MicroHarmonics

Isolators & Circulators 50-325 GHz

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Introduction

Micro Harmonics is a small high-tech company located in Fincastle, Virginia. We specialize in advanced ferrite components including Faraday rotation isolators and circulators. We offer a complete line of Faraday rotation isolators covering 60-325 GHz in every standard waveguide band from WR-12 through WR-3.4. We plan to extend this line to the WR-2.8 band (260-400 GHz) and possibly to the WR-2.2 band (330-500 GHz). We are currently developing a line of isolators designed for optimal performance at cryogenic temperatures. Initial prototypes in WR-10 will be fully evaluated during the fall of 2018. Cryogenic models at bands from WR-12 through WR-3.4 will follow.

We design and manufacture all of our products in the United States. Our components were developed under an SBIR grant through NASA JPL. Because of language in the congressional SBIR authorization, our products can be sole sourced for government acquisitions.

Why Choose Micro Harmonics Products?

Our products are the most advanced on the market today. They exhibit state-of-the-art performance in terms of low-insertion loss, broad-bandwidth and low port reflections. Our isolators employ a unique diamond heatsink for improved power handling and reliability. Every component is tested over the full band on a vector network analyzer to ensure compliance. All constituent parts are thoroughly examined for dimensional tolerance. Belcore testing (thermal stress testing) is periodically performed. We use nylon thread lockers to ensure that our components stay assembled in the field. All of our products are fully warranted. Yet with all of these technical advantages, our components remain competitively priced.

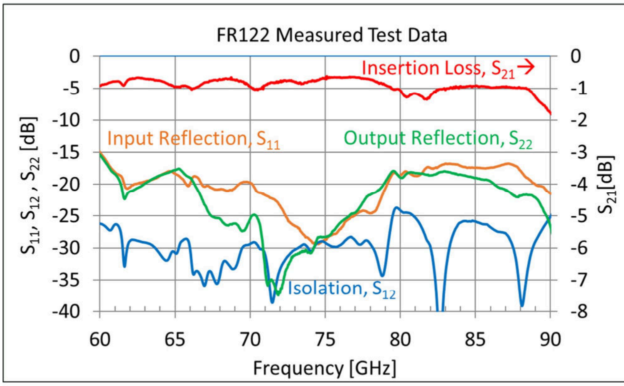
We encourage you to read some of the enclosed technical articles on our diamond heatsink technology, drop-in isolator technology and our methods for minimizing insertion loss.

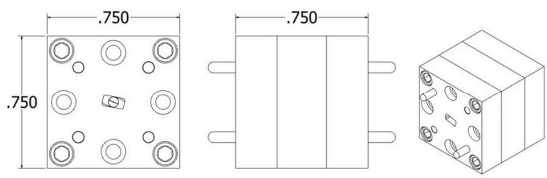
WR-12 Isolators

Model: FR122

Specifications	
Flange	WR-12
Frequency (GHz)	60-90
Insertion Loss (dB, typ)	0.9
Insertion Loss (dB, max)	2.5
Isolation (dB, typ)	25
Isolation (dB, min)	20
Input Return Loss (dB, typ)	19
Output Return Loss (dB, typ)	20
VSWR (max)	1.5:1
Maximum Power (W)	1.5
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.

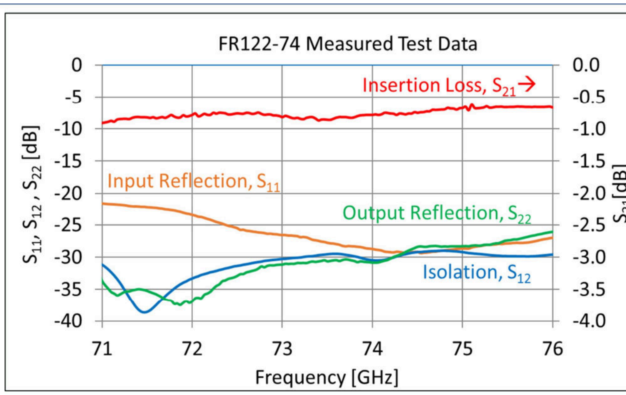


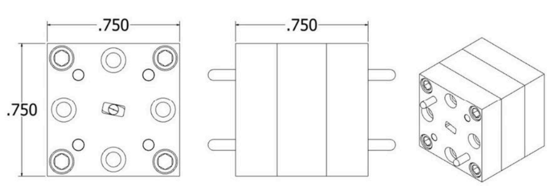


Model: FR122-74

Specifications	
Flange	WR-12
Frequency (GHz)	71-76
Insertion Loss (dB, typ)	0.9
Insertion Loss (dB, max)	1.1
Isolation (dB, typ)	27
Isolation (dB, min)	20
Input Return Loss (dB, typ)	25
Output Return Loss (dB, typ)	25
VSWR (max)	1.3:1
Maximum Power (W)	1.5
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.

