New Technique for Loss Measurement of a Direct UV Written Silica-on-Silicon Waveguide using Integrated Bragg Grating Structures

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Abstract—**We present an elegant new method for measuring the loss of a silica-on-silicon waveguide using integrated Bragg grating structures. This technique has been used to measure the losses of UV written FHD waveguides exhibiting losses of 0.23dB/cm.**

Keywords- direct UV written; Bragg grating; propagation loss; attenuation.

I. Introduction

Measuring the attenuation of a planar waveguide has many associated problems. These can be attributed to the short waveguide geometries which typically exhibit low total loss. A successful measurement technique must be able to differentiate between absorption loss and other losses associated with the waveguide, such as coupling losses and Fresnel reflections. There are many techniques which can be used to calculate losses within a waveguide; these include the cut-back method [1], prism-coupling technique [2] and the Fabry-Perot technique [3].

In this paper we present a new technique that is a variant on the cut-back approach. It removes uncertainty due to coupling losses, avoids the need for physical cut-back and by interrogating each grating with forward and backward propagating light provides a robust way of assessing loss.

Direct UV writing [4] produces waveguides within the photosensitive core layer of silica-on-silicon planar samples. Svalgaard and Kristensen [5] report propagation loss of <0.2dB/cm in silica-on-silicon waveguides produced by plasma enhanced chemical vapor deposition (PECVD). Samples produced by flame hydrolysis deposition (FHD) are expected to have similar loss characteristics.

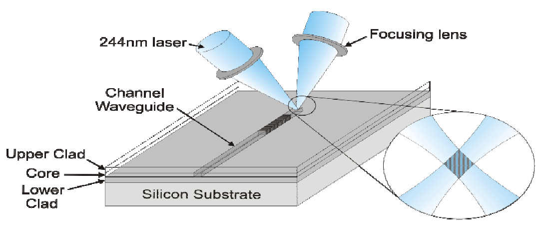

Figure 1. Direct UV written waveguide with integrated Bragg grating structure. Schematic shows focused crossed beam detail (inset).

We would like to thank the EPSRC for funding this research.

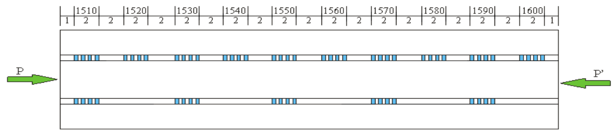

Figure 2. Direct UV written waveguide with integrated Bragg grating structure. Schematic shows focused crossed beam detail (inset).

Bragg grating structures are made using the direct grating writing (DGW) technique [4]. Precise modulation of the interference pattern produced by the crossed beams defines Bragg grating structures within the waveguide (Fig. 1). The wavelength of a Bragg grating is dependent on the local refractive index, so can be used to detect conditions at the device surface such as the presence of chemicals [6]. Additionally, measurement of the Bragg grating's response can be used to characterize the waveguide.

In this case, by simultaneous definition of Bragg gratings within the UV written waveguide, a variation on the cut-back method is used to calculate propagation losses within the waveguide. The method allows spatial mapping of the losses within integrated optical devices.

II. Experimental

The silica-on-silicon sample was fabricated via FHD to create three index matched doped silica layers on a silicon wafer. The core layer was doped with germanium to induce photosensitivity, which was further enhanced by hydrogen loading prior to waveguide fabrication. Exposure to UV radiation (λ=244nm) caused an increase in the refractive index of the local core region, forming the waveguide.

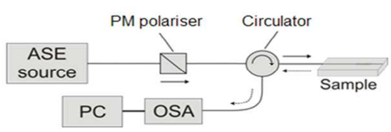

Figure 3. Characterization arrangement for analysis of Bragg grating spectra.

