A NOVEL TRAVELING WAVE DAW ACCELERATING STRUCTURE*

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Abstract

A novel idea for using DAW as traveling wave structure is proposed. Experiments have been performed to prove the feasibility of TW DAW structure as well as some initial experiment results are given out.

Introduction

Since the Disk-And-Washer (DAW) accelerating structure was proposed by V.G. Andreev in 1972,[1] a lot of work has been done on it.[2-6] All of the previous theoretical and experimental researches have shown that DAW is one of the promising high-beta SW accelerating structures even though some problems still exist to be solved, its advantages are attractive; such as high group velocity, high Q value and shunt impedance. Having studied the DAW for several years, we propose a novel idea: use DAW as TW accelerating structure. Now that the DAW has so many advantages which are very important to TW accelerating structure, why don't apply it to TW accelerating structure? As we known, disk-loaded waveguide has been successfully used in many TW linacs since 1940s, and its position has been found in the history of accelerators. Despite all this, problems still exist in it: to increase the shunt impedance, iris aperture must be decreased, which will lead to sharp increment of dispersion, harmfully to stably work. In contrast, for DAW, the microwave power is transmitted and coupled through the space between the disk and washer, decrement of beam hole will make the increment of the shunt impedance without causing the harmful effect on the dispersion. It is this advantage that make us render the new idea.

We have established a set of TW DAW accelerating tube (aluminium model). The problems concerning the design of coupler, fabrication and tuning of the DAW tank are solved. Initial experiment has demonstrated that the TW DAW accelerating structure really has many prominet properties to be a promising TW accelerating structure.

Proposal Of TW DAW

For disk-loaded waveguide, the contradiction between the shunt impedance and dispersion limits the further increment of shunt impedance.

Now DAW is a biperiodic accelerating structure (accelerating mode:. TM_{02}). The Microwave power is transmitted through the space between the disk and washer. Increment of coupling in DAW almost does not affect its shout impedance. Hence, the optimization of cavity to get the highest shunt impedance and the increment of the coupling can be considered and performed separately. In our opinion, the DAW used as TW structure at least has the following advantages:

(1) High shunt impedance.
(2) High Group Velocity.

The group velocity in DAW is as high as 0.5c. It means that DAW will have much shorter filling time than that of other structures.

(3) Small attenuation coefficient.

It will be proved in section 4 that the attenuation in DAW is very small, which make DAW possible to use in a long accelerating section.

(4) High Q Value.

The large stored energy in DAW will be beneficial to heavy beam loading.

It should also be point out that the TW DAW is a backward wave accelerating structure.

Establishment of TW DAW Tank

Basic Consideration

How to establish the traveling state in DAW tank? The following problems should well be considered:

(1) The conflunce of accelerating and coupling passband.
(2) Input and Output Coupler.

All previous work on DAW considered it as a SW structure and therefore only one feed-coupler for power input is needed. A co-axis bridge coupler is mostly adopted. While DAW working at the TW state, two couplers must be used respectively at the two ends of the tank. And the accelerating mode TM_{02} should be excited through couplers.

(3) Working Mode.

For SW structure, PAI-mode usually be chosen because it has the highest accelerating efficiency, so does the SW DAW structure. The problem of mode selection is encounted while the DAW working at TW state. For convenience, we temporally chose the PAI-mode as working mode, which is located at the middle of dispersion curve.

(4) Function of Coupling passband in the TW DAW.

It is the coupling cavity that takes part in coupling the power and forms the power-flow of backward wave in TW DAW. The existence of coupling passband also improve the form of the dispersion curve and make the TW DAW have the highest group velocity at the working frequency.

Design of the coupler

Full-cavity structure has been chosen as coupler. One half of it is DAW-like half cavity, another half is LANL-like half cavity. The field distribution of the coupler is shown in Fig.1. The coupling hole is located at the top of the LANL-like half cavity. For the convenience of fabrication, we actually make the coupler structure as shown in Fig.2.

Establishment Of TW DAW Tank

Having adopted the couplers designed above, we build a 20 cm long TW DAW tank (aluminium model) as shown in Fig.3. It has been extended to 0.5 cm long recently.

The tuning of input and output coupler

The tuning is performed by gradually filing the coupling hole to change the coupling coefficient and the frequency of terminal cavity. The experiment results of

* The project Supported by National Natural Science Foundation of China

initial tuning shows that the frequency range that VSWR below 1.2 is about 1.0 Mhz, VSWR below 1.5 is about 2 Mhz. The minimum VSWR is 1.04 (See Fig.4)

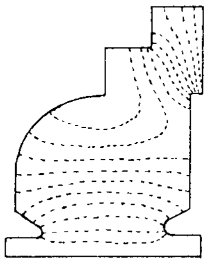

Fig.1 field distribution of the coupler for TW DAW

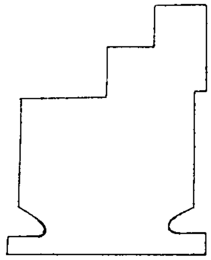

Fig.2 coupler structure made actually.