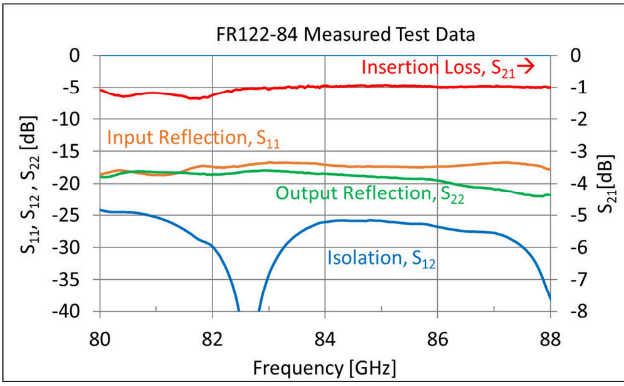


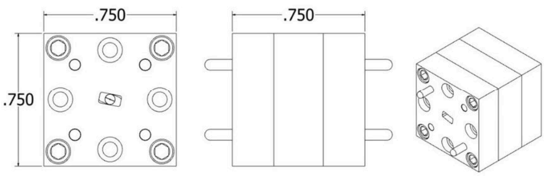


Model: FR122-84

Specifications	
Flange	WR-12
Frequency (GHz)	81-86
Insertion Loss (dB, typ)	1.1
Insertion Loss (dB, max)	1.4
Isolation (dB, typ)	26
Isolation (dB, min)	20
Input Return Loss (dB, typ)	18
Output Return Loss (dB, typ)	19
VSWR (max)	1.4:1
Maximum Power (W)	1.5
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.



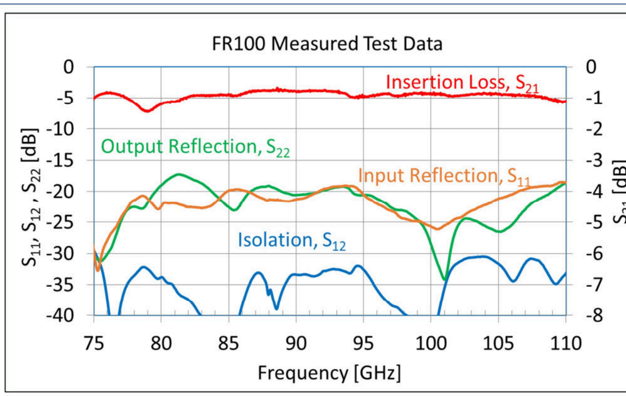


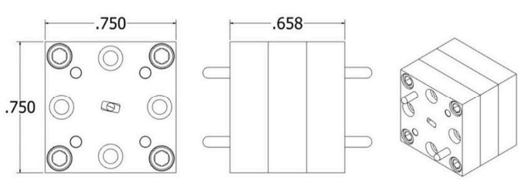
WR-10 Isolators

Model: FR100

Specifications	
Flange	WR-10
Frequency (GHz)	75-110
Insertion Loss (dB, typ)	1.2
Insertion Loss (dB, max)	2.1
Isolation (dB, typ)	30
Isolation (dB, min)	23
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	22
VSWR (max)	1.4:1
Maximum Power (W)	1.3
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.

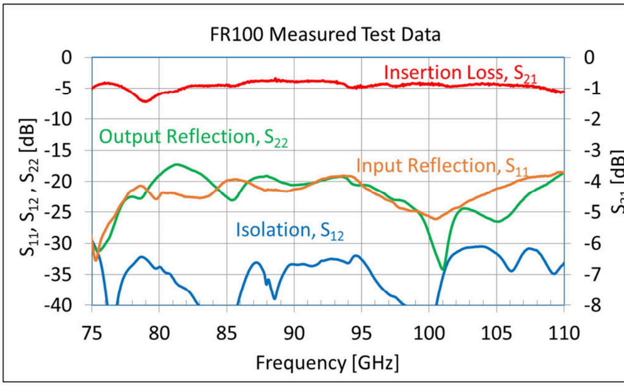


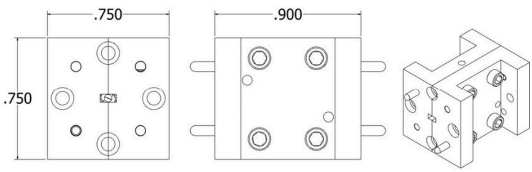


Model: FR100D*

Specifications	
Flange	WR-10
Frequency (GHz)	75-110
Insertion Loss (dB, typ)	1.4
Insertion Loss (dB, max)	2.4
Isolation (dB, typ)	30
Isolation (dB, min)	23
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	22
VSWR (max)	1.4:1
Maximum Power (W)	1.3
Diamond Heatsink	Yes

*See article on drop-in isolators in this catalog for more information.



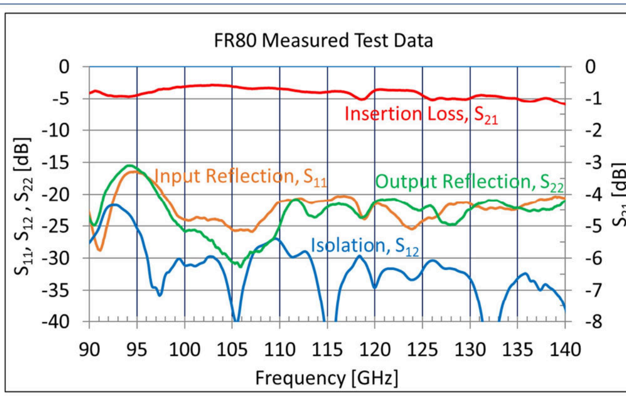


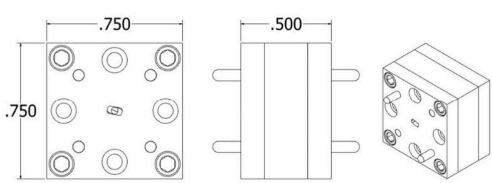
WR-8 Isolators

Model: FR80

Specifications	
Flange	WR-8
Frequency (GHz)	90-140
Insertion Loss (dB, typ)	0.9
Insertion Loss (dB, max)	2.2
Isolation (dB, typ)	30
Isolation (dB, min)	20
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	1.1
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.



