SELF-COOLED HIGHER ORDER MODE DAMPER

Yuichi MOROZUMI, Toshiyasu HIGO and Yoshishige YAMAZAKI

National Laboratory for High Energy Physics
Oho, Tsukuba, Ibaraki 305, Japan

Abstract

A self-cooled higher order mode damper was developed and employed for the suppression of beam instability in the TRISTAN accelerator.

Installed in a 9-cell structure cavity of the main ring, the damper, as designed, lowered the Q factor for the TM111 mode to less than a third of the intrinsic value and those for the other modes were observed to drop roughly to half. In the case of an 11-cell structure cavity of the accumulation ring equipped with one damper in each cell, the modes of TM011 and TM021 were so drastically damped that they could hardly be measured and the Q factor of the TM111 mode was reduced by more than an order of magnitude.

Experiments in beam showed that the damper appreciably suppressed beam instabilities caused by these modes and improved beam performance.

The coupling antenna is itself a single heat pipe leading to the external cooling fins, which works as an effective and maintenance-free auto-cooler against the induction heating of the antenna head due to RF fields in the cavity.

1 INTRODUCTION

The 508 MHz accelerating cavity tanks of an alternating periodic structure (APS), both in the accumulation ring (AR) and in the main ring (MR) of the TRISTAN accelerator at KEK, National Laboratory for High Energy Physics, were furnished with higher order mode dampers in order to reduce the coupling impedances of higher order modes responsible for beam instabilities (Photo). It was known that the higher order modes such as TM_{011} (866 MHz), TM_{110} (794 MHz), TM_{021} (1387 MHz) and TM_{111} (1045 MHz) have significant coupling impedances and therefore have undesirable large interactions with beam. There are 12 dampers installed in every 11-cell structure tank of the AR, 2 for the center cell and 1 for each of the other 10 cells. Each 9-cell structure tank of the MR has 2 dampers in its center cell.

2 STRUCTURE

The damper is made up of a coupler with an internal antenna, an external load resistor and a transmission line between them. The detail of the structure is described elsewhere (Ref. 1). It features the present damper that the whole system is designed to work maintenance-free.

<u>Coupler</u>

It consists of a rod-shaped coupling antenna, a coaxial-structured transmission system with a kind of accelerating mode rejector, a power extraction terminal and a cooling device for the RF-heated antenna head. It mounts in a cavity with its antenna pointing at the beam axis.

The early study on instabilities concluded that the transverse impedance for TM_{111} mode must be reduced to less than half so as to storage at least 20 mA beam current in the MR (Ref. 2). The length of the antenna was therefore chosen to get a loaded Q factor below a third of the intrinsic value with little influence on the accelerating mode. A certain damping of TM_{011} and TM_{021} modes was also aimed at.

The antenna and the inner conductor were composed of a single heat pipe leading to the external cooling fins. The heat pipe efficiently and automatically transfers heat from the antenna head to the fins with an effective thermal conductivity hundreds times higher than that of metal.

The extraction terminal was provided with a specially developed vacuum-tight feedthrough. The matching at the feedthrough was better than a VSWR of 1.05 over a wide frequency range from 0 to 2.3 GHz.

Parts of the coupler were in principle made of oxygen-free pure copper because of its high electric conductivity and low outgas in vacuum. The parts were brazed in a vacuum furnace.

<u>Load Resistor</u>

The load resistor requires broad-band impedance matching for a variety of higher order modes and high heat discharging performance.

The resistor was a resistive metal film evaporated on a backing plate of beryllia, a highly thermo-conductive ceramic comparable to metal. It was mounted in a thick copper (aluminium in the MR model) casing working as a matched terminator and also as a heat sink, where finned copper heat pipes were planted to remove heat to the atmosphere. The use of heat pipes enables an efficient natural cooling and a light weight.

<u>Transmission Cable</u>

A usual bendable coaxial cable equivalent to the standard WX-20D was used with rotatable BFX-20D connectors. From the viewpoint of radiation damage normal insulators were replaced by radiation-resistant materials. Coaxial conductors are made of oxygen-free copper.

