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MEASUREMENTS ON A SUPERCONDUCTING ACCELERATING CAVITY FOR DORIS*

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Summary

An experiment has been set up to test a superconducting cavity in the e^+-e^--storage ring DORIS (DESY, Hamburg). The cavity achieved accelerating field gradients E_{acc} of 3.2 - 4 MV/m and Q-values up to 6×10^9. The input coupling was tested up to 45 kW at total reflection, corresponding to 90 kW at matched conditions. Two higher mode couplers have shown $10^2 \leq Q_{ext} \leq 10^4$ for all modes below the beam tube cutoff frequency and $>10^8$ for the fundamental mode. The completed cryogenic system works as planned.

I. Introduction

The use of superconducting accelerating cavities in high energy storage rings reduces the power consumption and offers thereby higher energies [1,2]. To study the basic properties of such a cavity in a storage ring, a 500 MHz-niobium cavity was built and prepared for installation in DORIS. The components of the experimental setup have been tested successfully. The results of these tests and those obtained in the first tests of the completely assembled system are reported in this paper. Similar cavities have been investigated at KfK[3], CERN[4] and KEK[5], but these cavities had no higher mode couplers and no high power input coupling. A 60 cm long, 11-cell S-band cavity was operated successfully at 4 MV/m in the Cornell synchrotron for several months[6]; in contrast to our experiment for $\leq$ 380 µA of beam only $\leq$ 1 kW input power was needed and no higher mode couplers were necessary. A storage ring cavity test at a higher frequency is being prepared at CORNELL [7].

The basic parameters of our experiment are shown in Table I.

TABLE I
Basic properties of the DORIS-experiment and the cavity

Frequency (MHz)	500
Shuntimpedance (300 K, Cu) (MΩ/m)	22.5
Q-value (300 K, Cu)	4.2×10^4
Geometry factor (Ω)	241
peak el. field / acc. field	1.93
peak mag. field / acc. field (mT/MV m^{-1})	3.6
cavity losses (W)	5 - 10
beam power for 2.60 mA (kW)	~ 90

II. Cavity Measurements in a Laboratory Cryostat

Before installing the cavity in the horizontal DORIS-cryostat it was measured vertically in a laboratory cryostat. In the first series of measurements all coupling flanges were closed by niobium plates using preliminary RF-contacts. The results shown in Table II are analyzed in detail in ref. 8.

They can be summarized in the following way: The measurements include: Measuremnet of Q_o versus E_p (fig. 1), X-ray intensity and spectrum, electron current and Q_o-change versus $1/E_p$, observation of heat pulses, temperature dependence of the surface resistance and influence of magnetic shielding.

TABLE II
Results of measurements on DORIS I
(all coupling holes closed by blind flanges)

	4.2 K	1.8 K
Low field Q	2×10^9	6×10^9
High field Q	1×10^9	1×10^9
E_{acc}(cw) (MV/m)	3.7	4.1
E_{acc} (pulsed) (MV/m)		4.3
β (Fowler-Nordheim)[8]	600-890	

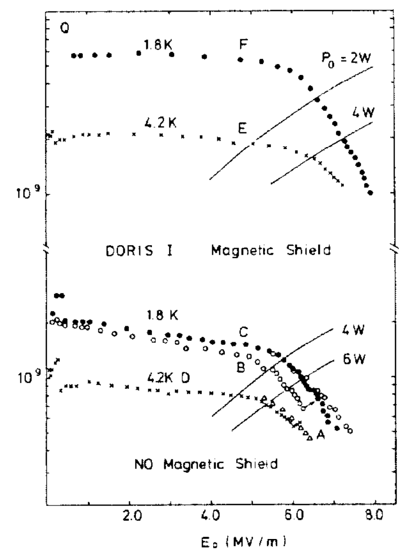

Fig. 1: Q_o versus E_p for runs A-F; cavity always kept under vacuum. Beside the improvement due to the magnetic shield all changes, especially the Q-jump in run B, are due to RF-processing

The results show

- a series of low multipacting levels, which can be processed away in few hours, presumably 2-side multipacting of order ~ 20. No one-side multipacting has been found.
- X-rays and electrons starting above E_p ~ 4 MV/m which can be reduced by RF-processing.
- breakdown at the position of the higher mode couplers observed by heat pulses in a region of enhanced fields and welding seams.
- heating already observed before breakdown by $\Delta 1/Q \sim E_p^2$ and heat pulses.