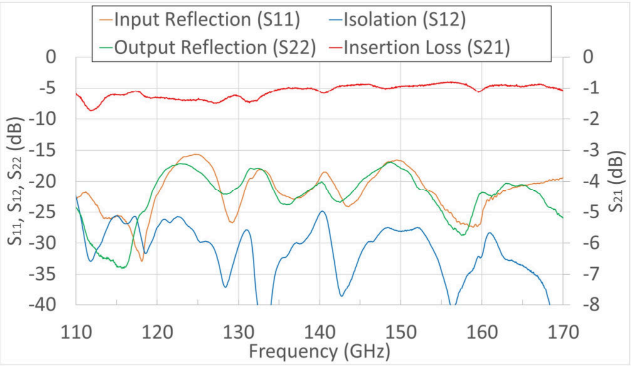


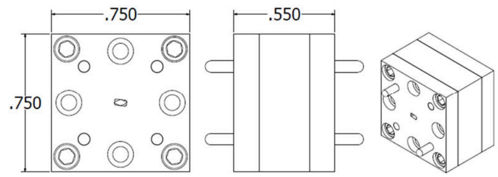
WR-6.5 Isolators

Model: FR65

Specifications	
Flange	WR-6.5
Frequency (GHz)	110-170
Insertion Loss (dB, typ)	1.1
Insertion Loss (dB, max)	1.9
Isolation (dB, typ)	24
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.4:1
Maximum Power (W)	0.9
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.



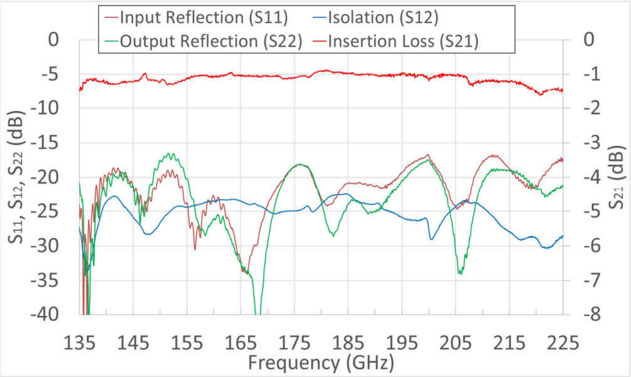


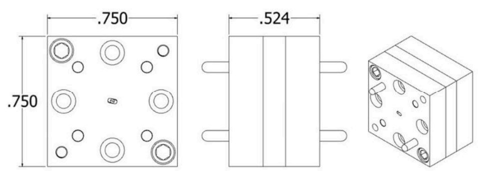
WR-5.1 Isolators

Model: FR51

Specifications	
Flange	WR-5.1
Frequency (GHz)	140-220
Insertion Loss (dB, typ)	1.4
Insertion Loss (dB, max)	2.7
Isolation (dB, typ)	24
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.5:1
Maximum Power (W)	0.75
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.



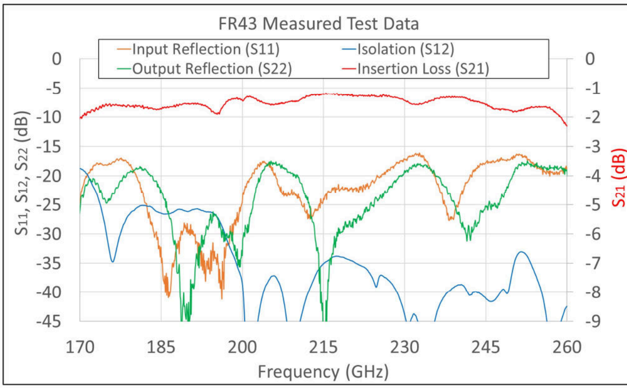


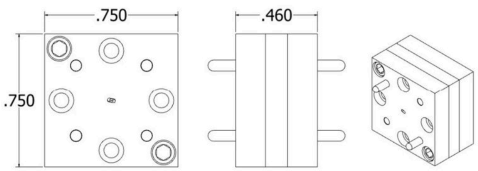
WR-4.3 Isolators

Model: FR43

Specifications	
Flange	WR-4.3
Frequency (GHz)	170-260
Insertion Loss (dB, typ)	1.9
Insertion Loss (dB, max)	3.8
Isolation (dB, typ)	20
Isolation (dB, min)	18
Input Return Loss (dB, typ)	20
Output Return Loss (dB, typ)	20
VSWR (max)	1.5:1
Maximum Power (W)	0.6
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.