3 CHARACTERISTIC AND PERFORMANCE

<u>Transmission Characteristic</u>

As designed the pass band of the coupler was centered at 1 GHz, around which the higher order modes concerned are situated. The coupler, installed in a cavity tank, drew out a minute leakage of -55 dB of the input driving power. The insertion of the coupler raised the resonance frequency of the cavity in the accelerating mode only by 2 kHz, which is unquestionably covered by the tunable range.

The impedance of the whole load resistor was matched with a VSWR better than 1.1 over a wide frequency range up to 2 GHz.

<u>Damping of Higher Order Modes</u>

In the case of an MR cavity tank the Q factor for TM_{111} mode dropped successfully below a third of the intrinsic value and those for TM_{011} and TM_{021} modes were also reduced to half.

In the early stage only 2 dampers were mounted on each accelerating tank in the AR as well as in the MR. Dampers were reinforced both in capacity and in quantity at the request of a high current operation. The comparison of the damping effect is presented in Figure 1 between 2 dampers on the center cell (upside) and 12 dampers distributed among all the cells (downside) in an AR 11-cell structure cavity tank. The former corresponds nearly to the case of the MR. The TM_{011} and TM_{021} modes were completely damped in an AR cavity tank equipped with additional 10 dampers. The Q factor of the cavity tank in TM_{111} mode was also degraded by more than an order of magnitude.

Cooling Performance

A normal RF input of 150 kW to an 11-cell structure cavity tank brought about a temperature rise of 13 K at the fin base of the coupler and the heat generation at the antenna head was estimated to be 30 W on the basis of a thermal calibration by simulation heating.

An average heat generated in the load resistor is supposed to increase in proportion to a square of beam current. The resistor casing was observed to be warmed by 10 K at a current of 45 mA and by 20 K at 60 mA in the AR. According to the calibration data of temperature rise versus input power a beam current of 45 mA gives the resistor 100 W and that of 60 mA 200 W. A temperature rise of 5 K was observed in the usual MR operation of 8 mA.

The temperature rise proved to be remarkably depressed.

Suppression of Instabilities

The effect of the damper is now under study in the AR. Until now it was investigated how the instabilities by TM_{111} mode is relaxed in comparison with those by the TM_{110} mode which is not damped by the damper. The former mode had initially twice the impedance of the latter. The threshold current of the instabilities was measured varying the cavity resonance frequencies in these modes (Figure 2). The current was over 20 mA at resonance points of TM_{111} mode whereas a few mA at those of TM_{110} mode. Its impedance is roughly calculated to be less than a tenth of that of TM_{110} mode, and therefore, less than a twentieth of the intrinsic value of TM_{111} mode. This is in agreement with the result of Q factor measurement. It was confirmed that the instability due to TM_{111} mode was considerably suppressed. Spectrum analysis of beam-induced resonant modes in cavity tanks also showed that instabilities caused by TM_{011} and TM_{021} modes were no longer present.

ACKNOWLEDGEMENT

The authors acknowledge the collaboration with Messrs. Y. Funakoshi, M. Suetake, T. Kageyama and Dr. H. Hayano in experiments.

REFERENCES

1 Y. Morozumi, T. Higo and Y. Yamazaki, in Proc. of the 14th Int. Conf. on High Energy Accelerator (Tsukuba, 1989), to be published

2 T. Higo et al., internal report (1985)

Photo Higher Order Mode Dampers on Accelerating Cavity Tank

Round-finned couplers are mounted aslant on a accelerating cavity tank and are connected to square-finned load resistors arranged above.