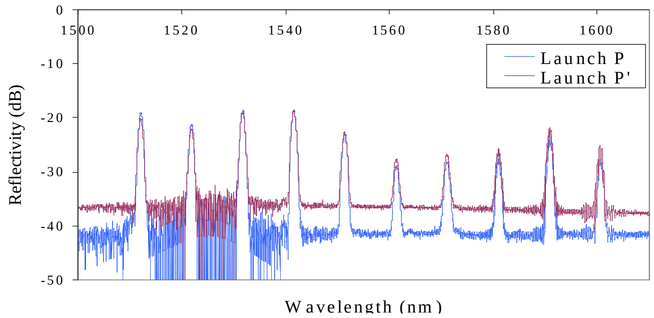

Figure 4. Reflected spectra from waveguide containing ten Bragg gratings, with light launched from directions P and P'.

The waveguides were produced in a 40mm sample, each containing a number of Bragg gratings with specific reflected wavelengths (Fig. 2). The arrangement shown in Fig. 3 was used to characterize the reflected spectra from the waveguide. Light was launched from each end of the sample in turn to obtain information on the spatial dependence of the reflectivity of the gratings. The normalized spectra obtained for the waveguide containing ten Bragg gratings can be seen in Fig. 4.

The loss of the waveguide can be calculated using the elegant relation

$$L = \frac{(P_1 - P_2) + (P_2' - P_1')}{4d}. \quad (1)$$

L is the attenuation in dB/cm, and d is the absolute distance between the centre points of the gratings in cm. P_1, P_2, P_1' and P_2' are the reflected power from gratings 1 and 2 in dB, when launching in directions P and P' respectively. The equation shows that the loss in a section of waveguide between a pair of Bragg gratings is independent both the insertion loss and launch power. In this experiment the magnitude of the peaks were obtained by applying a Gaussian fitting algorithm.

This analysis assumes that the gratings are weak and so have identical spectra from opposing directions. A second assumption is that the waveguide is of sufficient quality to support Bragg grating structures.

III. Results

Fig. 5 shows the reflected power ratio against the distance for the waveguide containing ten gratings. The gradient of this plot gives the average loss of the waveguide to be 0.235dB/cm.

To consider the loss of the gratings within the waveguide, a second waveguide was fabricated and characterized containing five gratings. Fig. 6 shows the plot of attenuation against absolute position of grating for this waveguide, and shows an average attenuation of 0.227dB/cm. This data suggests that the gratings provide no significant additional loss to the waveguides.

The simple relation (1) shows that this method provides more accurate loss measurements than the cut-back technique, as information about the reflectivity of the end facets of the waveguide is not required.

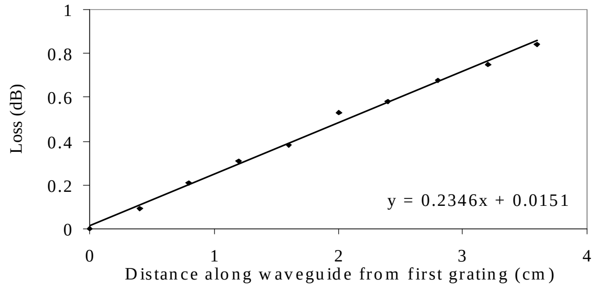

Figure 5. Shows the loss of each grating against the position of the grating within the waveguide. Waveguide contains ten gratings.

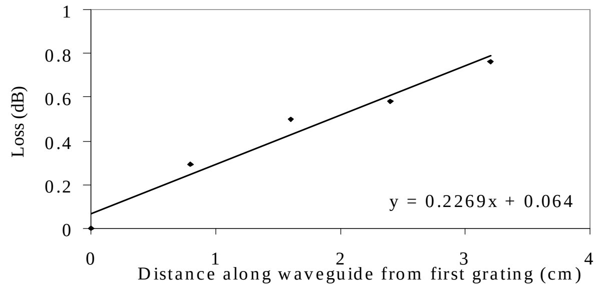

Figure 6. Shows the loss of each grating against the position of the grating within the waveguide containing five gratings.

IV. Conclusion

This work demonstrates a method of measuring loss in silica-on-silicon waveguides which could be applied to any photosensitive waveguide such as arrayed waveguide gratings (AWGs) or waveguides in chalcogenide glasses. We show that our UV written waveguides have a loss of 0.23dB/cm. We will present our latest studies on defects and losses of components such as micromachined grooves and couplers.

Acknowledgment

This research was funded by EPSRC, UK.

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