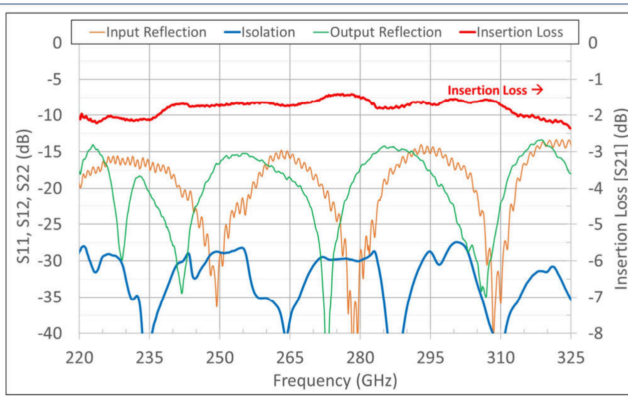


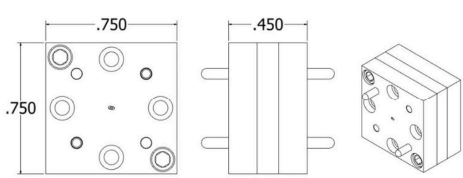
WR-3.4 Isolators

Model: FR34

Specifications	
Flange	WR-3.4
Frequency (GHz)	220-325
Insertion Loss (dB, typ)	2
Insertion Loss (dB, max)	3.5
Isolation (dB, typ)	25
Isolation (dB, min)	18
Input Return Loss (dB, typ)	18
Output Return Loss (dB, typ)	19
VSWR (max)	1.5:1
Maximum Power (W)	0.4
Diamond Heatsink	Yes

Every isolator is tested on a vector network analyzer to ensure conformity.





WR-2.8 & WR-2.2 Isolators

We are currently developing an isolator to cover the WR-2.8 band (260-400 GHz). Once that development is complete we will extend the work to the WR-2.2 band (330-500 GHz). The primary challenge is not EM design but rather fabrication and alignment of the constituent parts. Please visit our website for updates on our progress.

Cryogenic Isolators

We are currently developing a line of cryogenic isolators through an SBIR grant with NASA JPL. There are numerous material issues that must be addressed to ensure that the isolators are able to withstand the rigors of thermal cycling. Also, the ferrite saturation magnetization is temperature dependent. An isolator designed for room temperature operation will perform poorly when cooled. The degradation results from a roughly 20% increase in the magnetization which gives rise to a 9° over-rotation of the EM field. The end result is a slight rise in the insertion loss and a significant drop in isolation. This can be compensated by changing the ferrite length and retuning the transitions.

The initial development is being done in WR-10 (75-110 GHz). These units should be fully characterized by the end of 2018. During the ensuing two-year period 2019-2020 we will develop cryogenic isolators at every band from WR-12 through WR-3.4.

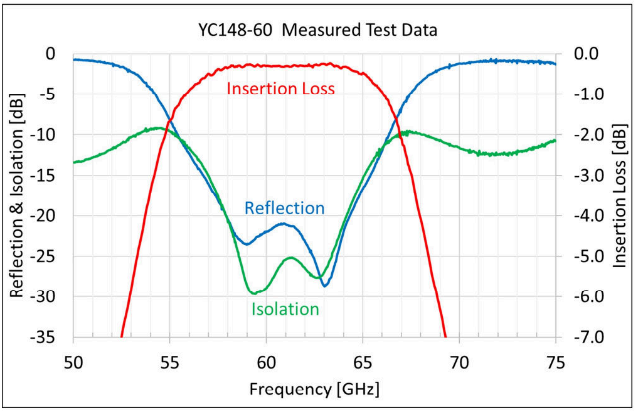
Warranty

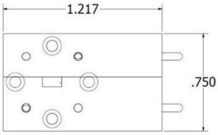
All Micro Harmonics products are fully warranted for one year from the time of purchase. Please visit our website for more information.

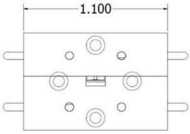
WR-15 Circulators

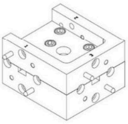
Model: YC148-60

Specifications	
Flange	WR-15
Frequency (GHz)	58-64
Insertion Loss (dB, typ)	0.3
Insertion Loss (dB, max)	0.6
Isolation (dB, min)	20
VSWR (max)	1.3:1





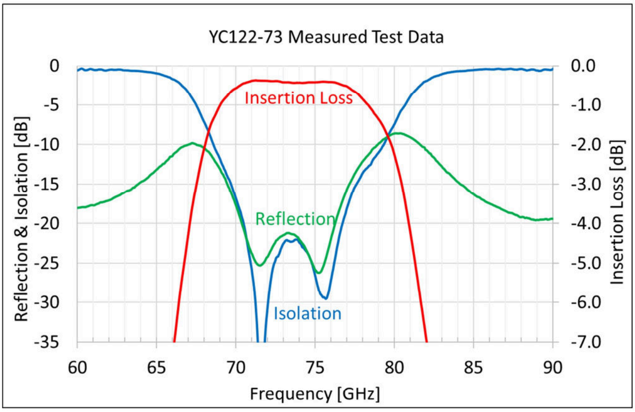


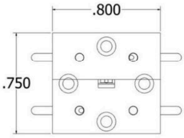


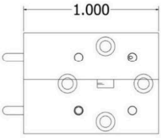
WR-12 Circulators

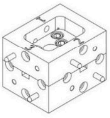
Model: YC122-73

Specifications	
Flange	WR-12
Frequency (GHz)	71-76
Insertion Loss (dB, typ)	0.4
Insertion Loss (dB, max)	0.6
Isolation (dB, min)	20
VSWR (max)	1.3:1



