HÜBNER Photonics

High-Power CW OPO Design for gap-free Wavelength Tuning across the Visible

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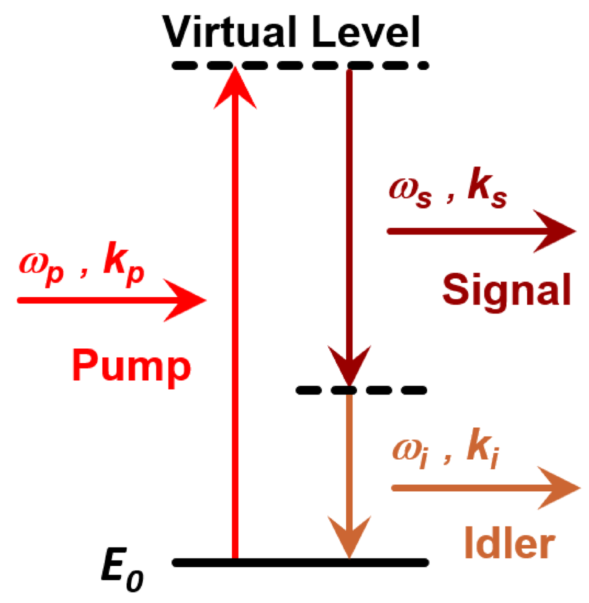
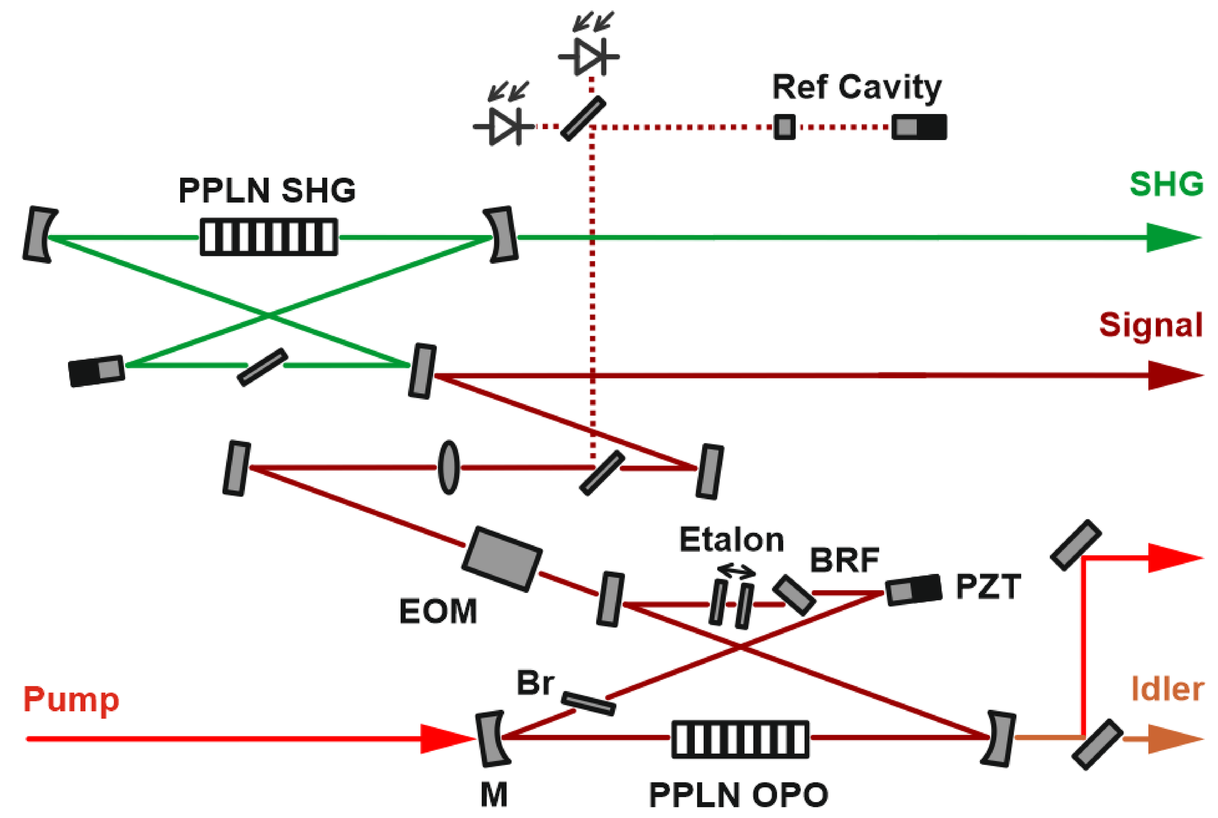
MOTIVATION

- *Commercial potential of tunable continuous-wave optical parametric oscillators (CW OPOs) derives from their wavelength versatility [1]*
- *Numerous applications call for gap-free tuning across the visible range (VIS) – a design challenge*
- *Unprecedented features demonstrated here:*
  - *Gap-free tuning over > 250 nm in the VIS*
  - *Watt-level output power*
  - *Typical linewidth < 500 kHz*

