Fabry- Pérot cavity in SiN for non-linear applications

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Abstract: We present side-coupling Fabry-Pérot-based resonant mirror cavities in the 800 nm thick silicon nitride platform, implementing tapered and conventional Bragg grating. Experimental results highlight enhanced Q-factors and tunability, crucial for femtosecond hybrid laser generation.

Keywords: optical devices, PICs, Lasers, PIC material platforms

1. Introduction

The demand for improved performance and miniaturization in optical sensing, laser technology, and emerging telecom applications like optical filtering and DWDM systems has driven the exploration of compact, enhanced integrated optical micro-resonators. These devices are pivotal in the development of integrated photonic circuits (PICs) for advancing next-generation photonic technologies. In this regard, the design of micro-ring resonators (MRRs) and Fabry-Pérot (FP) cavity resonators implemented on novel technological platforms and architectures have been studied in the literature. MRRs offer compact and high Q-factor on-chip resonators but are prone to strong and random line splitting due to backscattering from surface roughness, leading to mode crosstalk and resonance shifts. Moreover, they also offer limited dispersion engineering for nonlinear applications like comb generation and are highly sensitive to fabrication tolerances [1]. On the other hand, FP cavities enable more tunability in terms of dispersion engineering, manufacturing stability while avoiding resonance line splitting [2]. However, achieving high-Q resonances with FP cavities that are comparable to ring resonators is challenging. This work introduces a side-coupling scheme for the development of high-Q FP cavities on an 800 nm thick silicon nitride (SiN) platform. The side-coupling approach enhances coupling efficiency, improves Q-factors, and offers better control over resonator properties compared to traditional on-plane FP configurations [3]-[4]. The experimental results demonstrate better performance in terms of quality factor and modes excitation when tapered distributed Bragg grating (DBR) mirrors are implemented in side-coupled FP cavities with respect to standard DBR. The increased tunability and high-Q performance of the reported resonant mirror design enable advanced photonic applications, including femtosecond hybrid laser generation through four-wave mixing schemes (FWM) and nonlinear effects such as Kerr nonlinearity and soliton formation, after dispersion engineering.

2. Design and experimental results

The side coupling scheme employs an optical coupler characterized by second-order Bézier curves with bending radius of R=75 μm, a gap of 400 nm and 10 μm spacing between the top waveguide and the bottom section, which incorporates the FP cavity. The cavity consists of two mirror sections based on N=2000 Bragg gratings elements on each side spaced by a cavity length of 324 μm. Figure 1 reports a schematic of the proposed side-coupled FP cavities, fabricated using MPW run of LIGENTEC foundry on an 800 nm thick SiN platform with 6.6 μm top oxide layer and 4 μm bottom oxide. The geometrical parameters are optimized for ensuring reduced propagation losses and an 80-20

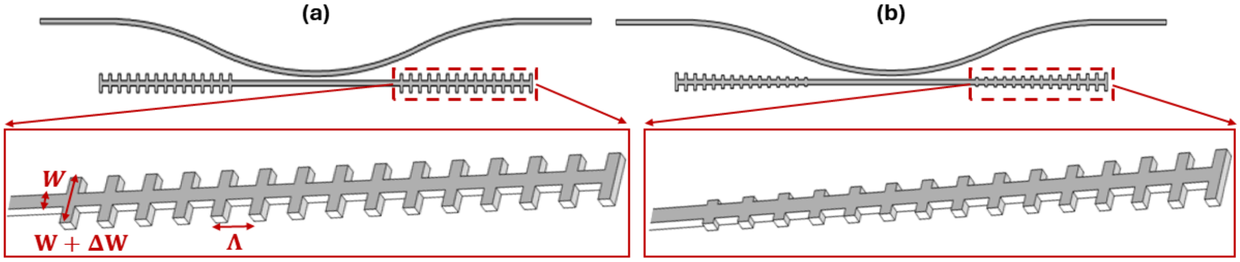

Figure 1: Schematic of the implemented side-coupled FP cavities with (e) conventional DBRs and (f) quadratic tapered DBRs. The cavity is characterized by a cavity length L_{cav}=324 μm and N=2000 Bragg mirrors based for each side.

coupling ratio between the coupler output and the DBR section. The weakly evanescent coupling enables better mode matching between the waveguide and the cavity mode, reducing scattering losses due to the indirect light injection. These factors contribute to improve Q-factor performance compared to the on-plane FP scheme. The unit cell of the SiN DBR is defined by waveguide width W=1 μm, a corrugation depth ΔW=0.8 μm and periodicity of Λ=440 nm which corresponds to a bandgap centered around 1570 nm as reported in Fig. 2(a-d). According to these parameters, it has been designed tapered-DBRs in side-coupled FP to improve mode-matching in the cavity and reduce reflection losses, consequently enhancing the quality factor values. Moreover, the smooth transition between consecutive grating sections significantly extends the overall optical path.

