Third Harmonic Generation by Optimized Hyperfine Aperiodic Optical Superlattice

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Abstract— Arbitrary spectral grids of second-harmonic generation (SHG) efficiency have been realized by hyperfine aperiodic optical superlattice (HAOS) optimized by iterative domino algorithm with unprecedented overall conversion efficiency. In this report, HAOS scheme is extended to third harmonic generation (THG) by designing two artificial wave numbers K_{SHG}, K_{SFG} that can phase-match SHG and sum-frequency generation (SFG) processes in a monolithic structure, respectively. We compared the performances of HAOS and conventional cascade structure composed of two periodic quasi-phase matching (QPM) gratings of the same length but different periods Λ_{SHG}, Λ_{SFG} numerically and experimentally. Simulation shows that HAOS outperforms the cascade structure in two aspects. (1) The THG efficiency of HAOS is 1.65 times higher than that of the cascade structure when the third-order QPM is used for SFG ($\Lambda_{\mathrm{SFG}} = 6\pi/K_{\mathrm{SFG}}$). (2) THG of any pump wavelength λ can be achieved by HAOS, while cascade structure could only permit discrete λ's due to finite resolution of mask patterning. For example, the achievable λ's (around 1595 nm) are spaced by $\sim$ 2 nm for cascade periodically poled congruent lithium niobate with 50-nm mask patterning resolution. We made a 5-cm-long QPM sample with HAOS and cascade channels to prove the concept. The HAOS channel gave a conversion efficiency of 1.0×10^{-6} at a CW pump of 500-mW average power and 1547.35-nm wavelength. In contrast, the THG signal produced by the cascade channel was below the sensitivity ($\sim$ 1 nW) of our measurement system. This is mainly attributed to the larger misalignment between the SHG, SFG efficiency spectra of the cascade channel arising from the deviation of actual wave numbers K_{SHG}, K_{SFG} from the designed values. We also proposed a three-section structure consisting of HAOS sandwiched between two first-order QPM gratings to exceed the maximum THG efficiency $\eta_{\max}$ achieved by cascade structure with two first-order QPM gratings. An analytical procedure shows that an optimal three-section structure can achieve $1.21\eta_{\max}$, which is the highest THG efficiency to the best of our knowledge.