laser cavity. The FBG F-P etalon discriminates and selects the laser longitudinal modes efficiently. The spatial hole burning effect is restrained by using fiber Faraday rotator. The output power is more than 50 mW and slope efficiency is 27%. The linewidth of the fiber laser is less than 10 kHz. The temperature tuning results indicate the laser exhibits good stability. The fiber laser has a number of potential applications for high resolution fiber sensor.

REFERENCES


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resonance frequency. As far as the resonance mode is concerned, the positions of excitation and probing affect the transmission response of the structure. Therefore, the positions of the two coupling aperture have to be properly designed to achieve a good performance in insertion loss. Besides, we found that the bandwidth of the band-pass filter can be altered by changing the length of the aperture. The detail information will be given in the following sections.

2. STATEMENT OF THIS PROBLEM

As shown in Figure 1, this band-pass filter consists of two dielectric layers; the top layer contains the input and output via-hole-wall waveguides and the bottom layer contains a via-hole-wall cavity. The electromagnetic field coupling between the via-hole-wall waveguide and cavity is through the two apertures etched on the top surface of the cavity, and on the bottom surface of the waveguides, as well. The two input waveguides was isolated by placing the via-hole array between them. Notice that the pitch of the via-hole array separating the input and output waveguides should be kept as small as possible for preventing the direct coupling between the two waveguides. Besides, the input and output via-hole-wall waveguides are fed, respectively, by the micro-strip line with linear taper transition. The waveguide side walls or cavity walls are made from the double rows of via-wall to reduce the electromagnetic wave leakage. The parameters designated for the structure, shown in Figure 1, are listed in Table 1, with their size given in the second column.

3. EXPERIMENTAL AND NUMERICAL RESULTS

In this paper, the theoretical analysis for the scattering characteristics, including the insertion- and return- loss, was carried out using CST Microwave Studio®, based on the Finite Integration Technique (FIT) in time domain. Besides, the band-pass filter was fabricated using microwave substrate RO4003 with thickness 20 mil. The via-hole arrays were implemented using electronic plating technique. In addition, the scattering parameters were measured by HP 8722D.

Figure 2 depicts the insertion- and return loss of the band-pass filter developed in this paper. The two coupling apertures share the same width and length, which are 0.6 mm and 17 mm, respectively. The length, width, and thickness of the resonance cavity are 15, 17, and 0.508 mm, respectively. The dashed lines denote the calculated result, while the solid lines represent the measured result. Since the thickness of the cavity is far smaller than the width and length, the major component of the electric field in the cavity is $E_z$, while $E_x$ and $E_y$ are negligible. Therefore, the lowest resonant mode is $TM_{110}$ in this example. The resonant frequency for the $(m, n, o)$ mode of the cavity without apertures is given below

$$f \text{ (in GHz)} = 150 \sqrt{\left(\frac{m}{w_y}\right)^2 + \left(\frac{n}{l}\right)^2} / \sqrt{\varepsilon_r}. \quad (1)$$

where the integer $m$ and $n$ denote the index number along width and length direction, respectively. The relative dielectric constant of the substrate is characterized by $\varepsilon_r$. However, because of the existence of two coupling apertures, the resonance frequency

<table>
<thead>
<tr>
<th>Table 1: Structure Parameter</th>
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<tbody>
<tr>
<td>Radius of via hole: $r$</td>
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<tr>
<td>Width of waveguide (cavity width): $w_y$</td>
</tr>
<tr>
<td>Via-hole array (waveguide wall) pitch: $p_1$</td>
</tr>
<tr>
<td>Via-hole array (partition wall) pitch: $p_2$</td>
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<tr>
<td>Via-hole array pitch (the second row): $p_3$</td>
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<tr>
<td>Aperture length: $a_y$</td>
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<tr>
<td>Aperture width: $a_x$</td>
</tr>
<tr>
<td>Input/output waveguide length: $l_{wg}$</td>
</tr>
<tr>
<td>Cavity length: $w_z$</td>
</tr>
<tr>
<td>Micro-strip line width: $w_s$</td>
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<tr>
<td>Micro-strip line length: $l_s$</td>
</tr>
<tr>
<td>Taper transition width: $t_w$</td>
</tr>
<tr>
<td>Taper transition length: $t_l$</td>
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</tbody>
</table>

Figure 2: Measured and calculated insertion- and return-loss for the band-pass filter with aperture length 17 mm.

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should be different with the value given in (2). From Figure 2, it is obvious to see that the excellent agreement between the calculated and measured results.

As mentioned earlier, the band-pass characteristic of this filter is based on the resonance effect of the cavity. To prove that the band-pass characteristic is due to the resonant mode, TM_{110}, we plot the contour map, depicted in Figure 3, for the vertical component of electric field strength \( E_z \) on the cross section at \( z = 0.5h \) (\( h \) is the thickness of the substrate). From this Figure, it is apparent that the maximum electric field is around the center of the cavity and the field variation resembles the function given below.

\[
E_z(x, y) \approx \sin \frac{\pi x}{w_x} \sin \frac{\pi y}{w_y}. \tag{2}
\]

In the following two examples, we change the aperture length while keeping all the other parameters given in the previous example. The lengths of the aperture are 15 and 13 mm in Figures 4 and 5. Comparing Figures 4 and 5 with Figure 2, it is apparent that the bandwidth is decreasing as the aperture length is decreased. It is noted that the insertion loss in Figure 5 increases, compared with those in Figures 2 and 4. It may be conjectured that because of the decrease in the length of coupling aperture the coupling coefficient between the waveguide and cavity decreases accordingly. The bandwidth of the three cases shown in Figures 2, 4, and 5 are 34.05%, 30.28%, and 24.4%, respectively. Although not shown here, we have also carried out the numerical simulations and experimental studies for the cases with several different aperture lengths. We found that the bandwidth decreases as the decrease in the aperture length, however, the insertion loss increases.

4. CONCLUDING REMARKS

In this research, we developed a new band-pass filter using a resonant cavity, which is implemented by the via-hole-wall technique. The resonant cavity was coupled by an aperture on a substrate integrated waveguide stacked on the top of the resonant cavity. Because of the vertical coupling between the substrate integrated waveguide and cavity, the size of the structure is further reduced. Specifically, the bandwidth of this band-pass filter can be changed by tuning the length of the coupling aperture. Because of the easy fabrication and compact size, this band-pass filter can be a potential candidate in the microwave and millimeter wave system.
DOUBLE-LAYER SUBSTRATE INTEGRATED WAVEGUIDE STRUCTURE WITH VARIABLE FRACTIONAL BANDWIDTH

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ABSTRACT: The propagation characteristics of double-layer SIW structures have been investigated in this paper. On the basis of the theory of resonance cavity and SIW, the simple theoretical formulas for the lower and upper frequencies in the passband have been found. The theoretical analyses have indicated that these two frequencies have much dependence on the width of SIW and the length of the coupling slot, the fractional bandwidth of the double-layer SIW structures can be controllable. Agreement between the simulation data and the calculated results from the formulas can be observed. © 2007 Wiley Periodicals, Inc.

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