BEAM TEST OF A THREE-CELL STRUCTURE IN THE TRISTAN ACCUMULATION RING

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1. Introduction

As previously reported [1], the three-cell 508 MHz niobium sturcture has been tested in the TRISTAN accumulation ring. Some of the ring parameters are listed in Table I.

Table I. Parameters of the TRISTAN accumulation ring.

Circumference	C = 377 m
Bending radius	ρ = 23.173 m
Length of rf cavities	L_{rf} = 29.6 m (designed) at present, 9.7 m normal rf cavities.
Revolution frequency	f_{rev} = 0.795 MHz
rf frequency	f_{rf} = 508.58 MHz
Injection energy	E_{inj} = 2.5 ∿ 3 GeV
Extraction energy	E_{ext} = 6 ∿ 8 GeV

At present the ring is running mostly at 5 GeV mainly for the calibration of the detectors for the TRISTAN experiments. Maximum electron beam intensity ever examined is 66 mA in single bunch.

2. Beam test with the superconducting structure

It was planned to start the beam test of the three-cell superconducting structure in March 1984. However when the structure was cooled down to helium temperature, the vacuum leak occured on one of the ceramic coaxial connector of the HOM coupler. It has happened twice, so the beam test was postponed until May 1984.

At the end of May 1984, the first beam test was done, the beam was stored at 2.5 GeV and accelerated to 5 GeV with the field gradient of 3.5 MV/m. Shortly after the first beam test, a vacuum leak developed at the input coupler. The cooling helium gas flow through the inner conductor was insufficient and the loop was heated up and got a crack.

After the input coupler was repaired, the second beam test was done at the beginning of July 1984. Temperature of the input coupler loop and helium gas flow for cooling were carefully monitored.

The structure was kept at 4.2 K for total of about three weeks during the first and second beam test. Before the first beam test, the structure was exposed to one atmospheric air for about twenty days during assembling or repairing the leaked connector.

Between the first and the second beam tests, the structure was rinsed by HF, pure water and methanol.

The results obtained during the beam test are listed as follows.

a) Q_0 at several field gradient were measured, Q_0 of 8×10^8 at E_{acc} = 3.7 MV/m was observed.

b) The accelerating field gradient was confirmed by synchrotron frequency, maximum field was E_{acc} = 4.3 MV/m and was limited by helium boil-up perhaps due to the heating of the input coupler. Also the maximum power given to the beam was limited to 4 KW due to the same reason.

c) Up to the beam intensity of 10 mA in single bunch was stored at 2.5 GeV, the current was limited by the heating of the gate valves at both ends of the cryostat. These valves will be replaced with the new valves before the next beam test.

d) Acceleration of the beam was tested, from 2.5 GeV to 5 GeV at 1 mA by the SC structure alone, from 2.5 GeV to 6.0 GeV at 1 mA and up to 6.5 GeV at 0.4 mA by the normal structure (33 cells) and the SC structure were achieved.

e) Frequency and field regulation worked well.

f) No additional helium loss of the cryostat by the beam was observed at 2.5 GeV and 5 mA, also at 4 GeV, 5 mA and 10 mA.

Fig. 1 shows the cryostat installed in the beam line of the TRISTAN accumulation ring.

3. Higher order modes

Higher order modes were studied at 2.5 GeV beam stored by normal rf system, many modes were scanned by changing the tuner postion.

3-1. Longitudinal HOM

In Table I the measured and calculated longitudinal HOM loss are listed. Frequency, loaded Q value and power loss (normalized to 10 mA) were measured, R/Q was calculated by SUPERFISH. Fig. 2 shows the observed longitudinal HOM by changing the tuner position. Six HOM were brought into the resonance, the beam instability due to the longitudinal HOM modes was not observed.

3-2. Transverse HOM

In Fig. 3, transverse higher order modes measured with changing the tuner position were shown. Many lines are crossing the resonance, but the beam instability was only observed with vertical oscillation by TE_{111} - π mode at 721.40 MHz without beam loss. Spectrum of a HOM coupler output when the vertical oscillation was observed is shown in

Fig. 4.

Table II summarizes the transverse HOM. Frequency, polarization and loaded Q were measured and R /Q was calculated by URMEL. The threshold current in the table are calculated for the transverse coherent dipole mode using the formula given by Suzuki and Yokoya[2], where the measured damping time of 15 msec for betatron oscillation was used in the calculation.