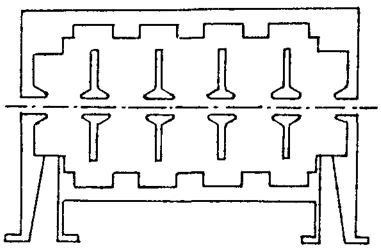

Fig.3 The established TW DAW Tank

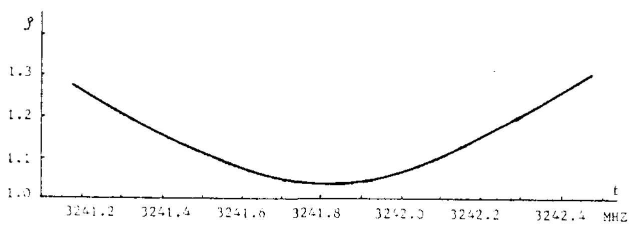

Fig.4 ρ~f curve of TW DAW Tank

Initial Experiment ON TW DAW Tank

Demonstration of traveling state in DAW tank

Measurement of ρ---f curve

It is well known that the TW accelerating tube's ρ---f curve is much flatter than that of SW accelerating tube, especially in the near region of f_0, the ρ almost keep constant. The frequency range that VSWR below 1.2 should have 1---4 Mhz, the minimum VSWR is approximately equal to 1.0. For our DAW tank, the measured minimum VSWR is 1.04, the frequency range that VSWR below 1.2 is 1 Mhz.

Property Of Power Transmission

The wave detector set is put to the output and input coupler to measure the power level separately.The input power P_{in} and output power P_{out} should satisfy the following equation

$$P_{out} = P_{in}\,(1-|\Gamma_1|)e^{-2\alpha L}\,(1-|\Gamma_2|) \qquad (1)$$

where Γ_1: reflection coefficient of input coupler
Γ_2: reflection coefficient of output coupler
α : voltage attenuation coefficient of tank
L: length of tank.

Our measured results are: ρ_1=1.04; ρ_2= 1.03; Pin=5.96; Pout=5.6; L=0.2 m, substituting above results into equation (1), we get

$$\alpha_{al} = 0.15 \ 1/m$$

In order to get the attenuation coefficient of OFHC copper tank for comparision, special experiment has been done to convert the aluminimum attenuation coefficient into OFHC's. The measured sesult is

$$\alpha_{cu} = 0.061 \ 1/m$$

then P_{out}/P_{in} = 94%, that means 94% input power is transmitted from output coupler.

From mentioned two experiments, it is demonstrated that the feasibility of TW DAW, and its attenuation coefficient is very small, which is 3---5 times smaller than disk loaded waveguide's.

Other experiments on proving the exsitence of traveling state, phase and field distribution in TW DAW tank are in progress.

Measurements on other Microwave Parameters

Shunt impedance, group velocity, Q value and dispersion curve have been measured:
Shunt impedance is 74.5 Mohm/m ,
Group velocity is 0.51 C ,
Q value is 24700,
Dispersion curve is shown in Fig.5.
Fig.5 shows that the dispersion in TW DAW tank is very weak and the full-passband is about 2000 Mhz.

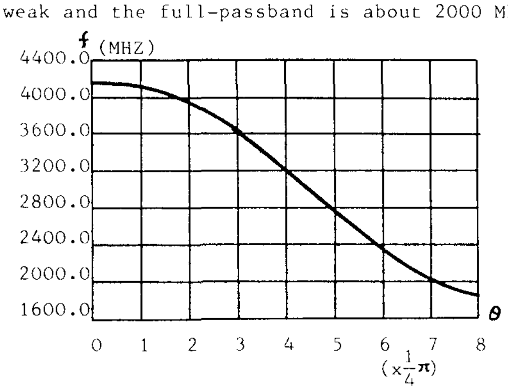

Fig.5 Dispersion curve of the DAW structure

Discussion

The novel idea to use the DAW as TW structure has been presented. The TW DAW tank has been successfully built. The feasilility of TW DAW have been proved. The advantages of TW DAW structure are obvious.

Comparing with the disk loaded waveguide, the TW DAW structure's shunt impedance, Q value and group velocity are separately 50%, 20---30 and 20---30 higher than that of disk loaded waveguide. The only shortcoming of TW DAW is that its diameter is slightly larger than that of other structures.

Between SW and TW accelerating, which is better? R.H. Miller recently has made a detailed discussion.[7] We believe that the DAW working at traveling state at least has the following five advantages:
TW structure is suitable for operation of differ-

ent beam currents

The field in TW structure reaches its stable state much quicker than that of SW structure.

For SW structure working at pulse state, full microwave power reflection occurs at the begining and the end of coming pulse, but the TW structure does not have this problem;

The TW DAW is a backward wave structure, which will be beneficial to the efficient usage of microwave power, especially for the bunching section of varying phase velocity;

The TW DAW is extremely suitable for short pulse working (nS.). Under the short pulse working state,beam gets its energy just from the stored energy of accelerating tube, undoubtedly the high Q value and large stored energy of TW DAW structure will make beam have narrow energy dispersion, which is very useful in practice.

ACKNOWLEGDEMENT

The authors would like to thank Prof.K. Takata in KEK for his help.

REFERENCES

[1] V.B. Andreev, et al. "study of High-Energy proton Linac structures" LA-5115 (1972)
[2] D.A. Swenson, et al. "Accelerating and Focusing structures for PIGMI" LA-UR 77-1545 (1977)
[3] L.Young, et al. "Deflecting Modes in the DAW structures for the Racetrack Microtron" AT-1 :82-59 March (1982)
[4] S. Inagaki, et al. "Development of Disk And Washer cavity in KEK" IEEE Trans. Nucl. Sci. NS-30 (1983) 3572.
[5] T. Tanaka et al. "Test of a 1m Long Disk-And-Washer Accelerating Tube" Proceedings of the 1984 Linear Accelerating conference (1984) 229.
[6] Y. Iwashita et al. "Q Value of DAW Linac with Biperiodic T stem". Proceedings of the 1986 Linear accelerating conference, SLAC -303. (1986) 151.
[7] R.H. Miller."Comparison of Standing-wave and Travelling-wave structures" SLAC-303 (1986) 200.