The field limitation is due to RF-field emission loading[8].

After these tests the installation in the DORIS-cryostat was begun by the following steps:

- the mechanical dimensions were adjusted to the requirements of the DORIS-cryostat, which was necessaiy

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due to tolerance errors during fabrication of the cavity.

- the coupling flanges were remachined to use RF-joints similar to those used in the KfK-CERN-separator.[9]
- the higher mode couplers were attached.

The result of the measurements (fig. 2) done after these changes was E_{acc} = 3.2 MV/m the breakdown limitation being the same as before. The Q-value was $.6\times10^9$ at high field, lowered presumably by residual losses due to imperfect RF-contacts at the coupling flanges.

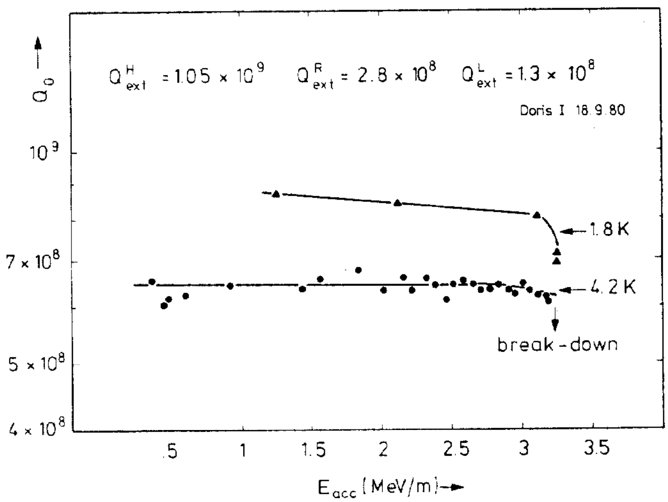

Fig. 2: Q_o versus E_{acc} measured in DORIS I after mechanical changes and with higher mode couplers

III. Other Components of the DORIS-Experiment

To install the cavity in DORIS a number of components is necessary. They can be divided in RF- and cryogenic components.

III.1 RF-Components

III.1.1 High Power Input Coupling. As shown in table I. about 90 kW RF power is needed to accelerate the beam of 2×60 mA up to E_{acc} = 3 MV/m. The RF-input coupling contains capacitive separations between the temperature levels 4.2/80/300 K to minimize the heat influx. Two ceramic windows at 80 and 300 K separate the vacuum inside the cavity from the outside. The parts operating at He-Temperature are made of niobium. All transitions inside the coax-system have been compensated , resulting in a return loss of - 43 db. The system was tested at room temperature up to 45 kW at total reflection, corresponding to 90 kW in matched condition. The Q_{ext} was adjusted to 4.2×10^4.

III.1.2 Higher Mode Couplers. The couplers (fig.3) have been investigated both during the experiments described above and in the DORIS-cryostat. Fig. 4 shows that the required damping of all higher modes between 600 and 1500 MHz - $10^2 \leq Q_{ext} \leq 10^4$ has been achieved. The supression of the fundamental mode demands a very accurate adjustment both of the angle ϕ and the distance z between coupling loop and field transformer:
$10^8 \lesssim Q_{ext} \lesssim 10^9$ for the fundamental mode has been achieved by bending the field transformer slightly up or down after assembly.

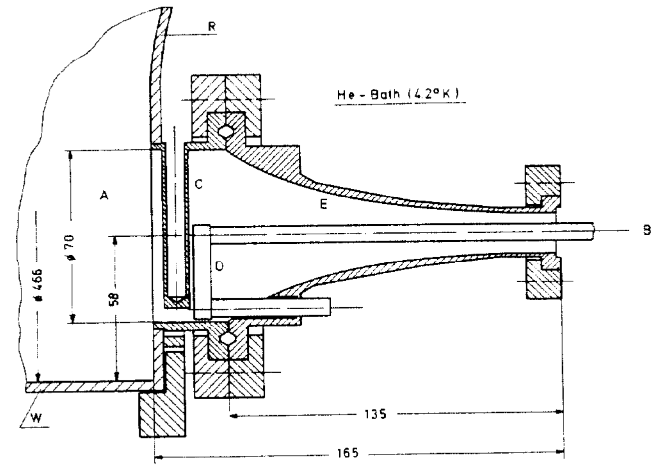

Fig. 3: Higher mode coupler. A: Cavity interiour, B: Coaxial line, C: Field transformer, D: Coupling loop, E: Exponential line, R: Cavity endplate, W: Cavity cylinder wall