Acknowledgements

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References

1) Y. Kojima, this workshop.
2) T. Suzuki and K. Yokoya, Nucl. Instr. Meth., 203, (1982), 45.

Table I. Logitudinal higher order modes.

Mode		Freq. (MHz)	R/Q* (Ω)	Q_L meas.	Ploss** meas.(w)	Pcalc.*** (w)
TM_{010}	- 0	504.82	< 1.3	5.6×10^6		
	- π/2	507.34	$< 6 \times 10^{-3}$	$\sim 1 \times 10^8$		
	- π	508.58	395	1.3×10^6		
TM_{011}	- 0	953.06	109	3.3×10^4	0.68	off resonance
	- π/2	946.99	13.4	3.2×10^4	0.17	off resonance
	- π	941.60	2.6	7.0×10^4	31.7	18.3
TM_{020}	- 0	1079.90	0.13	1.8×10^6	45.8	24.4
	- π/2	1088.57	0.13	1.4×10^6	17.5	17.9
	- π	1096.24	0.05	7.4×10^5	$\lesssim 1 \times 10^{-3}$	off resonance
TM_{021}	- 0	1412.83	0.03	1.3×10^5	1.0	4.3
	- π/2	1384.65	9.67	4.2×10^4	4.3	40.6
	- π	1369.84	2.73	9.9×10^4	17.9	27.1

* Calculated by SUPERFISH
** Normalized to 10 mA
*** Assuming 10 mA and 1.2 cm of bunch length

Table II Transverse higher order modes

Mode	Polarization	Freq. (MHz)	$R_\perp/Q$* (Ω/m)	Q_L	Threshold current(mA)	Brought to resonance
TE_{111} - 0	+ 45°	689.74	40	6.6×10^5	4.1	yes
	- 45°	689.78		6.8×10^5	4.0	yes
- $\pi/2$	- 45°	702.09	290	2.1×10^5	1.8	yes
	+ 45°	702.43		2.4×10^5	1.6	yes
- π	- 45°	721.40	212	2.8×10^5	1.8	yes**
	+ 45°	721.68		8.2×10^4	6.2	yes
TM_{110} - 0	Ver.	749.67	99	4.3×10^5	2.5	
	Hor.	750.66		3.2×10^5	3.3	
- $\pi/2$	Ver.	746.01	274	9.3×10^4	3.0	yes
	Hor.	746.25		2.3×10^5	1.2	
- π	Ver.	733.70	73	1.8×10^5	4.3	
	Hor.	734.43		1.1×10^5	7.2	
TM_{111} - 0	+ 45°	1034.26	511	4.4×10^5	0.5	
	- 45°	1034.56		2.1×10^5	1.1	yes
- $\pi/2$	Ver.	1039.94	8.7	6.8×10^4	136	yes
	Hor.	1040.48		7.3×10^4	125	
- π	- 45°	1057.36	39	1.1×10^5	26.6	
	+ 45°	1058.05		1.2×10^5	23.8	
TE_{112} - 0	Hor.	1140.10	1.2	8.2×10^3		
	Ver.	1141.10		8.1×10^3		
- $\pi/2$	Ver.	1122.90	7.3	2.8×10^4		
	Hor.	1123.39		2.8×10^4		yes
- π	Ver.	1061.90	58	1.1×10^5	13.3	yes
	Hor.	1063.44		8.4×10^4	16.8	yes