As depicted in Fig.1(b), the grating teeth are tapered from W to W+ΔW according to a quadratic profile, in contrast with the uniform corrugation depth shown in Fig.1(a). Notably, the effective cavity length for the tapered DBR is approximately $L_{eff,\ cav}$≈1800 μm, while the conventional DBR-based FP which has an effective length of around $L_{eff,\ cav}$≈370 μm. The tapered configuration (marked in blue) provides significantly experimentally measured higher loaded (Fig. 2(e)) and unloaded Q-factors (Fig. 2(f)), ranging up to $Q_{loaded} \approx 5 \cdot 10^4$and $Q_{unloaded} \approx 1.5 \cdot 10^5$, which directly improve the sharpness and selectivity of the resonances shown in standard DBR scheme (marked in black).

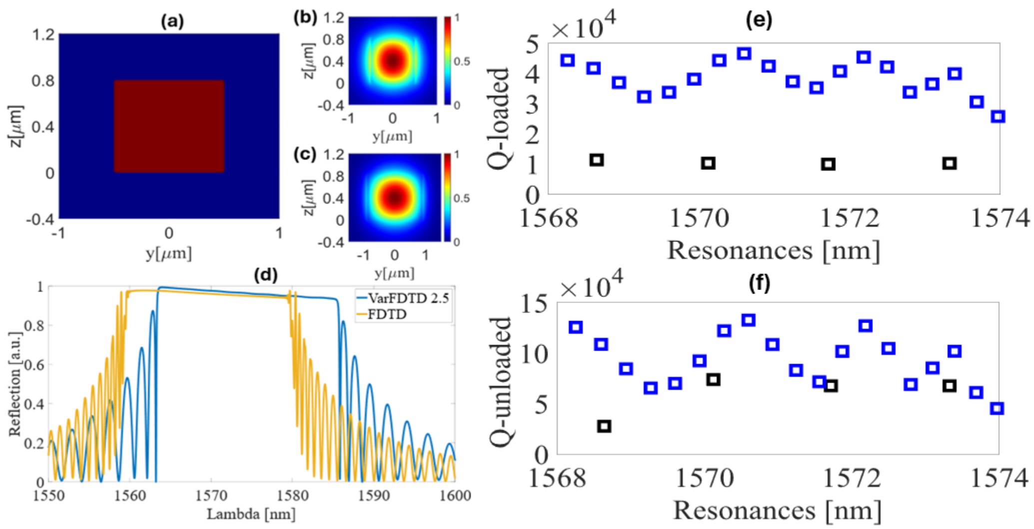

Figure 2: (a) Cross section of LIGENTEC AN800 waveguide: SiN (red) buried in SiO2 (blue). TE00 mode distribution for (b) W=1 μm waveguide width (n_{eff}≈1.749) and (c) W+ ΔW=1.8 μm (n_{eff}≈1.819) at 1570 nm. (d) Reflection of DBR characterized by P=440 nm, W=1 μm and $\Delta W = 0.8\ \mu m$ designed in VarFDTD 2.5 and FDTD. (e) Loaded and (f) unloaded Q-factors experimental results for un-tapered side-coupled FP (black square) and tapered ones (blue square). It shows $Q_{loaded} \approx 10^4$ and $Q_{unloaded} \approx 7 \cdot 10^4$ for normal DBR and $Q_{loaded} \approx 5 \cdot 10^4$ and $Q_{unloaded} \approx 1.5 \cdot 10^5$ in the tapered configuration.

3. Conclusions

In this work, we presented high-Q Si_3N_4 resonant mirrors based on side-coupling FPs. The side-injection scheme provides greater tunability for fine-tuning the grating coupling strength and increased overall DBR reflectivity, due to the less strict losses constraints. We demonstrate enhancements in terms of loaded and unloaded Q-factors, resulting in $Q_{loaded} \approx 5 \cdot 10^4$ and $Q_{unloaded} \approx 1.5 \cdot 10^5$, when a tapered corrugation depth is implemented. The improved sharpness of the resonances paves the way for advanced applications in high-stable on-chip comb laser generation.

4. References

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