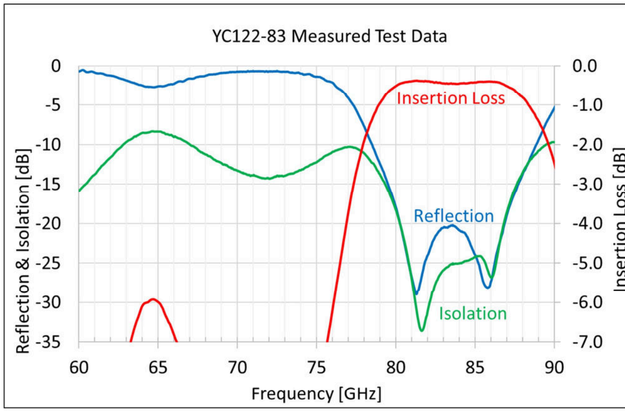


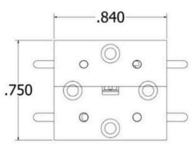


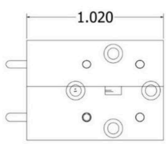


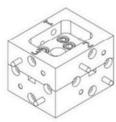
Model: YC122-83

Specifications	
Flange	WR-12
Frequency (GHz)	81-86
Insertion Loss (dB, typ)	0.5
Insertion Loss (dB, max)	0.7
Isolation (dB, min)	20
VSWR (max)	1.3:1





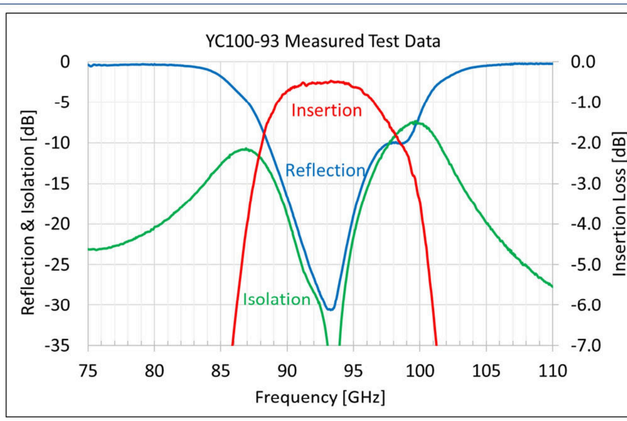


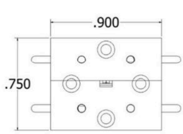


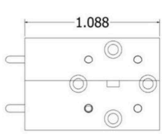
WR-10 Circulators

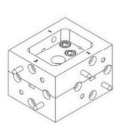
Model: YC100-93

Specifications	
Flange	WR-10
Frequency (GHz)	90-95
Insertion Loss (dB, typ)	0.6
Insertion Loss (dB, max)	0.8
Isolation (dB, min)	20
VSWR (max)	1.4:1



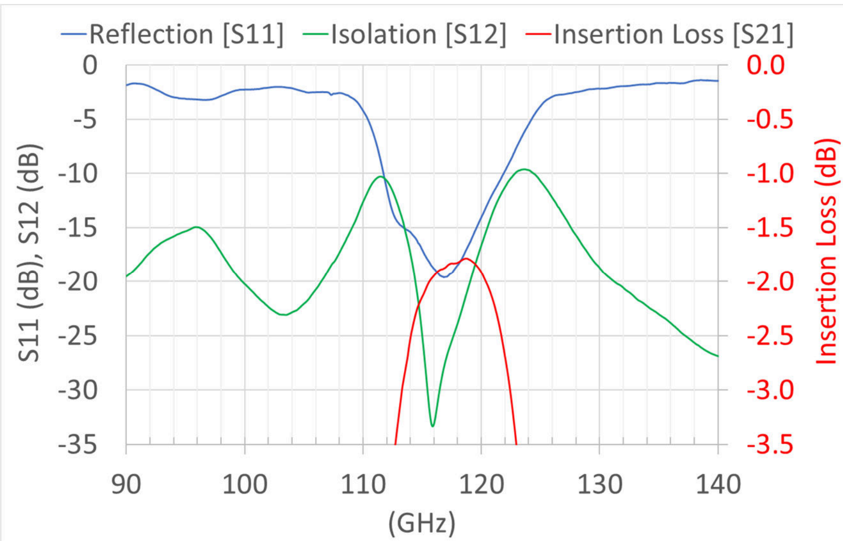


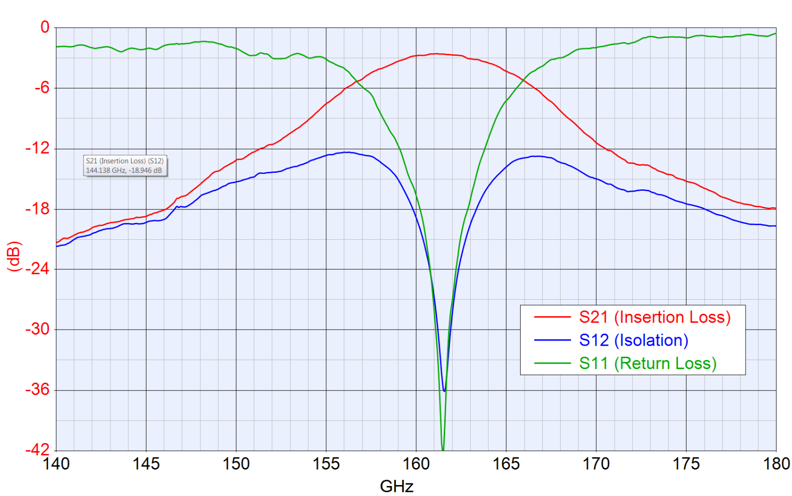




WR-8 & WR-5.1 Circulators

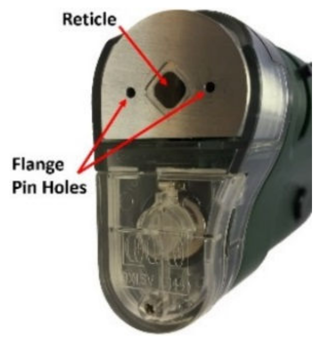
The graphs below show initial measured results from our WR-8 and WR-5.1 prototypes. The high insertion loss is primarily due to waveguide loss which is constrained by the flange dimensions. The tuning is highly sensitive to changes in the ferrite dimensions. Please visit our website for more information on our circulator development.