* Calculated by URMEL
** Vertical oscilation without beam loss

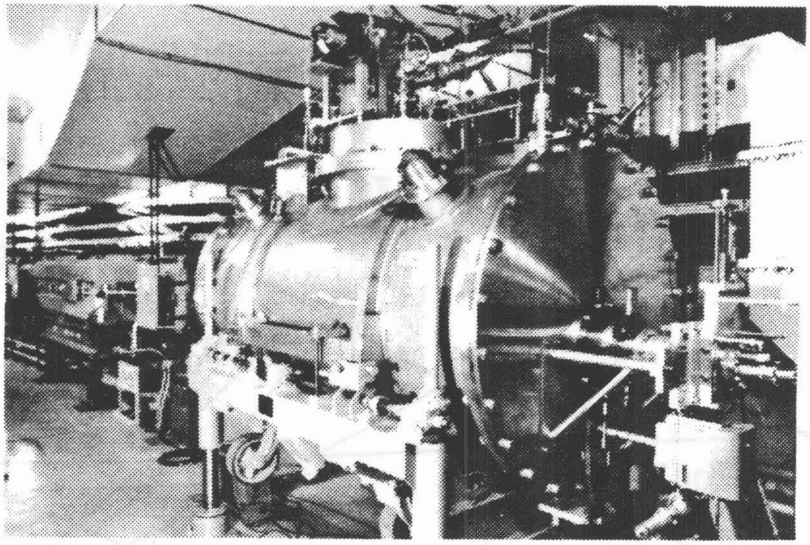


Fig. 1 A cryostat of the three-cell structure installed in the TRISTAN accumulation ring.