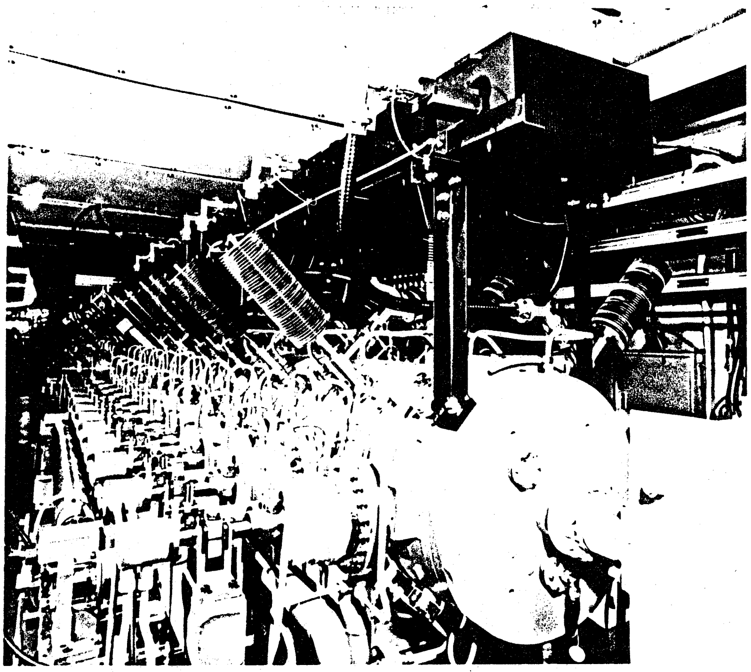


Figure 2 Threshold Current of Instability

Instabilities by TM_{110} are still present, but not those by TM_{111}.

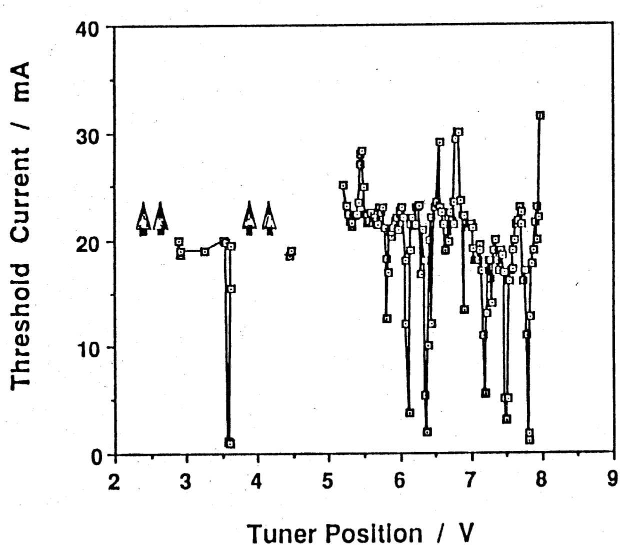
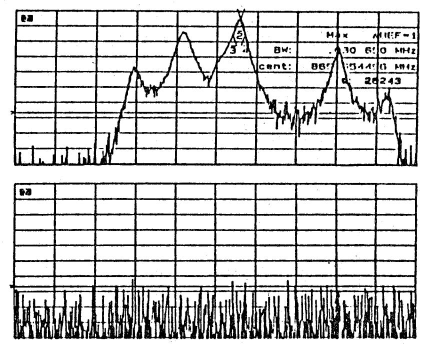


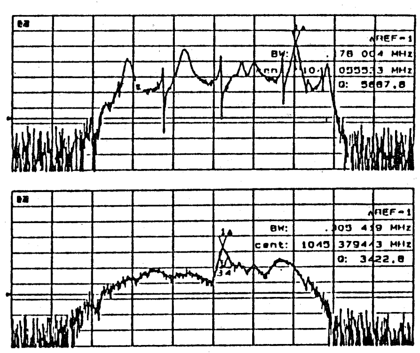
Figure 1 Reduction in Q Factor

horizontal axes : frequency
vertical axes : relative amplitude
upside : dampers off but 2
downside : dampers fully on

TM_{011}
center : 865.5 MHz
span : 1 MHz



TM_{111}
center : 1045 MHz
span : 15 MHz



TM_{021}
center : 1386.5 MHz
span : 4 MHz