Simple planar Bragg grating devices for photonic Hilbert transform

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Hilbert transformers are important devices widely used in information processing and signal analysis in the electronic domain. For example, for spectral efficiency improvement, it is used to construct the analytic signal for single sideband (SSB) modulation from a real signal. Photonic Hilbert transformers (PHTs) are proposed for a similar range of applications and would allow the direct processing of optical signals at bandwidths far beyond current electronic technologies.

Recent publications have explored theoretical simulations, or have described multi-component implementations; however, as yet no simple PHT device has been experimentally reported. Here we experimentally demonstrate a photonic Hilbert transformer implemented in a planar waveguide, using a correctly apodized planar Bragg grating with a π-phase shift in the grating. The planar Bragg grating is fabricated by direct UV grating writing technology (DGW) in a silica-on-silicon substrate.

Photonic Hilbert transformers have a finite frequency bandwidth and temporal impulse response. An ideal PHT has a π-phase shift at the zero point of the frequency response, whereas its amplitude remains constant. In our device the π-phase shift, which is the primary function of a Hilbert transformer, was simply induced by placing a π-phase-shift in the refractive index modulation of the Bragg grating. The utilization of direct UV writing to produce gratings allows for arbitrary control of apodization and phase shift and lets us fabricate these devices.

The devices incorporate an apodization profile together with the required π-phase shift, and are similar to the simple weak-coupling fiber Bragg grating devices proposed in recent literature. To obtain the ideal temporal impulse response along a finite-time interval, the grating apodization profile is specified as a particular function, including the effective refractive index, the total grating length, and the operation bandwidth, as well as the zero-crossing point position in the apodization function.

The demonstrated planar Bragg grating device was fabricated using direct UV grating writing (DGW) technology. This method involves focusing two crossed laser beams (λ=244nm) into a photosensitive core of a planar sample. Precise translation of the sample and modulation of the interference pattern define the channel waveguide and simultaneously create grating structures. The spot size is only approximately 6μm in diameter, allowing us to add phase shifts and apodization features on a far shorter scale than in conventional fiber Bragg grating writing.

It was necessary to make accurate measurement of the fluence vs. photosensivity response of the samples in order to give correct operation of the apodization function, results on this process will be presented.

By using direct grating writing we have successfully fabricated Bragg gratings that exhibit the required phase shift and spectral response for Hilbert transformer operation. With the modulation phase-shift method we are able to characterize the reflectivity and group delay of these devices. These first proof-of-principle devices operate at 1549.1nm and have bandwidths of about 1.6nm based on the delay measurements. The grating itself had a period of 534.18nm and was 15mm in length. Future work will include the utilization of inverse scattering techniques to design optimal performance high reflectivity photonic Hilbert transformers.