

DEVELOPMENT OF THE APS CAVITY FOR TRISTAN e+e- STORAGE RING

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ABSTRACT

The alternating periodic structure with nine electrically coupled accelerating cells is developed for TRISTAN Main Ring. The determination of the structure, the construction method and the results of the low power test are described. It was found that every accelerating cell should be tuned accurately to avoid the Q value degradation.

INTRODUCTION

For a high energy e+e- storage ring, the RF accelerating cavity should have a high shunt impedance to achieve necessary energy gain for limited space and available RF source power. In order to save the cavity space for a given structure, the number of the accelerating cells in a cavity should be as large as possible. However, a finite coupling coefficient limits the cell number in a cavity to obtain a desired field stability. The amount of the power flow possible for an RF input coupler also limits the cell number in a cavity. Considering these factors, we adopt a 508MHz cavity with nine cells for TRISTAN. The nine cell cavity in the π mode should be operated with confluent condition in order to obtain field stability. The structure which can be operated in such a mode is the side-coupled-structure(SCS)¹, disk-and-washer-structure(DAW)² or alternating-periodic-structure(APS)^{3,4}. The DAW has the highest shunt impedance. However, many parasitic modes exist which may deflect the beam and cause instabilities.⁵ The SCS and APS are operated at fundamental mode, and they have not so many parasitic modes as the DAW. The SCS with many cells is widely used for linacs in L and S bands. However, it is not axially symmetric and therefore the fabrication of a large cavity of 508MHz region is rather difficult. The APS is axially symmetric, and thus even a 508MHz cavity can be fabricated easily. Therefore, we adopt the APS.

APS CAVITY DESIGN

The APS is a biperiodically loaded structure. This structure is operated at the π mode corresponding to the $\pi/2$ mode of the uniformly loaded cavity. Therefore, the large group velocity of the $\pi/2$ mode is retained, if the frequency F_c of the unexcited (coupling) cell coincides with the frequency F_a of the excited (accelerating) cell (confluent π mode). Furthermore, the shortening of the coupling cell raises the shunt impedance compared to that of the uniformly loaded cavity.

Three possible shapes of the APS with electrical coupling through beam aperture

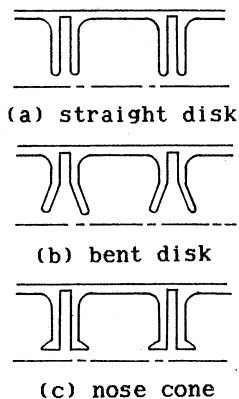


Fig. 1

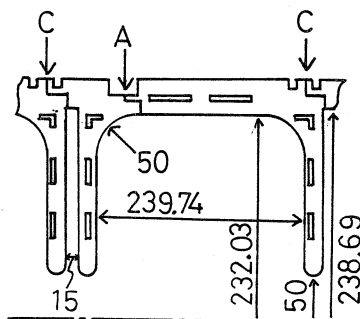
are shown in Fig. 1. The straight disk type (a) has a shape very simple to construct. Typically, the calculated shunt impedance is 27.6 Mohm/m and the relative band width $k=(f(2\pi)-f(0))/f(\pi)$ is about 1%. The bent disk type (b) has a shunt impedance higher by about 10%, but the relative band width becomes half of that of the type (a) for a disk bend angle from 20 to 60 degrees. The nose cone type (c) has the highest shunt impedance but the band width becomes extremely small. In order to obtain 1% relative band width it is necessary to make openings on the disk for magnetic coupling, but such openings degrade the Q value by 15%. We adopt the straight disk type that is most easily machined and has relatively large band width.

The disk thickness should be small to obtain high shunt impedance. A thickness of 20mm is chosen by considering the necessity of the cooling water channel and the mechanical strength of the disk.

The coupling cell gap g_c should also be small to obtain a high shunt impedance as seen in Table 1. Also the transverse broad band impedance⁶ R_t becomes lower, as the g_c decreases, resulting in higher threshold current I_{th} for the instabilities.⁷ However, the value of g_c is chosen to be 15mm, which is considered to be practically the smallest value for the following reasons. First, the F_c becomes very sensitive to the disk bending, since the change of F_c versus disk bending angle is inversely proportional to g_c . For instance, the disks bend thermally by 0.03 degree at the maximum power operation (17kw/cell). This bending will lower F_c by 1MHz. Second, the ratio Q_c/Q_a is nearly equal to the ratio g_c/g_a , where the Q_c and Q_a (and g_c and g_a) are the Q values (and gap length) for the coupling cell and the accelerating cell, respectively. Then, the Q value of the actual cavity will be easily degraded if the coupling cells are excited by some causes.

g_c (mm)	15.0	30.0
R (Mohm/m)	27.6	27.0
R_t (kohm/m/cell)	2.0	2.3
I_{th} (mA)	5.7	5.0
$dF_c/d\theta$ (MHz/deg)	36.	17.
Q_c	4830.	9030.

