L-BAND WAVEGUIDE ELEMENTS FOR SRF APPLICATION

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Abstract

L-band waveguide elements such as phase shifters, variable hybrids are described in the work. Elements were designed as air filled ones for several MW power level. Elements are supposed to use in KEK Superconducting Test Facility (STF). Design parameters, results of low and high power tests are presented.

L-BAND PHASE SHIFTER

1. PREFACE

For developing and checking superconducting technology for future International Linear Collider (ILC) the Superconducting Test Facility (STF) is building in KEK. STF is supposed to include several cryomodules, each of them will contain several accelerating structure. All accelerating structures are fed through RF power distribution system from one or two 1.3 GHz klystrons. Because all accelerating structures are not completely identically, each structure should be fed with individual optimal level of RF power and phase. To provide this possibility the distribution system has to contain power splitters and phase shifters. To make possible the adjustment during operation it is preferable to have these elements to be variable with remote control. To make distribution system cheaper and simpler it is better to have it are filled if possible.

2. PHASE SHIFTER REQUIREMENTS AND PRINCIPLES OF OPERATION.

It is supposed to have phase shifter before input of each structure. From this we can understand the requirements for phase shifter. Phase shifter has to reliable operate at RF power level about 500 MW working to the short (or 2MW working to matched load). Phase shifting range should be around 100^O and device has to have low level of reflected wave. For higher reliability it is better to have all parts of phase shifter are made of metal without dielectric. Metal parts can sustain numerous breakdowns and can be conditioned. Dielectric can be irreversible destroyed by single breakdown.
The properties of waveguide with fin were used to design the phase shifter, Fig.1. When the fin is placed in the center of waveguide the properties are close to properties of coaxial line and value of longitudinal wave vector is close to wave vector in free space. When the fin is shifted to the wall the effective width of waveguide becomes effectively smaller and longitudinal wave vector larger. Thus we can change the phase by moving the fin.

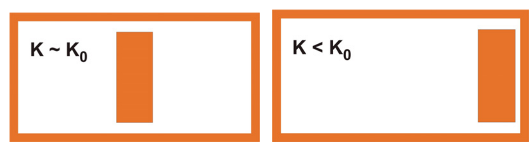

Fig. 1: Moving fin inside the waveguide we can change value of longitudinal wave vector and thus we can change the phase of wave coming through the waveguide.

3. PHASE SHIFTER DESIGN, PARAMETERS AND RESULTS OF TESTS.

The main problem of phase shifter design is how to provide the matching batwing rectangular L-band waveguides at the ends of phase shifter and waveguide with fin. Reflection should be around -30 dB for any position of fin. For this propose the fin with spatial geometry was design which has low reflection in whole range of position and provide phase shift about 120^O. Fig.2 shows geometry of phase shifter based on WR650 waveguide and geometry of fin.

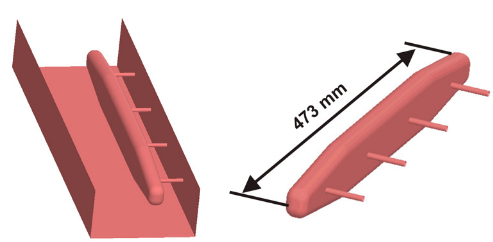

Fig. 2: Geometries of phase shifter based on WR650 waveguide and fin. Special geometry of fin provides low reflection (~ -30dB) in all range of position.

Phase shifter based on this design was built and tested. Photos of device are presented at Fig.3. Fig.4 shows the

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results of low power measurements: phase shift and reflection vs. fin position Phase shifter was tested at high RF power level. It worked for matched load without breakdowns at power level 2.9MW. Power was limited by RF source. Expected breakdown limit of phase shifter with air filling is about 5.5MW. Table 1 summarizes the property of phase shifter

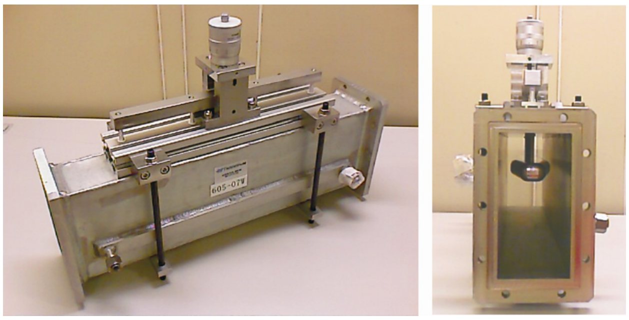

Fig. 3: L-band phase shifter based on WR650 waveguide. Phase shift 120^{O}, maximum power > 2.9MW, reflection < -28dB, length 600mm.

