

Interferometric integrated planar Bragg filter for all-optical single-sideband suppression

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Abstract—An integrated planar Bragg filter is proposed and experimentally demonstrated. X-couplers and Bragg gratings, operating as photonic Hilbert transformer and flat-top band gap reflectors, are incorporated. Optical signals reflected from these two gratings interference with each other are suitable for single sideband suppression. The device is fabricated by Direct UV grating writing technology in silica-on-silicon.

Keywords—planar Bragg grating; photonic Hilbert transformer; single sideband suppression; direct UV writing

I. INTRODUCTION

In the all-optical communication systems, optical bandwidth is currently limited so frequency efficiency is important to improve the bandwidth performance. One significant approach is to use optical single-sideband (SSB) modulation [1]. Various methods have been proposed and demonstrated [2]-[4]. Bragg-grating-based photonic Hilbert transformers (PHTs) were implemented in the fiber-based optical SSB system [3]. Here we present initial efforts to fabricate an integrated SSB modulation device, based on silica-on-silicon planar geometry which provides a route to realize compact optical modules for applications.

In this work, we practically demonstrate an integrated photonic device, composed of an X-coupler, PHT and flat top reflector, shown in Figure 1. The photonic Hilbert transformer was implemented using an appropriate apodized planar Bragg grating with a π -phase shift in the grating length. Sinc-apodized Bragg grating was utilized as flat top reflector in wavelength region. All structures are located in a single chip and fabricated by direct UV grating writing technology [5].

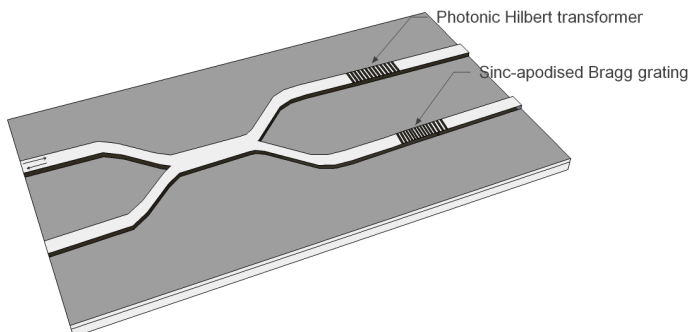


Figure 1 Proposed 3D structure of an integrated all-optical SSB modulator.

II. OPERATION PRINCIPLE

The Hilbert transform in frequency domain is given as [1]:

$$\hat{H}(\omega) = -j\text{sgn}(\omega) \quad (1)$$

Where $\text{sgn}(\omega)$ is the sign function (which is +1 for $\omega > 0$ and -1 otherwise), and ω is the baseband frequency. Thus, the frequency response of the Hilbert transformer has a π -phase shift at $\omega=0$, whereas the amplitude remains constant. To physically realize the PHT, the grating apodization profile is given by [2]:

$$\Delta n(z) \propto \frac{\sin^2(\pi n_{av} \Delta f (z - z_0)/c)}{(z - z_0)} \quad (2)$$

For $0 \leq z \leq L$, where n_{av} is the average refractive index of the planar Bragg grating, c is the speed of light in a vacuum, L is the total grating length, z_0 is the zero-crossing point in the apodization function, and Δf is the operative bandwidth. z_0 is set to the centre of the grating length for simplicity. The grating period is $\Lambda = \lambda_B / 2n_{eff}$.

Sinc-apodized Bragg gratings are applied as flat top reflectors in the other arm. The grating apodization profile is given as:

$$\Delta n(z) \propto \frac{\sin[\pi(z - z_0)]}{(z - z_0)} \quad (3)$$

The sinc-apodized grating is designed to obtain identical reflectivity amplitude response as Hilbert transformer, in order to enhance the suppression effect. Gratings are 12mm long and central wavelength is 1550nm. The grating refractive index modulation depth is $\Delta n = 0.0008$. A transfer matrix method is employed to model the grating spectrum. Reflectivity, optical phase, group delay and apodization profile of the Hilbert transform grating (line) and sinc-apodized grating (dot) are illustrated in Figure 2. As anticipated, the sinc-apodized grating responses are similar to the Hilbert transform grating, except the π phase-shift in the central wavelength.

