Equivalent Phase-Shift Bragg Gratings on SOI using Optical Lithography

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Phase-shift Bragg gratings play an important role in photonic devices such as distributed-feedback (DFB) semiconductor lasers [1]. Figure 1(a) is a schematic of a phase-shift grating where half is shifted by $\Delta\Lambda$ to form a spatial phase-shift $\Delta\varphi=2\pi\Delta\Lambda/\Lambda$. Hence a peak is generated in the stopband of the optical transmission spectrum at the Bragg wavelength $\lambda_B=2n\Lambda$, as shown in Fig. 2(a) where a quarter-wave shift is applied ($\Delta\Lambda=\Lambda/2=\lambda_B/4n$). To make an accurate phase-shift, high pattern-placement accuracy in wavelength scale is required. Most of the phase-shift gratings are made using scanning-electron-beam lithography (SEBL) [2][3]. However, this technique lacks long-range spatial-phase coherence due to various distortions in electron-beam systems.

In this paper, we describe a novel method, called sampled Bragg grating (SBG), to achieve an equivalent phase-shift, without the use of SEBL. A uniform grating is modulated by a sampling function $S(z)$ with period P to form an SBG, as shown in Fig. 1(b). The SBG has a multi-channel transmission response as shown in the inset of Fig. 2(b). If the sampling function is periodic and shifted by ΔP in the center, a phase-shift is introduced in each channel. Specifically, a phase shift of $\Delta\varphi=2\pi\Delta P/P$ is generated in the -1st channel. Figure 2(b) shows the optical transmission spectrum of the -1st channel where $\Delta P=P/2$ is selected to form a quarter-wave-shift, which has the same spectrum in the -1st channel as the conventional phase-shift grating in Fig. 2(a). Therefore, shifting the sampling function in SBG is equivalent to shifting the grating pattern in conventional phase-shift gratings. The advantage of this method is that the sampling period can be much larger than the grating period ($P/\Lambda>100$), making it easier lithographically to precisely control the phase-shift in SBG. In other words, the requirement of pattern placement accuracy in SBG is relaxed by more than a factor of 100. To demonstrate this method, we fabricated an SBG in SOI. The grating was patterned by interference lithography which has a good long-range spatial-phase coherence, and the sampling was patterned by low-cost optical-contact lithography. Figure 3 shows SEM images of the fabricated device. Fabrication techniques and optical characterization of the device will be reported.

References:

[1] K. Utaka, *et al*, IEEE Journal of Quantum Electronics, Vol. 22, No.7, pp. 1042-1051, 1986
[2] S. Honda, *et al*, Electronics Letters, Vol. 43, No. 11, 2007
[3] S. A. Rishton, *et al*, J. Vac. Sci. Technol. B 20(6), pp. 2749-2752, 2002

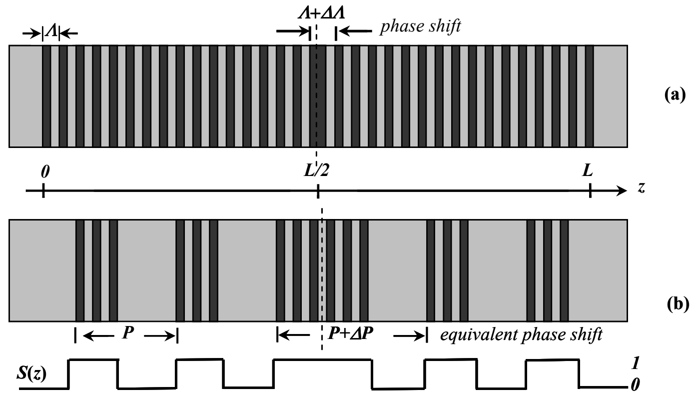

Fig. 1 (a) a conventional phase-shift grating; (b) an equivalent phase-shift grating using sampled Bragg grating

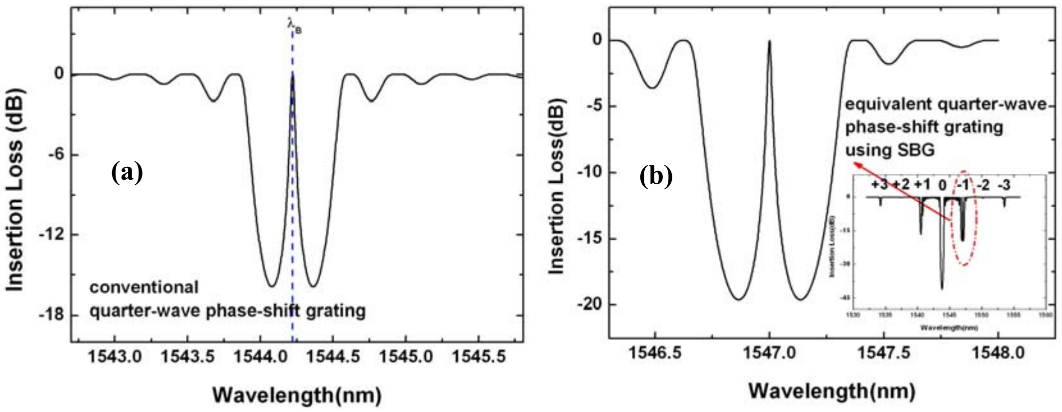

Fig. 2 Simulated transmission spectrum of (a) a conventional quarter-wave phase-shift grating; (b) an equivalent quarter-wave phase-shift grating using SBG (inset: the entire spectrum of SBG)

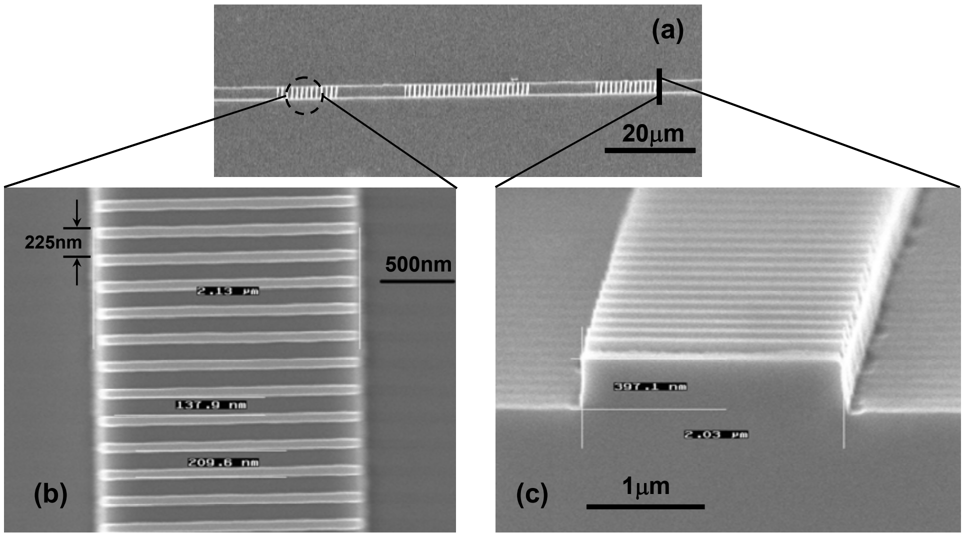

Fig. 3 Scanning-electron micrographs of the fabricated SBG: (a) top-view of a section of the SBG; (b) a zoom-in view of the grating; (b) cross-sectional view of the facet of the SBG