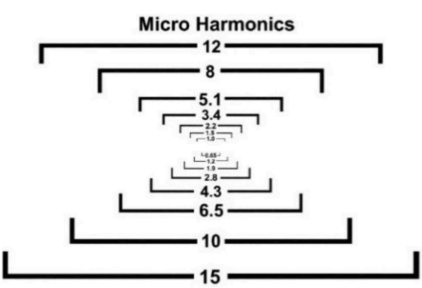


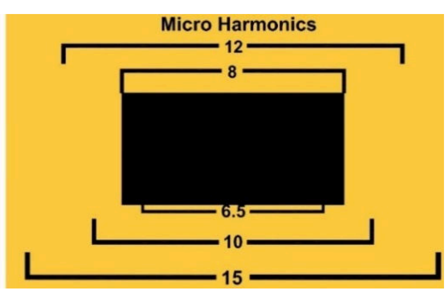
MMW Flange Identifier Tool

This tool is designed as a low-cost way to identify waveguide flanges from WR-15 to WR-0.65 (50 GHz to 1.7 THz). It comprises a microscope with adjustable zoom (20-40 X), adjustable focus, LED illumination and a reticle. The reticle has features to identify the waveguide flange. A pair of waveguide flange alignment pin holes are located at the bottom of the microscope. Slide the alignment pins of the flange you wish to identify into the holes at the base of the microscope. The reticle is slightly recessed so that it will come into close proximity but not touch the flange.

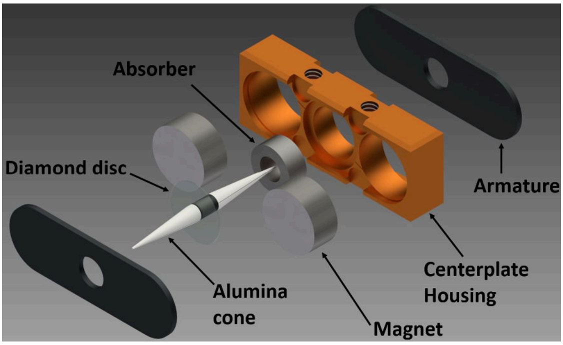


When the microscope is held to a lighted background (no waveguide flange attached), all of the features on the reticle are visible as shown in the left side of the graphic below. Before attaching to a waveguide flange, adjust the focus and magnification. When the microscope is attached to a waveguide flange, the area on the interior of the waveguide will go dark since there is no reflecting surface. For example, the graphic on the right shows the illuminated reticle with the microscope attached to a WR-8 waveguide flange. Although the markings for the 15, 12, 10 and 6.5 are still visible, only the "8" marker spans the exact length of the broad-wall of the waveguide thus identifying the flange as WR-8.



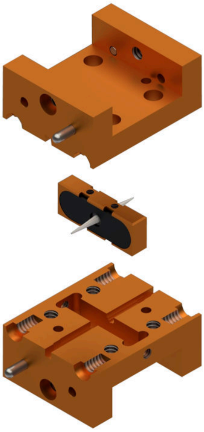


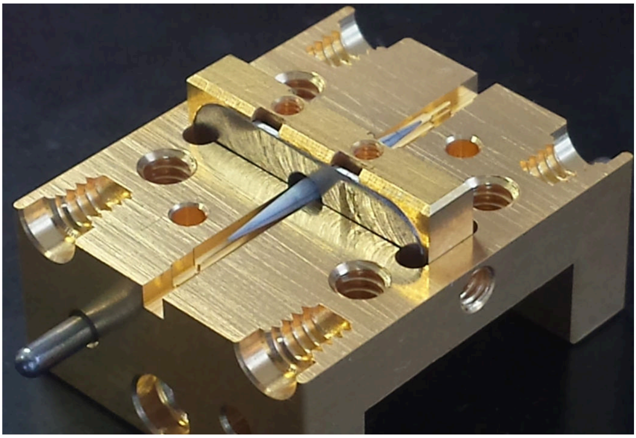
Drop-in Isolators



We developed a Faraday rotation isolator that can be integrated with other components in a single waveguide block. The drop-in isolator comprises a centerplate that houses the core assembly (ferrite, cones, absorber, magnets, armatures) and an E-plane split waveguide block that houses the centerplate and provides stepped waveguide twists on both the input and output ports.

The graphic below shows how the centerplate assembly fits into the E-plane split waveguide block. The photograph shows a centerplate assembly sitting in the base half of the E-plane split waveguide block.