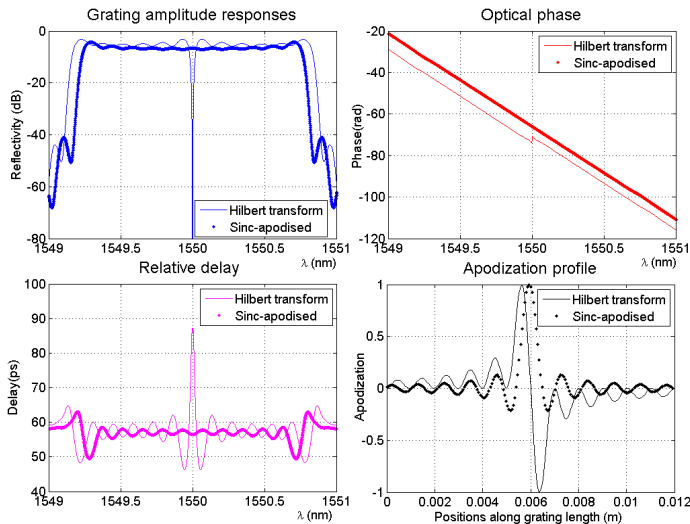


Figure 2 Simulation of Hilbert transform (*line*) and sinc-apodized grating (*dot*) responses in wavelength region.

III. FABRICATION AND MEASUREMENT

The preliminary effort is to fabricate an X-coupler with designed Bragg gratings in each arm, shown in Figure 1. The proposed planar Bragg grating was fabricated using direct UV grating writing (DGW) technology. This method involves focusing two crossed laser beams ($\lambda=244\text{nm}$) into a photosensitive core of a planar sample. Precise translation of the sample and modulation of the interference pattern creates grating structures and simultaneously define the channel waveguide [5]. This spot size is approximately $6\mu\text{m}$ in diameter, providing the unique ability over traditional FBG to manipulate the grating's structure at the micron level. This ability allows precise engineering of the amplitude and phase response of the gratings with complex structures.

The effective refractive index of the mode within the gratings was $n_{\text{eff}}=1.4472$, the two gratings were both 12mm long and the crossing angle of the X-coupler is 2.5 rad. The experimental data is shown in Figure 3. The grating responses in reflection were directly measured using the optical spectrum analyzer with an erbium fibre based ASE broadband source.

Figure 3(a) shows the reflectivity spectral of Hilbert transform (green) and sinc-apodised (red) gratings. The data is normalized by comparison with the 4% reflection from the cleaved far end of the fiber to calibrate the actual reflection from the grating. In Figure 3(b) the SSB suppression ratio of X-coupler1 is $\sim 7\text{dB}$, whereas in X-coupler2 in Figure 3(c), an additional phase-shift in one arm of the device results in a suppression of the opposite side band of $\sim 7\text{dB}$. Greater suppression will be achieved by phase trimming, optimization of the X-coupler parameters and the grating responses.

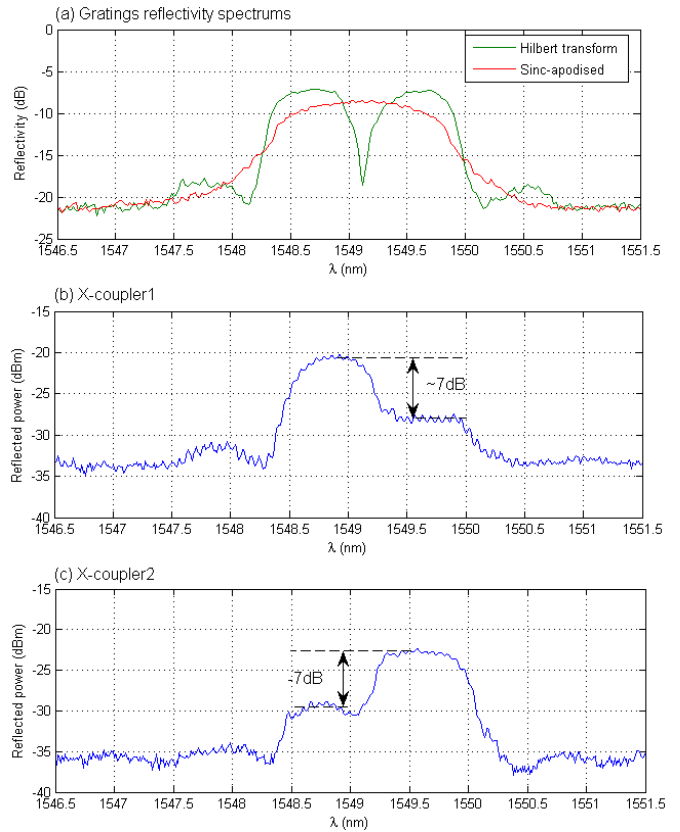


Figure 3 Experimental data: (a) gratings reflectivity spectral with Hilbert transform (*green*) and sinc-apodisation (*red*); (b) reflected power from X-coupler1, with $\sim 7\text{dB}$ suppression ratio; (c) extra phase shift was applied to the X-coupler2, with the suppression ratio around $\sim 7\text{dB}$.

IV. CONCLUSIONS

We have presented preliminarily data demonstrating an interferometric integrated SSB suppression filter. The suppression ratio will be enhanced by tuning the optical phase. In the future, the integrated nature of planar geometry will allow these devices to be combined with other functions, such as thermal tuning elements and liquid crystals to generate reconfigurable devices.

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