Table 1



Dimensions of the adopted structure

Fig. 2

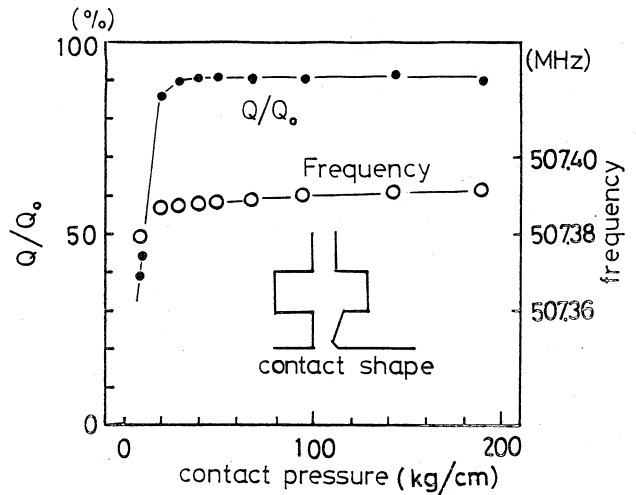
The dimensions of the adopted structure are shown in Fig. 2. The cavity consists of nine accelerating cells and eight coupling cells. Every second accelerating cell has a tuner with a diameter of 105mm. A plunger of a 9mm diameter is equipped in every coupling cell to tune Fc. A loop coupler for the RF input is located at the center cell.

CONSTRUCTION METHOD

One period unit of the cavity is divided into two parts as shown with the arrows A and C in Fig. 2. Each part is made of low carbon steel and the inner surface is electroplated with Cu in pyrophosphorous acid bath. After plating, each joint is machined to the shape shown in Fig. 3 to get an edge contact for RF surface current, and then welded with a TIG method. By the welding we obtain not only a vacuum seal and a mechanical rigidity but an enough contact pressure which is generated by local shrinks of the welding region.

First, the welding of the joint at A is performed to obtain a contact pressure of 200kg/cm. This contact pressure is sufficiently large for the good RF contact, since the contact pressure for saturation of the Q value is 30kg/cm as shown in Fig. 3. As the pressure at this contact is rather high, it bends the disks about 0.1 degree. Thus, before welding Fa's and Fc's should be tuned 200kHz lower and 2MHz higher than the designed value, respectively.

Then, each joint at C is welded. Since the surface current near the joint at C for the accelerating mode is very much small compared to that of the joint at A, the contact pressure is lowered by an order of magnitude from that of the joint at A in order to suppress the disk bending. In fact, the disk bending due to the welding results in a frequency change of only about 200kHz for Fc and negligibly small change for Fa.



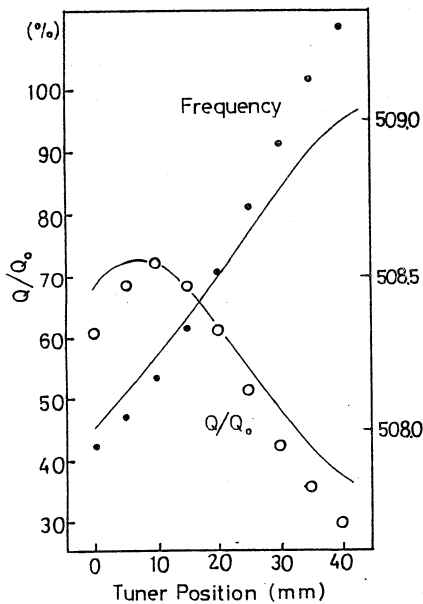
Measured Q values vs. contact pressure. The Q_0 is the Q value calculated with SUPERFISH.

Fig. 3

RESULTS OF THE LOW POWER TEST AND DISCUSSION

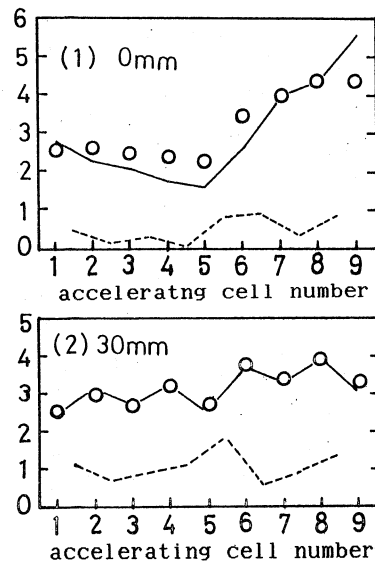
Variations of the frequency, Q value and field distribution for the nine cell cavity were measured versus tuner position as shown in Fig. 4. Here, all tuners were moved in phase. The Fc's were fixed to 509.6+0.02MHz, since the Fc's should be slightly higher than the Fa's.⁸

As seen from Fig. 4, the Q value and the field uniformity were found very sensitive to the tuner position. The Q value was at best 73% of that calculated with SUPERFISH at the



Measured frequency and Q value vs. tuner position. Solid lines are the calculated values. The Q_0 is the Q value calculated with SUPERFISH.