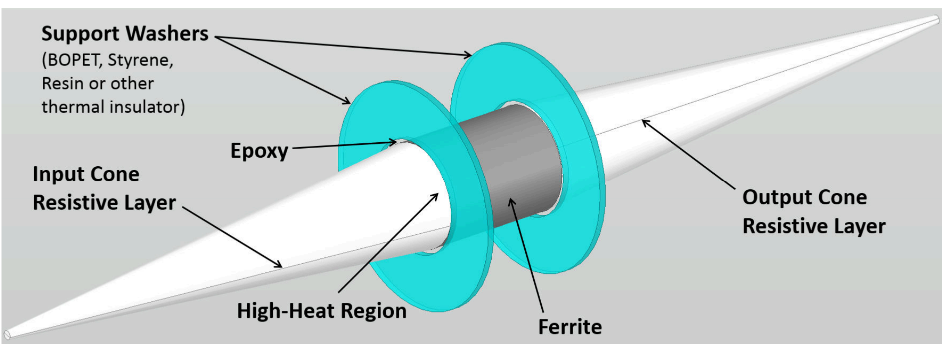


Our drop-in isolators are shipped with the centerplate assembly housed in the outer waveguide block. This provides protection of the centerplate assembly and allows the drop-in isolator to be used as a standalone component. If the customer wishes to integrate the isolator into their system, they can remove the outer housing and return it to Micro Harmonics for a reimbursement. Please visit our website for more information.

Diamond Heatsink Technology

Our isolators employ a modern design yielding much lower insertion loss than other commercial products. They also work over much broader bandwidths in excess of standard waveguide bands. But there is another important difference that sets them apart from the competition. Our isolators employ a diamond support disc that channels heat from the resistive layer in the cone to the metal waveguide block and thus they can handle greater reverse power levels. To our knowledge no other commercial isolators offer this advantage.

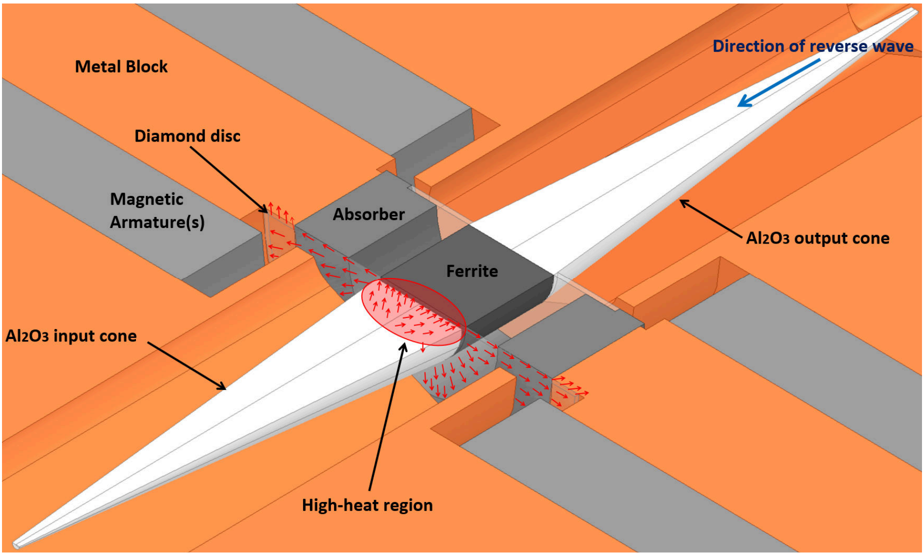
At the heart of a Faraday rotation isolator is a pair of alumina cones and a cylindrical ferrite core. The cones are used to couple EM fields from the waveguides to the ferrite. The cones are bisected by a resistive layer along their central axis. In most commercial Faraday rotation isolators, the ferrite and cones are suspended by a pair of washer-shaped supports as shown in the sketch below.



The cone & ferrite assembly is inserted through the inner support holes and then attached with a non-conductive epoxy. The support material is typically BOPET, Styrene, a resin or some other material with a low dielectric constant and low loss at millimeter-wave frequencies. Materials with these characteristics are generally in the class of thermal insulators and thus the cones and ferrite are thermally isolated from the metal block.

Power entering the output port of the isolator is absorbed in the resistive layer bisecting the input alumina cone. The absorbed power is converted to heat energy. Very little of this heat energy can be channeled away by thermal conduction through the washer-shaped supports, rather it must be dissipated through a radiative process or by means of convection through the surrounding air. The resistive layers are thus subject to high heat levels and even damage if too much reverse power is incident on the device. Historically this was not an issue as there was very little power available at these frequencies. But as higher power sources are becoming available there is a renewed interest in the power ratings of these devices.

At Micro Harmonics we have replaced the input support washer with a uniform high-grade optical CVD diamond disc. The diamond disc does not have a hole at the center. Diamond is the ultimate thermal conductor approaching 2200 W/mK, more than five times higher than copper. The graphic below shows a split-view of the isolator to give a better view of the constituent parts.



The diamond disc is sandwiched between the base of the input cone and the ferrite. The diamond disc is in intimate contact over the entire area of the cone base. This is the optimal location for the diamond disc since it is the region subject to the highest heat levels. The diamond disc is attached to the metal waveguide block over its entire periphery and thus provides an excellent conduit to channel heat away from the resistive layer. The red arrows indicate the path of heat flow. This topology is clearly superior for thermal conduction and thus our isolators will operate at lower temperatures.

Isolators Designed for Low-Insertion Loss

Commercial Faraday rotation isolators have been around since the 1970's. Traditional builds have good isolation throughout the microwave and millimeter-wave bands. The insertion loss is low in the microwave bands, but steadily increases with frequency. At mm-wave frequencies the insertion loss becomes problematic. For instance, in the WR-10 band (75-110 GHz) the insertion loss can exceed 3 dB. In the WR-3.4 band (220-325 GHz) the insertion loss can be more than 7 dB. There are few manufacturers in the bands above 50 GHz. Isolators in the WR-4.3 and WR-3.4 bands were manufactured many years ago but are now difficult to find. At these high frequencies the constituent parts are very small, and difficult to fabricate and align. And with > 7 dB insertion loss, there isn't much demand.

