ENGINEERING AND FABRICATION OF A LOW β PROTOTYPE SUPERCONDUCTING ACCELERATOR MODULE FOR FORSCHUNGSZENTRUM JÜLICH

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Abstract

The Forschungszentrum Jülich is evaluating the possibility of a superconducting high energy part of a proton linac for the European Spallation Neutron Source ESS [1], [2]. A superconducting prototype module has been designed and constructed by ACCEL (see Fig. 1) consisting out of a 500 MHz β=0.75 niobium 5-cell cavity. The assembly of the cryomodule with the chemically prepared and ultrapure water rinsed cavity is scheduled for end of 1999. The module will be equipped with tuning mechanism and an input coupler allowing an adjustment of the external Q from 10^6 to 10^9. The module will be delivered ready for cryogenic low power and high power measurements at Forschungszentrum Jülich.

1 LAYOUT AND PRODUCTION OF THE CAVITY

The module is equipped with a 500 MHz 5-cell cavity. The shape of the cavity is optimized for a relative particle velocity of β=0.75. The main design parameters of the cavity are listed in table 1.

The mechanical stability of the cavity was analyzed by finite element calculations with the computercodes ANSYS (Fig. 2). The lowest eigenfrequency is well above 50 Hz.

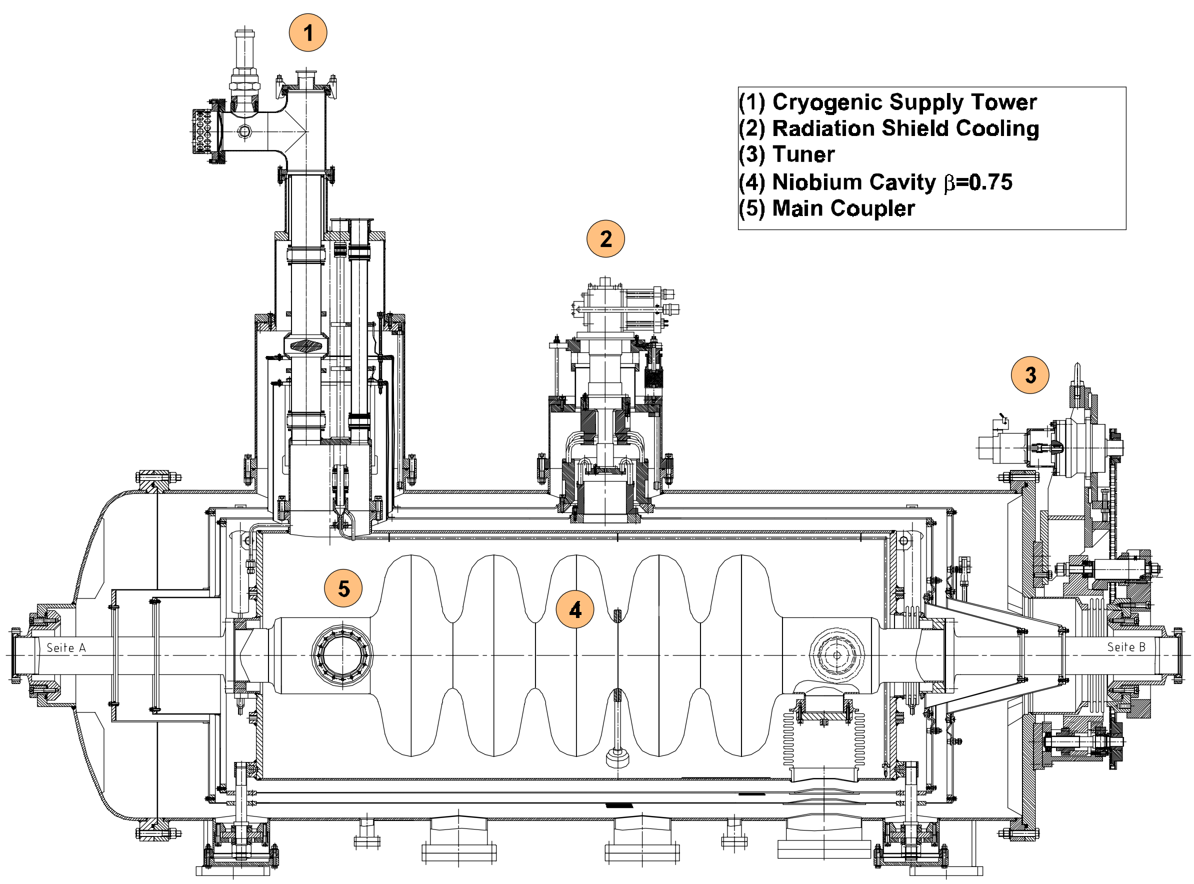

Figure:1 Overview of the accelerating module

Table:1 Design parameters for the superconducting 500 MHz 5-cell β=0.75 cavity.

$R/Q = V_{acc}^2/(P_{diss} \cdot Q_0)$	297 Ω
Geometric constant	203 Ω
Active length	1.125 m
Equator diameter	541.6 mm
Iris diameter	202.0 mm
E_{peak}/E_{acc}	2.6
B_{peak}/E_{acc}	5.6 mT/(MV/m)
Tuning range	600 kHz

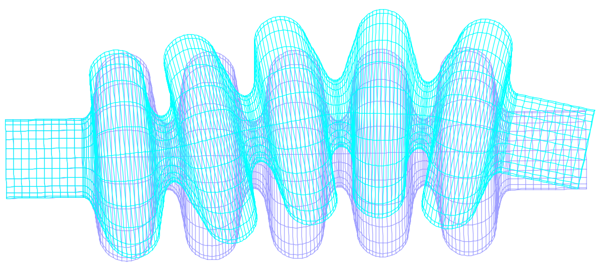

Figure 2: First mechanical eigenmode of the cavity

For the production of the cavity high purity niobium sheet material is used. The Residual Resistivity Ratio (RRR) of the niobium is about 300. The individual cells are formed by deep drawing from the niobium sheets. The half cells are joined together by electron beam welding.