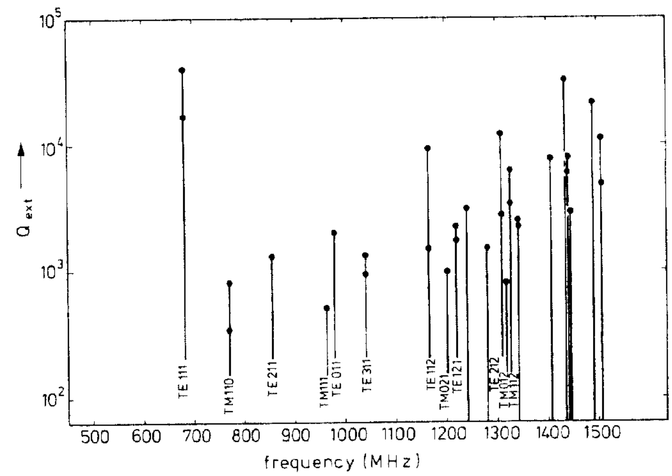

Fig. 4: Q_{ext} for all higher modes between 600 and 1500 MHz. Above 1000 MHz the mode identification becomes uncertain.

III.1.3 Tuner. The tuner - a mechanical system that changes the frequency by pushing and pulling at the endplates of the cavity - has been tested in the DORIS-cryostat. It covers a tuning range of 250 kHz with a speed of 10 kHz/m.

III.2 Cryogenic components

The experiment will be operated by helium supplied from 500 l containers. About 50 l/h are needed. The cryogenic setup consists of the cryostat, the transferlines for helium and nitrogen, the compressor unit, LN_2 and H_2O-heat exchangers for cool-down and warm-up, and the control equipment.

The whole system has been operated many times and works as planned. The helium losses of the cryostat are 5.5 W, transfer losses are 20 W. Cool-down from 300 K to 100 K is done by LN_2 in 24 h, from 100 K to 4.2 K plus complete filling in 10 h, requiring 640 l He_2. During the last runs the cavity was built in and the RF-properties were measured. Due to technical difficulties (enhanced RF-losses at joints and increased insulation losses in the higher mode coupling lines) which are being solved at the time of this writing no final results can be given at present.

IV. Conclusions

The DORIS cavity achieved accelerating field gradients above 3 MV/m at Q-values of about 10^9. The technical components necessary for operating the cavity in DORIS are completed and tested successfully separately. The test of the complete setup is under way.

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References

1 D. Ritson, M. Tigner, CLNS report-406 (Cornell-University, Ithaca, N.Y., 1978)

2 W. Bauer, A. Brandelik, A. Citron, W. Lehmann, L. Szecsi, M. Yoshioka, IEEE Trans. Nucl. Sci. NS-26 (1979) 3252

3 K. Yoshida, M. Yoshioka, J. Halbritter, IEEE Trans. Nucl. Sci. NS-26 (1979) 4114

4 Ph. Bernard, B. Cavallari, E. Chiaveri, E. Picasso, V. Picciarelli, H. Piel, Proc. 11th Int. Conf. High Energy Acc., Geneva (Birkhäuser, 1980) 878

5 T. Furuya, S. Hiramatsu, T. Nakazato, T. Kato, P. Kneisel, Y. Kojima, A. Takagi, Jpn J. Appl. Phys.

6 J. Kirchgessner, H. Padamsee, H.L. Philips, D. Rice, R. Sundelin, M. Tigner, E. von Borstel, IEEE Trans. Nucl. Sci. NS-22 (1975), 1141

7 J. Kirchgessner, P. Kneisel, H. Padamsee, J. Peters, D. Proch, R. Sundelin, M. Tigner in ref. 4 p 892

8 Sh. Noguchi, Y. Kojima, J. Halbritter, Nucl. Instr. Meth. 197 (1981) 205

9 M. Grundner, H. Lengeler, E. Rathgeber, Nucl. Instr. Meth. 141 (1977) 57