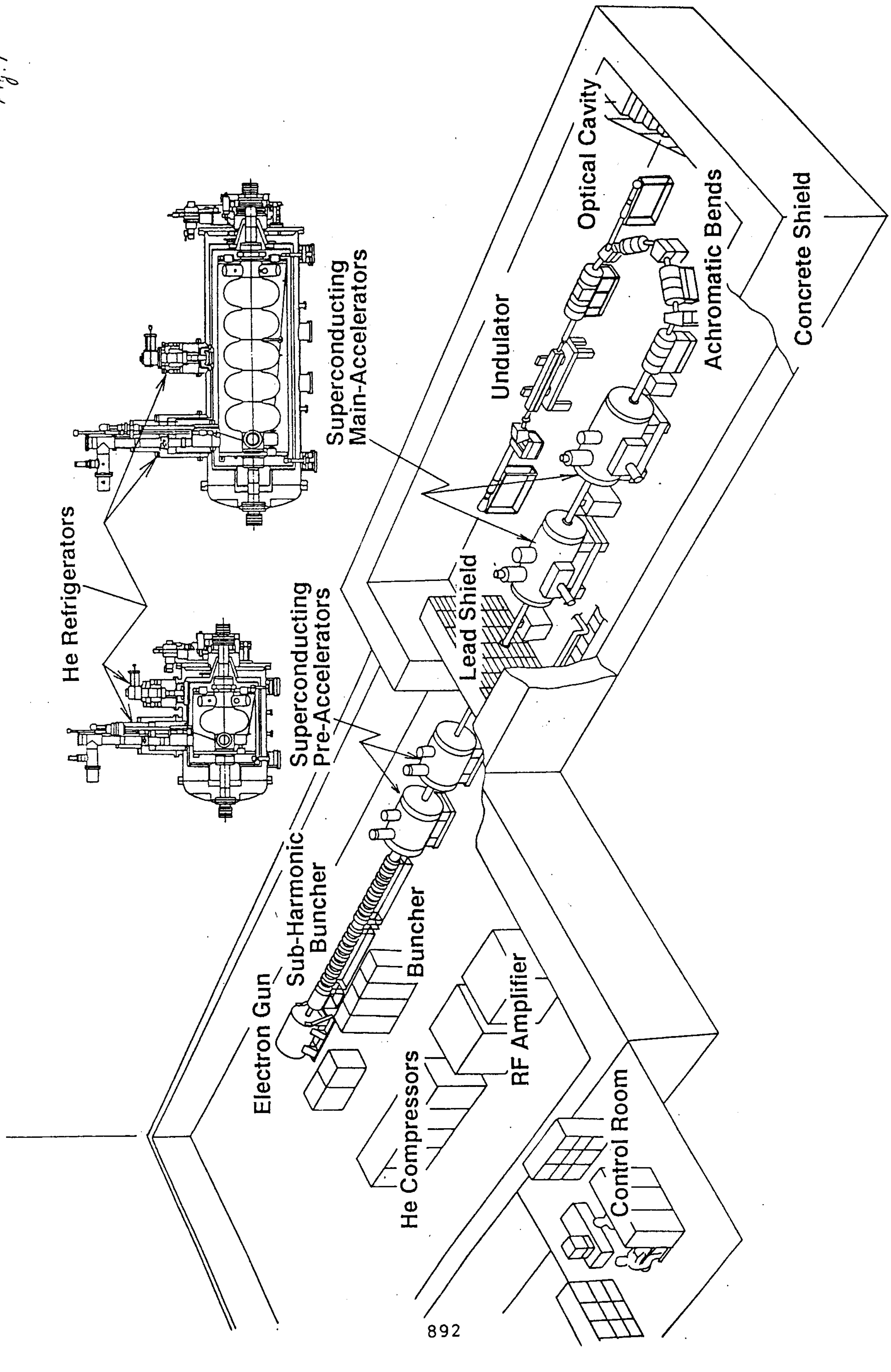

He Refrigerators
Superconducting Main-Accelerators
Superconducting Pre-Accelerators
Sub-Harmonic Buncher
Buncher
Electron Gun
He Compressors
RF Amplifier
Control Room
Lead Shield
Undulator
Optical Cavity
Achromatic Bends
Concrete Shield