After production the cavity was tuned to field flatness at ACCEL. The cavity was then chemically prepared (100 µm) and tested in a vertical bath cryostat in a close collaboration with CERN using CERN facilities.

2 CAVITY TEST RESULTS

The test result is summarized in Fig. 3. At a bath temperature of 4.2 K an accelerating gradient of E_{acc} = 5.8 MV/m has been achieved. The quality factor Q_0 at low fields was $1.7 \cdot 10^9$. At E_{acc} = 5.8 MV/m a quality factor of $1.2 \cdot 10^9$ was achieved. The cavity was limited by the available amplifier power of 200 W. From the BCS theory of superconductivity, the RF surface resistance of niobium at 500 MHz and 4.2 K can be estimated to be about 90 –130 nΩ. The geometric factor G is reduced in low β cavities compared to β = 1 structures. The β = 0.75 cavity has G = 203 Ω. So the measured Q values are very close to the theoretical limit.

At a bath temperature of 2.6 K the quality factor of the cavity was $6.5 \cdot 10^9$. As the BCS resistance decreases exponentially with temperature, one can conclude, that the Q_0 is determined from the residual resistance at this bath temperature and a value of 25 nΩ for the residual resistance can be calculated. At 2.6 K accelerating gradients of 7.8 MV/m could be reached. Also at this temperature the cavity was limited by available RF power. Above 6 MV/m radiation was observed on the top plate of the cryostat, indicating that field emission was present at high gradients.

The cavity was excited in all other modes of the fundamental passband. During this measurements it was possible to establish higher gradients in individual cells. The measurements are listed in table 2. One can conclude, that all cells have the potential for gradients above 8.6 MV/m and that some cells can achieve gradients above 12.6 MV/m.

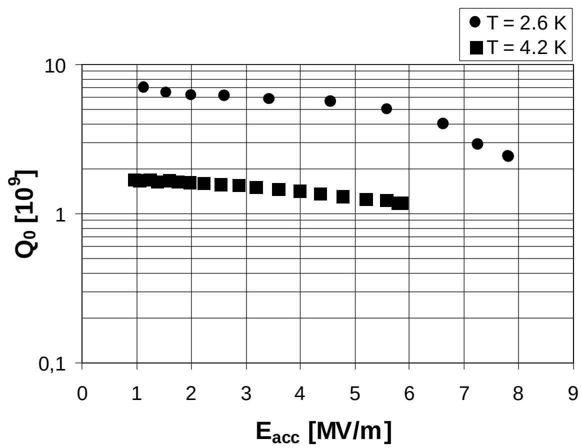

Figure 3: Vertical test result at different bath temperatures. The cavity was limited by available RF power. Above 6 MV/m field emission was present.

Table 2: Gradients achieved in individual cells during mode measurements of the fundamental passband.

mode	Cell 1&5 [MV/m]	Cell 2&4 [MV/m]	Cell 3 [MV/m]	Limit
π	7.8	7.8	7.8	Power
4/5π	8.0	4.9	0	Power
3/5π	10.2	3.9	12.6	Power
2/5π	5.3	8.6	0	Power
1/5π	3.2	8.3	10.3	Power
Max	**10.2**	**8.6**	**12.6**	

4 CRYOMODULE

The cryostat (see Fig. 1) is based on ACCEL's design for the low loss cryomodules for the JAERI FEL Linac [3]. The two radiation shields are cooled by a Gifford Mc Mahon type refrigerator at temperatures of 20 K and 80 K. The static heat losses at 4.2 K temperature levels are designed to be well below 3 W (table 3).

Table 3: Calculated heat balance of the cryomodule.

	Heat load in Watt at temperature level		
	4.2 K	**20 K**	**80 K**
Beam tube A	0.08	1.62	5.8
Beam tube B	0.08	1.62	4.9
Main coupler	0.74	3.90	5.7
GF-UP support	0.003	0.06	0.23
Radiation 80 K shield			5.2
Radiation 20 K shield		0.32	
Radiation LHe tank	0.1		
Supply power	0.07	0.65	3.4
RF cable	0.42	1.65	1.70
sum	**1.48**	**9.85**	**27**

The tuner drive is mounted outside the cryostat. This simplifies the maintenance and increases the reliability of the tuning system. The tuning forces are transfered to the cavity by the beam tubes.

5 OUTLOOK

After the successful vertical test has been completed now the assembly of the cavity with the cryomodule starts. The cryomodule is scheduled to be delivered to Forschungszentrum Jülich end of 1999.

6 REFERENCES

[1] THE ESS TECHNICAL STUDY, Volume 3, ESS-96-53-M

[2] CONCEPTUAL DESIGN OF THE HIGH ENERGY LINEAR H^- ACCELERATOR FOR THE ESS

[3] M. Shibata, " SUPERCONDUCTING RF ACTIVITIES AT JAERI", Proceeding of the 6th Worshop on RF Superconductivity, Newport News, p. 124-130, 1993