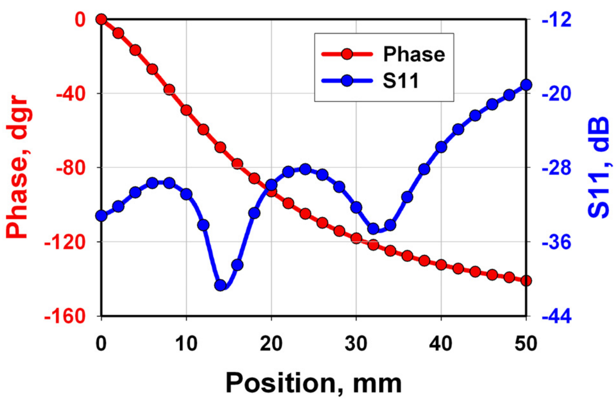

Fig. 4: Results of low power measurements of phase shifter presented at Fig.3.

Table 1: Parameters of phase shifter

Operating frequency	1.3 GHz
Phase shift	120^{O}
Reflection	< -28dB
Maximum power (air)	> 2.9MW
Waveguide	WR650
Length	~500mm

Recently a new phase shifter with cylindrical shape of fin was designed. Estimated breakdown power limit of new device is 12MW. Cylindrical shape is simpler and easier to make but it has to be longer to provide the same phase shift. Geometry of phase shifter with cylindrical fin is presented at Fig.5. Phase shifter with new geometry is under production and it is supposed to be tested soon.

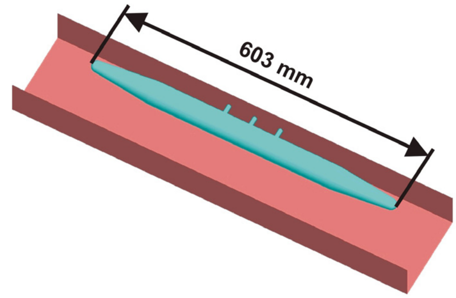

Fig. 5: Phase shifter with cylindrical shape of fin. Phase shift is 120^{O}, expected breakdown power limit is 12MW.

VARIABLE HYBRIDS

1. PRINCIPLES OF OPERATION

Based on the described phase shifters we can build the hybrid with the variable coupling. Let us consider a wide waveguide where only two modes TE10 and TE20 can propagate. If we have two identical fins in the waveguide, which are moved symmetrically and synchronically, we have phase shifters for both modes, Fig 6. We can expect different phase shifts for different modes for the same displacement of fins. It happens that sensitivity of TE10 mode is rather weak but phase of TE20 is high sensitive to fins position. Thus moving the fins we can change phase difference between modes TE10 and TE20. Just exactly this property is necessary to build variable hybrid.

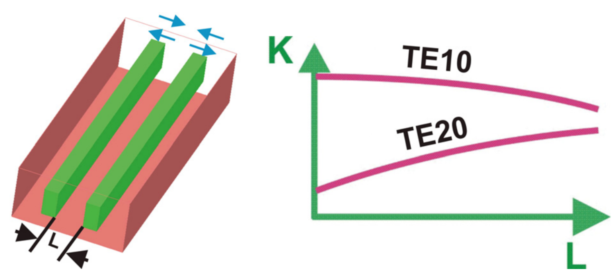

Fig. 6: Moving symmetrically and synchronically two fins in wide waveguide we can change the phase difference between modes TE10 and TE20. Just exactly this property is necessary for variable hybrid

2. HYBRID DESIGN AND PARAMETRS

Based on this idea two designs of variable hybrids were made. One of them has full range of coupling variation from 0 to 1. Other one has partial range but it has shorter length. Figs. 7 and 9 demonstrate shapes of variable hybrids. Figs 8 and 10 show graphs of dependences of S-parameters on fins displacement. The fins with cylindrical shapes were used in hybrid designs. The expected breakdown power limit for air filling is 12 MW. Now the hybrids are under production and will be tested for high power in nearest future.

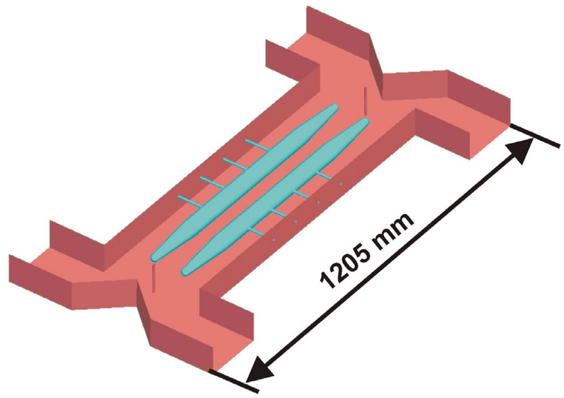

Fig. 7: Geometry of variable hybrid with full range of coupling variation. Input-output waveguides are WR650. Operating frequency is 1.3GHZ

