BRIDGE COUPLER

Yuichi MOROZUMI and Yoshishige YAMAZAKI

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

Absract

A couple of models were proposed for the bridge coupler of the Japanese Hadron Facility linac and their fundamental properties were investigated from the viewpoint of feasibility. Among them the most promising is a multi-celled cylindrical cavity which is free from the problem of modal mixing peculiar to a long cylindrical shape of the conventional type.

Necessity and Advantage

An accelerating cavity tank of annular coupled structure is now under development for the future Japanese Hadron Facility linear accelerator (Ref.). The accelerating tank is forced to be divided into a number of units in order to install focusing magnets in between. The principal role of a bridge coupler is literally to bridge a train of accelerating structure units over the magnets, mutually coupling one accelerating structure to another electromagnetically for power feed and transfer. A bridge coupler consists of a bridging cavity and two coupling cavities on its both sides. The conceptional plan of arrangement and connection is as drawn in Figure 1.

The present bridging method has numerous advantages over alternative methods such as, for example, a direct input method of individual power feed directly from one wave guide to one accelerating structure unit.

The first is an auto-matching of phase among the accelerating structures. The bridge coupler transfers the phase of field as if it were itself an accelerating cavity.

The second is the conservation of symmetry in the accelerating structures. The direct input method requires large coupling irises or antennas on the side wall of the accelerating structure, introducing appreciable asymmetry. A bridge coupler takes over perturbing asymmetry from the accelerating structures. An asymmetry of the bridging cavity, which is placed off beam, gives rise to little distortion in accelerating fields.

The third is the saving of microwave circuit parts such as wave guides, tees, vacuum-tight windows. More parts are necessary for the direct individual input method.

Structure

The design principle is to make it simple. A complicated structure often brings about difficulty both in analysis and in manufacture.

The simplest is a conventional single cylindrical cavity (Figure 2), but operated in TM_{012} mode to gain group velocity for stability while the existing one of the same type at LAMPF is working in TM_{010} mode. The axial length is adjusted to the interval between accelerating structures, which depends on beam velocity and the radius varies according to the axial length.

The second simplest is probably a multi-celled cylindrical cavity (Figure 3) operated in TM_{010} $\pi/2$ mode for high stability and low power loss. The number of cell is restricted to 5, 9, 13 and so on by phase relation.

To minimize the power loss in the bridging cavity the coupling between bridging cavity and coupling cavity should be as large as possible.

Simulation

The electromagnetic fields in the bridge coupler were computed with the code MAFIA. The model was a simple system composed of a cylindrical bridging cavity, single or multi-celled, and two cylindrical coupling cavities. Because of the limitation of the number of mesh points only a quarter geometry of the model divided by the three symmetry planes were input with boundary conditions there (Figure 4).

It is expected that the intrinsic modes in the bridging cavity and in the coupling cavity are separately measured by detuning one of them on certain boundary conditions at the symmetry planes. Since both the bridging mode and the coupling mode are TM_{01} modes, it is always electrical open at the longitudinal symmetry plane. The bridging mode appears on the condition of electrical short both at the transverse symmetry plane and at the horizontal one while the coupling mode on the condition of electrical open there. The coupling cavity was tuned in so that the frequency of the coupling mode is equal to that of the bridging mode. The coupling of the bridging mode and the coupling mode is realized under the condition of electrical short at the transverse plane and electrical open at the horizontal plane.

Single Cavity

The frequency spacing of TE_{11} and TM_{01} modes is too narrow to decouple neighboring modes in the presence of asymmetry such as the opening to the coupling cavities (Graph 1). The modal coupling becomes more conspicuous in more closely coupled system and the fields in the bridging cavity are confusing rather than distorted. The eigenmodes in a single cylindrical cavity is no longer good eigenmodes to express fields in a coupled system of the bridging cavity and the coupling cavities and this modal mixing leads to difficulty not only in analytical treatment but also in measurement and control, even if operated in any mode.

Multi-Celled Cavity

The disadvantage of the single cavity results from its long cylindrical geometry and is eliminated by the partition of it into short flat cells by bored discs. In a short cylindrical cavity with an axial length less than its radius the frequencies of TE modes and of higher order TM modes are far above that of TM_{010} mode, which is isolated free from modal mixing. The model bridging cavity was a cylinder 9.5 cm in radius and 80 cm in axial length divided into 9 cells 8 cm long by 8 discs 1 cm thick. The number of division must be more than 9 so as to make the cell length sufficiently short. The bore radius of discs should be as large as possible in order to get a large inter-cell coupling for stability. The coupling coefficient exceeded 10 % for a bore radius of 5 cm (Graph 2). Without field distortion a fairly high coupling coefficient of 15 % was obtained between the bridging and coupling cavities, which means the power loss in the bridging cavity is a half of that in an accelerating cavity.

Concluding Remarks

Because of modal mixing a bridge coupler with a conventional bridging cavity will hardly work irrespective of its operation mode.

A reliable and stable bridging function is expected with a multi-celled cylindrical cavity operated in TM_{010} $\pi/2$ mode.

Further study including experimental investigation is under way.

Acknowledgement

Precious suggestion of Dr. L. Young is acknowledged. The authors are grateful to Mr. T. Kageyama for valuable discussions.