FIG. 2

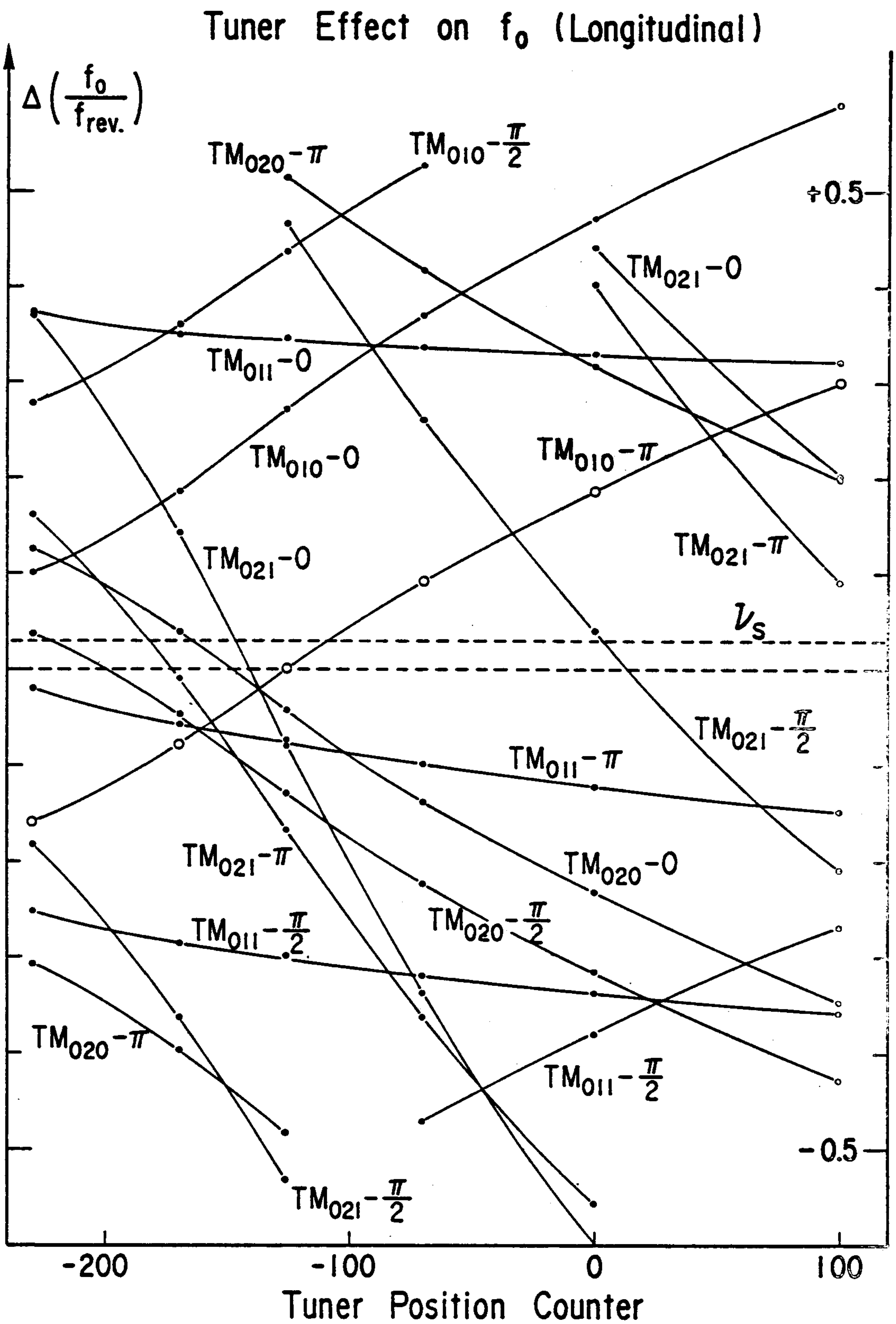
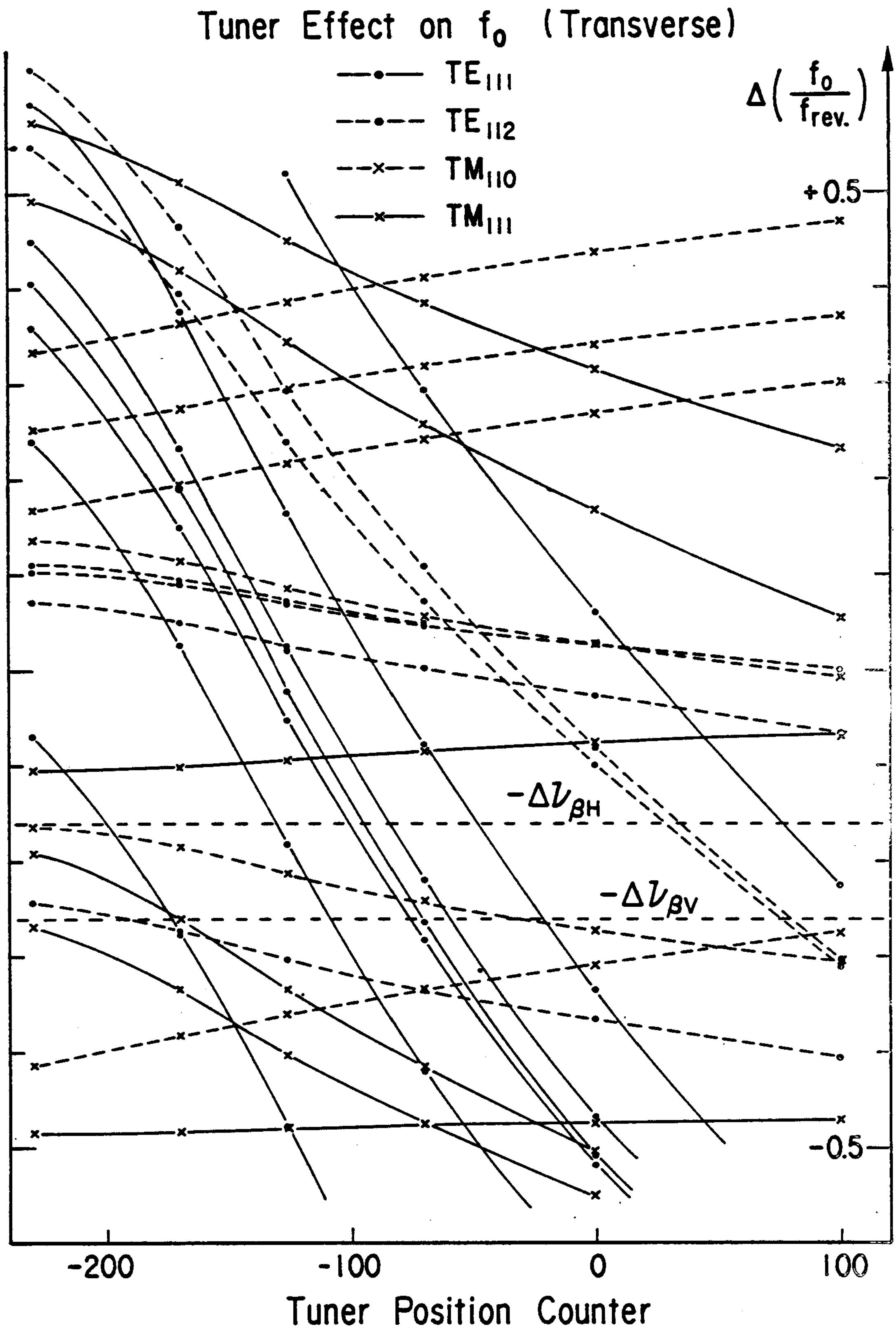