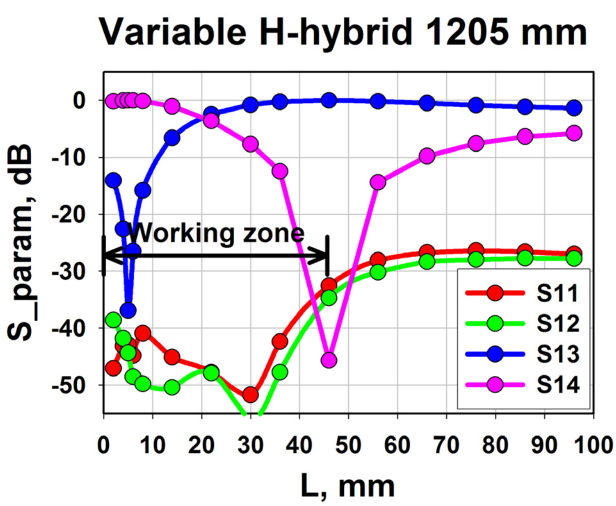

Fig. 8: S-parameters of variable hybrid with full range of coupling variation vs. fins displacement.

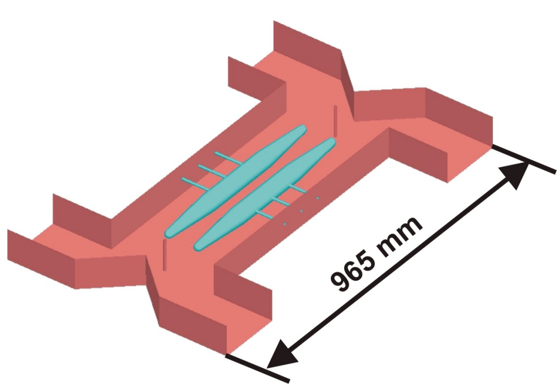

Fig. 9: Geometry of variable hybrid with partial range of coupling variation. Input-output waveguides are WR650. Operating frequency is 1.3GHZ.

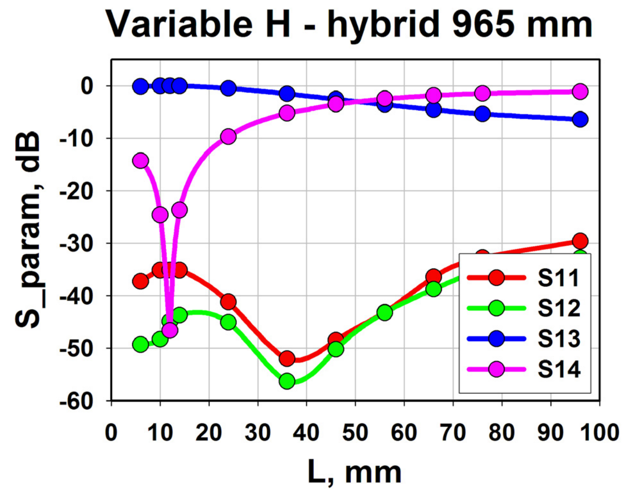

Fig. 10: S-parameters of variable hybrid with full range of coupling variation vs. fins displacement

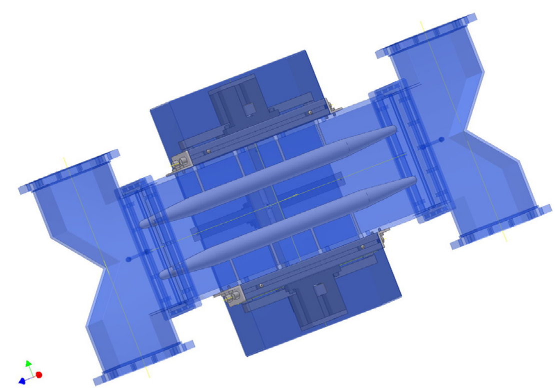

Fig. 11: Mechanical design of variable hybrid with remote control.

CONCLUSION

New type L-band phase shifter was invented, design, built and tested. Phase shifter has following parameters: operating frequency 1.3GHz, phase shift 120^{O}, reflection is less then -28dB. Air filled phase shifter was tested till 2.9MW without breakdown Power was limited by RF source. Expected breakdown power limit is 5.5MW. More powerful model is designed and will be tested soon. Expected power limit of new model is 12MW.

New type of variable L-band hybrid was invented. Hybrids with full and partial range of coupling variation were designed. Design values of reflections from ports and coupling of neighbor ports are less then -30dB. Expected breakdown power limit of air filled hybrids is 12MW. Hybrids are under production and will be tested in nearest future.