References

T. Kageyama et al., in Proceedings of this meeting

Figure 1 Accelerating Cavity Tanks and Bridge Couplers

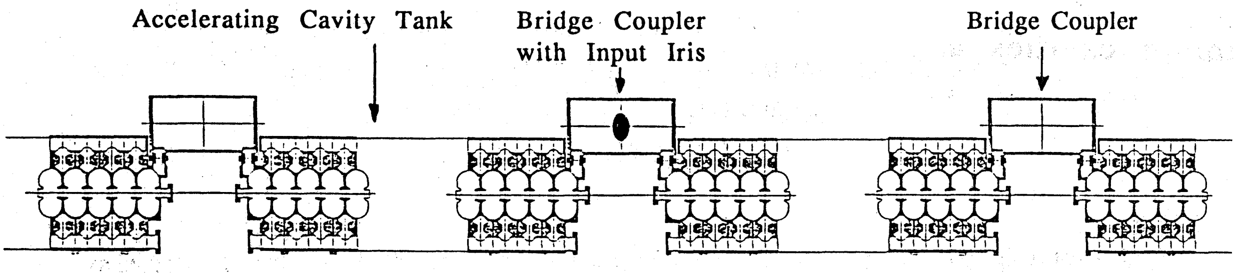


Figure 2 Bridge Coupler with a Single Cavity

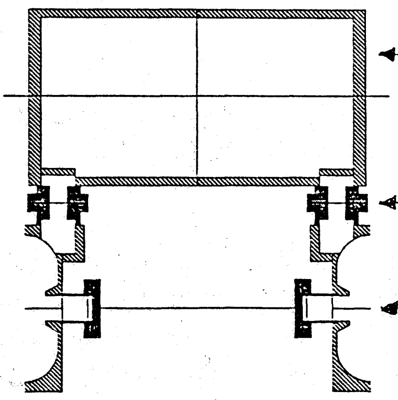


Figure 3 Bridge Coupler with a Multi-Celled Cavity

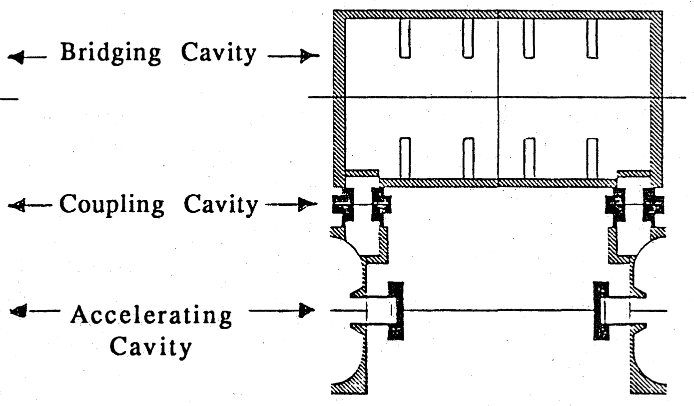
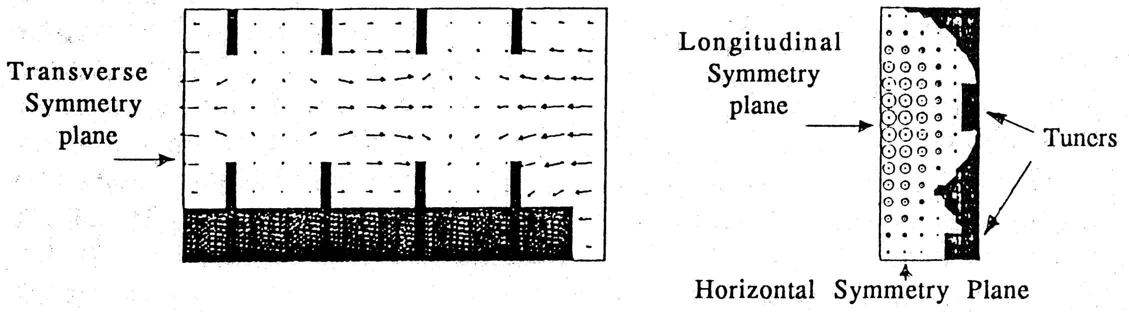
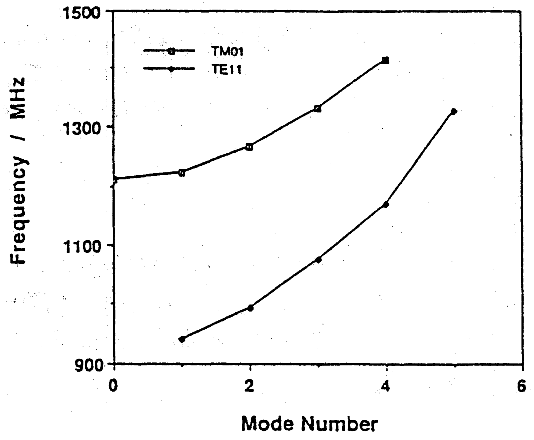


Figure 4 An example of Computed Geometry of Bridging Cavity



Graph 1 Dispersion Relation of TM_{01} and TE_{11} Modes in Single Cylindrical Cavity



Graph 2 Dispersion Relation of TM_{010} and TE_{111} Modes in Multi-Celled Cylindrical Cavity