Tuner Effect on f_0 (Longitudinal)
$\Delta\left(\frac{f_0}{f_{rev.}}\right)$
$TM_{020}-\pi$
$TM_{010}-\frac{\pi}{2}$
+0.5
$TM_{021}-0$
$TM_{011}-0$
$TM_{010}-0$
$TM_{010}-\pi$
$TM_{021}-0$
$TM_{021}-\pi$
ν_s
$TM_{021}-\frac{\pi}{2}$
$TM_{011}-\pi$
$TM_{021}-\pi$
$TM_{020}-0$
$TM_{011}-\frac{\pi}{2}$
$TM_{020}-\frac{\pi}{2}$
$TM_{020}-\pi$
$TM_{011}-\frac{\pi}{2}$
-0.5
$TM_{021}-\frac{\pi}{2}$
-200
-100
0
100
Tuner Position Counter

FIG. 3


Tuner Effect on f_0 (Transverse)
TE111
TE112
TM110
TM111
$\Delta\left(\frac{f_0}{f_{rev.}}\right)$
+0.5
-0.5
$-\Delta\nu_{\beta H}$
$-\Delta\nu_{\beta V}$
-200
-100
0
100
Tuner Position Counter

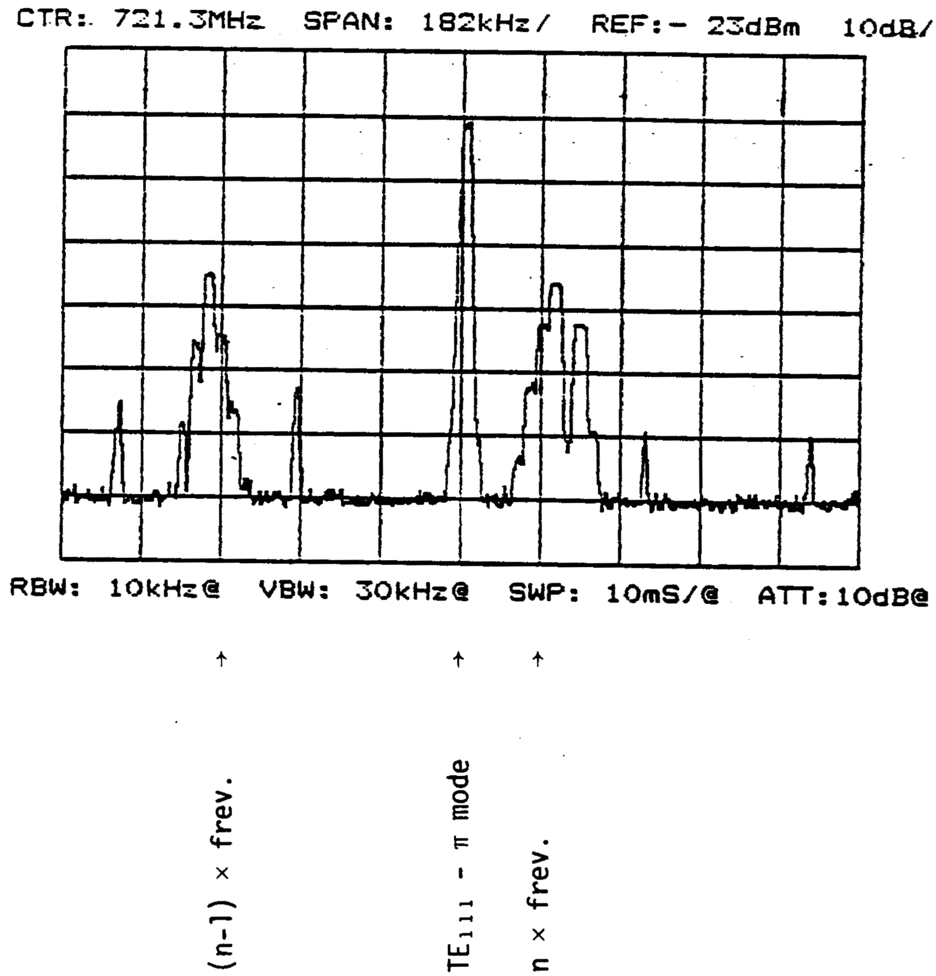


Fig. 4 Spectrum of a HOM coupler output when the vertical oscillation was observed by TE_{111} - π mode.