# Kerr-comb-driven Widely-tunable Integrated Green Light Source

**Gang Wang**[1], **Ozan Yakar**[1], **Xinru Ji**[2], **Marco Clementi**[1,3], **Ji Zhou**[1], **Christian Lafforgue**[1], **Jiaye Wu**[1], **Jianqi Hu**[1], **Tobias J. Kippenberg**[2], **and Camille-Sophie Brès**[1]

[1]Photonic Systems Laboratory (PHOSL)
École Polytechnique Fédérale de Lausanne, Switzerland
[2]Laboratory of Photonics and Quantum Measurements (LPQM)
École Polytechnique Fédérale de Lausanne, Switzerland
[3]Dipartimento di Fisica "A. Volta"
Università di Pavia, Via A. Bassi 6, 27100 Pavia, Italy

**Abstract**— With the advancement of integrated photonics, silicon nitride ($Si_3N_4$) has emerged as a mature, commercially viable low-loss platform that exhibits considerable third-order ($\chi^{(3)}$) nonlinearity. The combination of nonlinearity and resonant enhancement, is widely leveraged for the design of efficient frequency converters. Recently there is significant interest in converting light towards the visible, driven by quantum applications [1]. Successful demonstrations of on-chip green light generation on $Si_3N_4$ platforms through third-harmonic generation [2] and $\chi^{(3)}$ optical parametric oscillation (OPO) [3] have shown the potential for applications in telecommunications and quantum photonics. Recent studies on photo-induced second-order ($\chi^{(2)}$) nonlinearity have further expanded the potential of $Si_3N_4$ by all-optical poling (AOP) [4], where integrated green light generation is also realized through $\chi^{(2)}$ nonlinear frequency conversion processes [5]. However, existing on-chip green light sources remain limited in their tunability. This limitation arises from the strict phase-matching requirements as well as the restricted tunability of the pump wavelength. In this work, we demonstrate a widely tunable on-chip green light source powered by Kerr-comb-driven AOP, where a record-breaking tuning range of 29 nm was achieved. Moreover, the device reached a high signal density of 11.6 $nm^{-1}$ without the need for temperature control, which is over six times higher than the record of tunable OPO-based green light sources [6]. This technique is based on the first demonstration of non-cascaded sum-frequency AOP, where coherent sidebands generated via four-wave mixing co-participate with the pump wave in the AOP process. The inclusion of coherent sidebands significantly broadens the upconversion wavelength range, allowing for a tunable green light output with an 11 nm wavelength span achieved with less than 20 pm shift in the pump wavelength. Additionally, we reveal the influence of different Kerr combs on the AOP processnamely, coherent primary combs, solitons, and incoherent modulation instability combsin a single resonance sweep. This Kerr-comb-driven AOP mechanism provides an innovative approach to wavelength tunability, effectively addressing the longstanding limitations associated with pump wavelength constraints. It substantially improves the potential of $Si_3N_4$ for visible light generation and, in principle, can be adapted for application in other challenging spectral regions.

## REFERENCES

1. Bernien, H., B. Hensen, W. Pfaff, G. Koolstra, M. S. Blok, L. Robledo, T. H. Taminiau, M. Markham, D. J. Twitchen, L. Childress, et al., "Heralded entanglement between solid-state qubits separated by three metres," *Nature*, Vol. 497, No. 7447, 86–90, 2013.
2. Levy, J. S., M. A. Foster, A. L. Gaeta, and M. Lipson, "Harmonic generation in silicon nitride ring resonators," *Optics Express*, Vol. 19, No. 12, 11415–11421, 2011.
3. Lu, X., G. Moille, A. Rao, D. A. Westly, and K. Srinivasan, "On-chip optical parametric oscillation into the visible: Generating red, orange, yellow, and green from a near-infrared pump," *Optica*, Vol. 7, No. 10, 1417–1425, 2020.
4. Yakar, O., E. Nitiss, J. Hu, and C.-S. Brès, "Generalized coherent photogalvanic effect in coherently seeded waveguides," *Laser & Photonics Reviews*, Vol. 16, No. 12, 2200294, 2022.
5. Porcel, M. A., J. Mak, C. Taballione, V. K. Schermerhorn, J. P. Epping, P. J. van der Slot, and K.-J. Boller, "Photo-induced second-order nonlinearity in stoichiometric silicon nitride waveguides," *Optics Express*, Vol. 25, No. 26, 33143–33159, 2017.
6. Sun, Y., J. Stone, X. Lu, F. Zhou, J. Song, Z. Shi, and K. Srinivasan, "Advancing on-chip kerr optical parametric oscillation towards coherent applications covering the green gap," *Light: Science & Applications*, Vol. 13, No. 1, 201, 2024.