Fig. 4. (a)



Measured field strength of the accelerating cells at the tuner position of (1) 0mm and (2) 30mm. Solid lines and dotted lines are square roots of the calculated stored energy for the accelerating cells and the coupling cells, respectively.

Fig. 4. (b)

optimum tuner position and decreased rapidly as the tuners were moved away from the position. On the other hand, the field flatness became better as the tuners were inserted.

In order to study the tuner dependence, the coupled resonator model calculation⁹ was performed. The result of the calculation is in reasonable agreement with the experimental result as seen in Fig. 4.

It is found from the calculation that the excitation of the coupling cells decreases the total Q value, since the Q value of the coupling cell is by an order of magnitude smaller than that of the accelerating cell. In order to elucidate how the coupling cells are excited, the model calculation was also performed for the cavity shown in Fig. 5. It is seen that the excitation of the coupling cell is arising from the difference of the Fa's, resulting in the Q value degradation. Therefore, all the Fa's should be tuned as accurately as possible to avoid the Q value degradation.

The field difference between the accelerating cells was also studied in Fig. 5. It is seen that the uniformity of the fields becomes poorer as the frequency difference $F_3 - F_1$ increases, unless the confluent condition ($F_c = F_a$) is satisfied exactly. On the other hand, if the confluent condition is satisfied, the field is always uniform independent of the Fa difference. This behavior is seen in the tuner dependence of the field uniformity for the measured nine cell cavity. The stop band width becomes smaller as the tuners are inserted. Then, it is reasonable that the overall uniformity of the accelerating fields is improved by inserting the tuners as shown in Fig. 4. Since the stop band width of 0.6MHz remains even at the tuner position of 30mm, the field difference between the neighboring accelerating cells is still induced by the difference of the Fa's between the cells. The stop band width is not always small, since the thermal detuning of the Fc amounts to about 1MHz. Therefore, it is again necessary to tune all of the Fa's accurately to obtain the overall field uniformity.

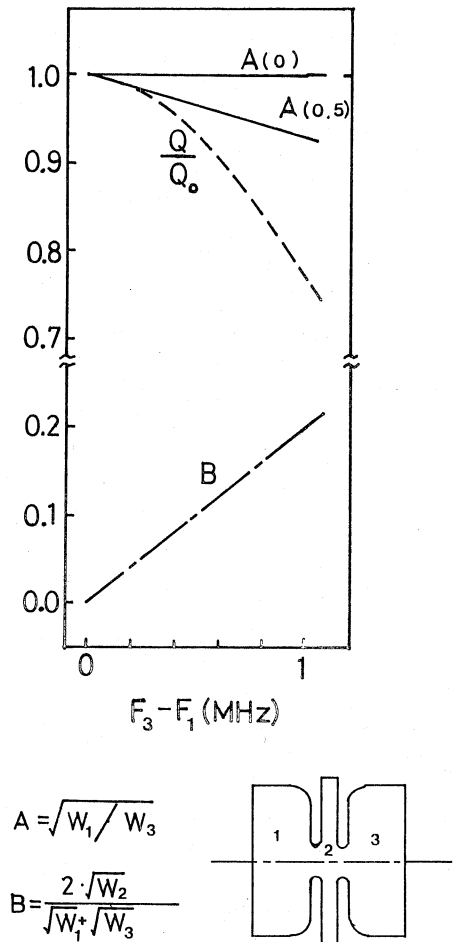
In conclusion, it is necessary to adjust all of the Fa's accurately to keep the high Q value. This condition will also ensure the good field uniformity among the accelerating cells, even if the confluent condition is not satisfied exactly.

ACKNOWLEDGEMENT

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Results of the calculation for the cavity with two half end cells indicated by 1 and 3 and one coupling cell indicated by 2. The F_i and W_i are the frequency and the stored energy of the cell indicated by i . The number in the parentheses are the stop band width $F_c - F_a$ in the units of MHz. The Q/Q_0 and B are independent of the $F_c - F_a$. The Q_0 is the Q value calculated with SUPERFISH.

Fig. 5.