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Contactless Cost-effective Polarizer for mm-Wave Dielectric Rod Waveguide

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Abstract—We present a method to control the polarization of guided waves in a mm-wave dielectric rod waveguide. A pair of optical posts is situated on either side of the waveguide, and this markedly raises the cutoff of the undesired mode. The isolation is 20 dB over a frequency span from (55-87) GHz. This can be viewed as a proof-of-concept for reconfigurable, general-purpose polarization control and dispersion engineering in mm-wave and terahertz-range dielectric waveguides.

1. INTRODUCTION

All-Silicon waveguides are emerging as a promising platform due to low loss, inexpensive manufacture, and scalability across the mm-wave and terahertz (THz) ranges [1-4]. Dielectric waveguides always support at least two modes with orthogonal polarization, thus facilitating applications that require polarization diversity. However, the presence of more than one propagation mode can also lead to undesired interference whenever irregularities are encountered. For this reason, techniques to control polarization are required.

The history of mm-wave polarizers begins with Jagadish Chandra Bose in the late 19th century, when he interleaved the pages of a book with sheets of tinfoil to realize a 60 GHz polarizer [5]. Contemporary mm-wave and THz polarizers fall into following categories: wire grid polarizer, reflection polarizer, and birefringent polarizer [6]. Birefringent polarizers exhibit high extension ratio but suffer from absorption loss, as materials such as nematic liquid crystals exhibit very large absorption in this region [7]. Wire grid polarizers are the simplest form of mm-wave polarizers exhibit larger aperture, high extension ratio, and low insertion loss. However, to achieve this they have lengthy manufacturing processes and high production costs [8]. Free standing polarizers made with carbon nanotubes has a high extinction ratio but suffers from 50 % loss [9]. Crucially, all of the above-mentioned devices are intended for a freespace beam, which makes them bulky, and limits the scope of application. Guided-wave approaches have been underexplored because hollow metallic waveguides, which are dominant in the mm-wave and THz range, can simply select the polarization by tailoring the inner conductor dimensions. However, the growing interest in dielectric waveguides motivates the development of guided-wave polarizers.

We present a straightforward contactless technique for polarization control that does not require modification to the dielectric rod waveguide (DRW) itself. This is possible due to evanescent fields that extend into the surrounding space. We exploit this by introducing ordinary, electrically conductive optics posts at either side of DRW, thereby inhibiting tangentially polarized waves. In this way, we demonstrate 20 dB isolation over 55-87 GHz frequency band.

![Diagram](image-url)
2. CONCEPT

The structure of the polarizer is illustrated in Fig. 1(a). A DRW is situated between two parallel cylindrical metallic optical posts that, at their closest point, from a parallel-plate waveguide that encloses the DRW. Increasing the separation between DRW and optical posts will decrease the cutoff frequency for vertical polarization. Through this, we can estimate the separation. This combined structure exhibits a marked increase in cutoff frequency for the polarization that is tangential to the optical posts, i.e., the vertical polarization. The reasonably large radius of curvature ($3\lambda_0$) acts as a natural progressive matching structure for the desired polarization. Modal analysis of the waveguide both with and without the presence of the electrical conductors is given in Fig.1(b)-(c). It can be seen that, whilst the cutoff of the vertical polarization has almost doubled, the horizontal polarization has not changed at all, as expected.

3. EXPERIMENT

The DRW is fabricated from a high-resistivity intrinsic silicon wafer using a deep reactive ion etching process. A photograph of the experimental setup is given in Fig. 2(a). A hollow waveguide is connected to each end of the DRW via a linear tapered, 8 mm long spike, which is inserted directly into the hollow waveguide without making contact with sidewalls. These hollow waveguides are interfaced with a mm-wave vector network analyzer. The desired polarization is launched by appropriately rotating the hollow waveguide. Thereafter, optical posts are introduced. These posts are inexpensive commercially available components. Alignment with the DRW is accomplished with translation stages. In order to ensure consistency across measurement of both polarizations, the relative separation is monitored using an optical microscope. Care is taken to ensure symmetrical placement of the optical posts on either side of the DRW. Received power is normalized against measurement with the posts removed in order to deembed the impact of the posts upon each transmission.

![Experimental Setup](image1)

![Modal Analysis](image2)

Fig. 2. (a) A photograph of experimental characterization of the transmission measurement in horizontal polarization, and (b) Comparison of measured and simulated transmission.
We present the measured and simulated transmission response in Fig 2(b), for both vertical and horizontal polarization. It can be seen that the vertical polarization is strongly attenuated below 94 GHz, and that the horizontal polarization is able to pass through, as anticipated. The variation in the measured results is likely due to minor asymmetry in the alignment, which can excite higher-order modes that are not accepted by the hollow waveguide, and thereby create a standing wave between the hollow waveguide and the polarizer. Apart from that, insertion loss is higher than expected for horizontal polarization, especially at lower frequencies. We ascribe this to the surface roughness and finite conductivity of the optical posts. We anticipate that these issues will be resolved by the manufacture of bespoke, polished metal posts.

4. CONCLUSION

We have demonstrated that the presence of adjacent conductors can markedly attenuate the transmission of the vertical polarization wave in a DRW, whilst allowing the horizontal polarization to pass. In this way, inexpensive optical posts operate as a mm-wave polarizer for guided wave. The fact that this technique is contactless offers the potential for its reconfigurability, and the overall structure can readily be scaled for higher-frequency operation. Thus, this concept holds the potential to realize arbitrary polarization conversion and control in mm-wave and THz range DRWs.

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