Fig. 2

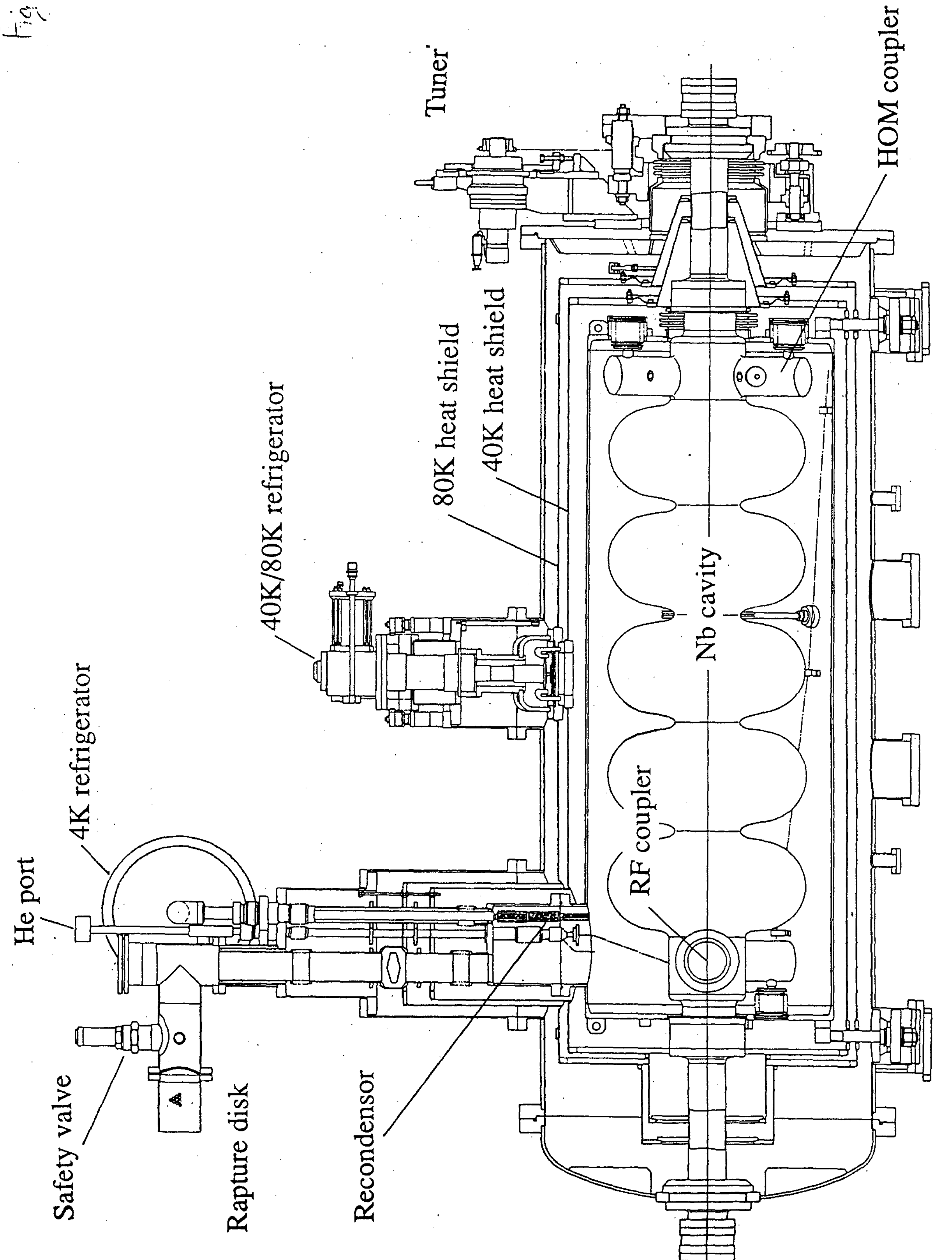
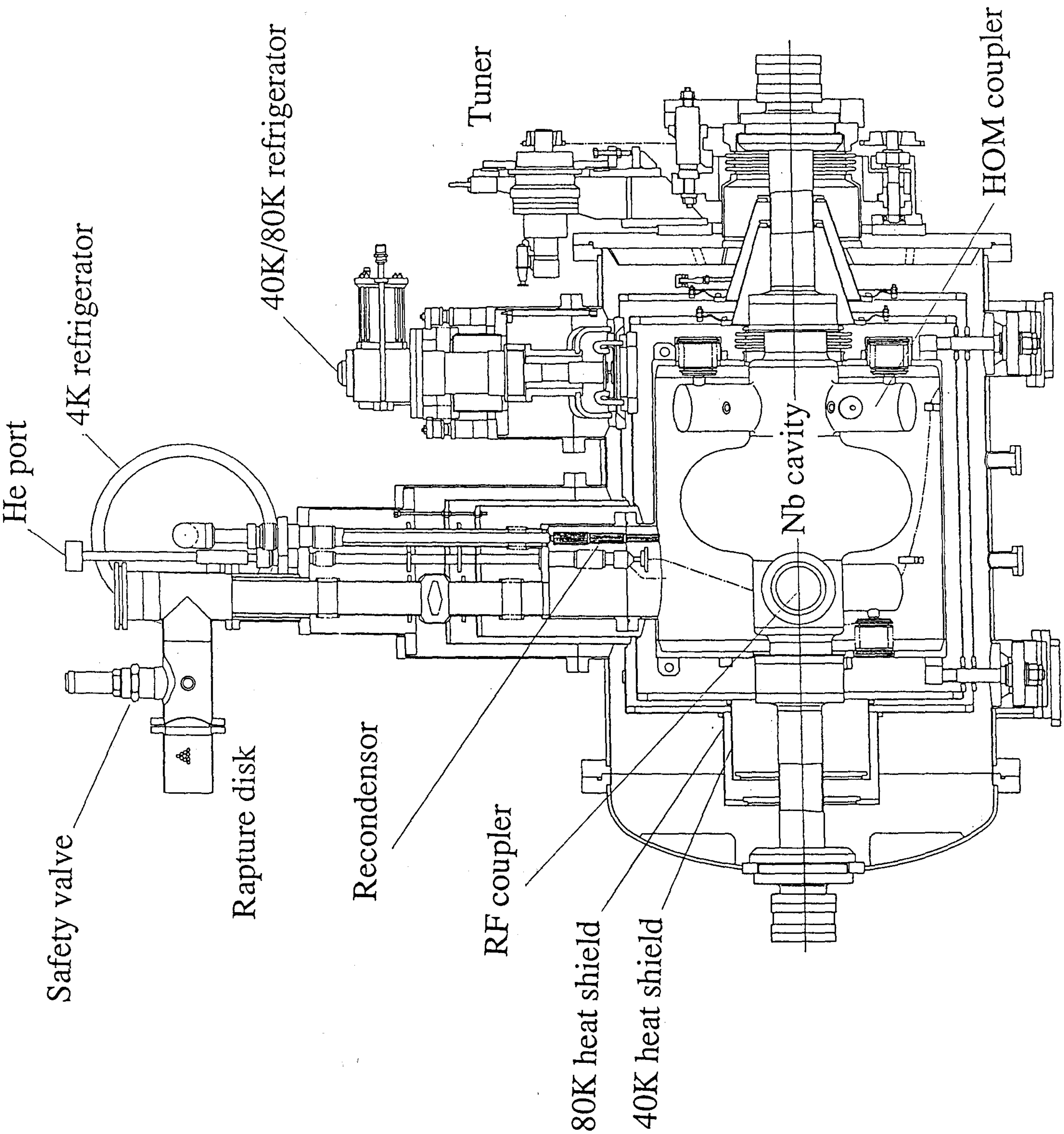

Tuner
HOM coupler
80K heat shield
40K heat shield
40K/80K refrigerator
Nb cavity
RF coupler
4K refrigerator
He port
Safety valve
Rapture disk
Recondensor

Fig. 3


He port
4K refrigerator
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Nb cavity
Safety valve
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Recondensor
RF coupler
80K heat shield
40K heat shield