At Micro Harmonics we design isolators that are optimized for low-insertion loss. The typical insertion loss is about 1 dB for our WR-10 isolators and about 2 dB for our WR-3.4 isolators. These numbers are game changers and mm-wave system developers are now reconsidering their use. So how do we do it? There are many factors to consider, but here we focus primarily on;

1) Minimizing Ferrite Loss
2) Minimizing Waveguide Loss
3) Precision Fabrication and Alignment

1) Minimizing Ferrite Loss - A good starting point is to consider the equation for EM field rotation in a Faraday rotation isolator.

$$\theta = \frac{4\pi M_Z \Upsilon l \sqrt{\varepsilon}}{2c}$$

Where,

$4\pi M_Z$ is the axial magnetization

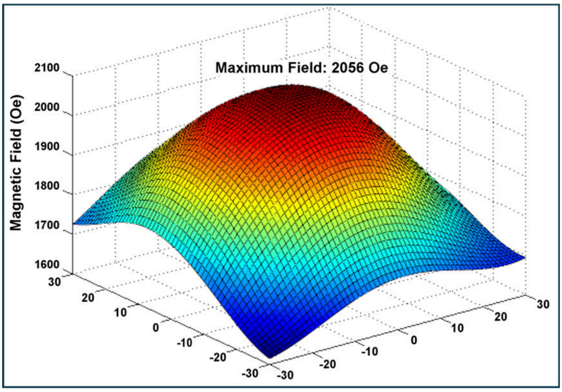
Υ is the gyromagnetic ratio (8.795×10^6xg rad/s/Oe)

l is the ferrite length

c is the speed of light

ε is the ferrite dielectric constant

This equation shows that the field rotation is directly proportional to the ferrite length and the axial magnetization. Minimum insertion loss and maximum isolation occur when the EM field is rotated by 45° as it passes through the ferrite. Ferrites are lossy at millimeter-wave frequencies, so it is essential that the length be reduced as much as possible. The traditional method used to tune Faraday rotation isolators is to use ferrites that are substantially longer than the minimum required length and then tune the magnetic bias field to achieve optimal performance. At Micro Harmonics we use a saturating magnetic bias field and the minimum possible ferrite length.



We measure our magnetic bias fields to insure the ferrites are saturated. We use magnetic armatures to achieve a focused, uniform bias field in the ferrite. The graph shows the measured magnetic bias field near the surface of the ferrite core. The peak measured value of 2000 Oe is substantially more than what is required for saturation. The measurements extend well outside of the area of the ferrite.

2) Minimizing Waveguide Loss – Since the EM field is rotated by 45° as it passes through the ferrite, it is necessary to realign the flanges. In traditional builds this is accomplished by twisting extruded waveguide (see photo). The twist must be implemented over a sufficiently long distance to avoid damaging the extruded guide. In the WR-10 through WR-3.4 bands the total length of extruded waveguide is about 2.3 inches in traditional builds, with some variations from band-to-band and between manufacturers.

At Micro Harmonics we use machined twist steps which are substantially shorter than the extruded waveguide twists. They yield good broadband performance and reduced waveguide loss. The total flange-to-flange length of a Micro Harmonics WR-3.4 isolator is 0.45 inch (see photo to the right). At WR-10 the reduction in the waveguide loss is only 0.2 dB, but at WR-3.4 the reduction is 0.9 dB and at WR-2.8 it is 1.3 dB.

3) Precision Fabrication and Alignment – There are substantial challenges in fabricating and assembling the isolators at the higher bands. The parts become increasingly smaller and some of the materials are very difficult to machine. Aside from the myriad fabrication complications there are considerable alignment difficulties that must be overcome.

Small misalignment of the cones and ferrite by a few degrees can result in significant degradation of the isolator performance. The area near the ferrite can support more than thirty modes. Misalignment can cause significant coupling to the higher order modes resulting in unwanted structure in the response, increased insertion loss and port reflections as well as decreased isolation. Misalignment can alter the orientation of the resistive layers so that a component of the E-field of the forward travelling wave is in the plane of the resistive layer, resulting in higher insertion loss and lower isolation.

The assembly process is an art form. No two isolators have exactly the same signature. At Micro Harmonics we continually strive to improve our techniques and the uniformity of assemblies. We also comprehensively test every isolator on a calibrated vector network analyzer to insure it meets our specifications. Some competitors spot-check their components at a few frequencies using less sophisticated systems. This can lead to erroneous test data and missed signatures in the response. We also periodically perform thermal stress testing to verify the mechanical reliability of our devices.

The Micro Harmonics Advantage

At Micro Harmonics we are advancing the state-of-the-art in mm-wave isolators and circulators. The significantly reduced insertion loss of our isolators makes them suitable for use in mm-wave systems where signal power is at a premium. For example, a traditional WR-3.4 isolator covering the band 220-325 GHz can have an insertion loss of more than 7 dB while a Micro Harmonics isolator in the same band has a typical insertion loss of less than 2 dB. Our advanced ferrite products offer:

- **Compact size**
- **High isolation**
- **Low insertion loss**
- **Extended bandwidth**
- **50 GHz to >325 GHz**
- **Diamond heatsinks**
- **Cryogenic options**
- **Competitive prices**

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