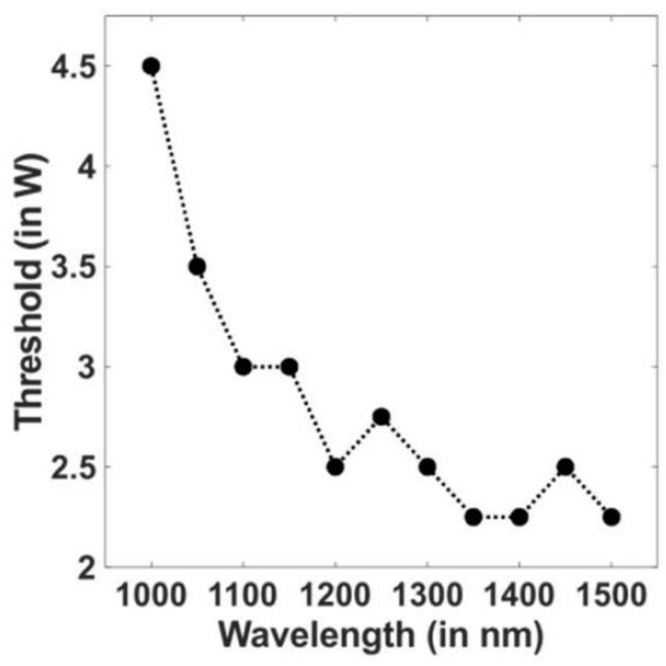


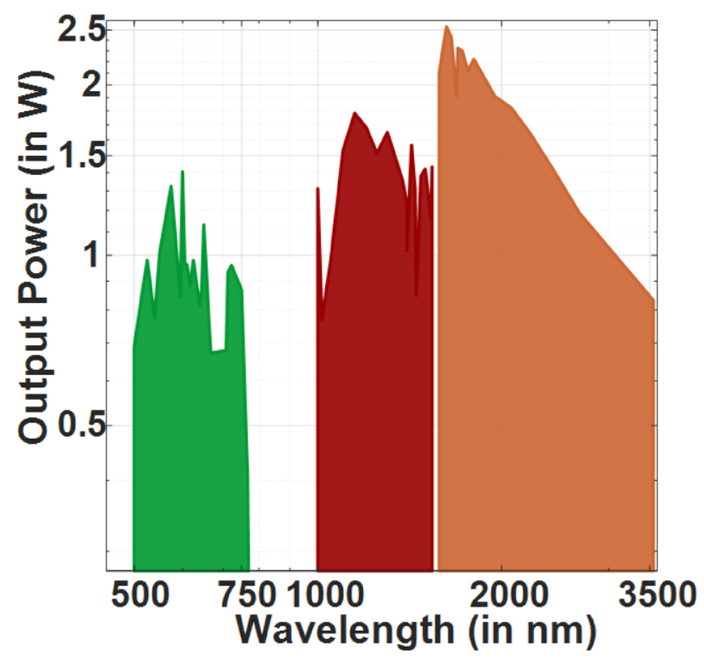


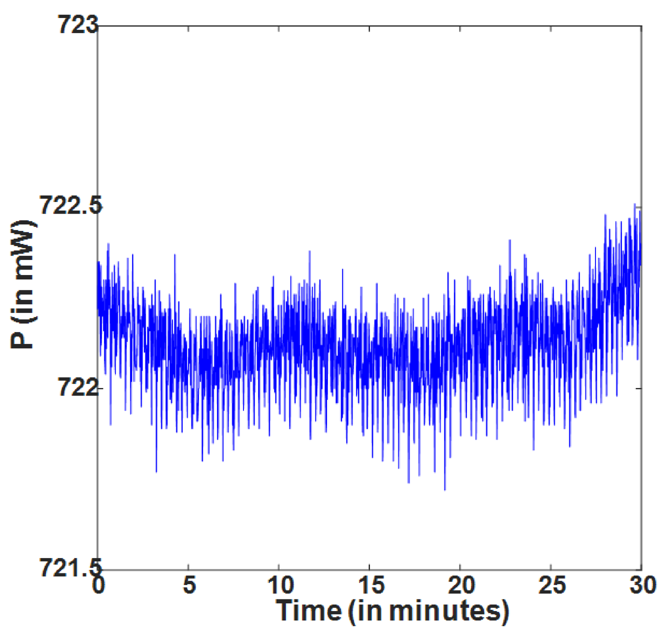
LEFT: *Schematics of optical parametric conversion in a nonlinear medium. The three-wave mixing of pump, signal and idler is subject to conservation of photon energy and photon momentum.* **RIGHT:** *CW OPO design tailored for gap-free tuning across the visible range at optimum output power. A 780 nm laser generates a signal (idler) wave in the range 1000 - 1540 nm (1580-3540 nm). Subsequent second harmonic generation (SHG) converts signal photons into the range 500 - 765 nm.*

DESIGN CONCEPT, CHARACTERISTICS, AND TUNING MECHANISMS

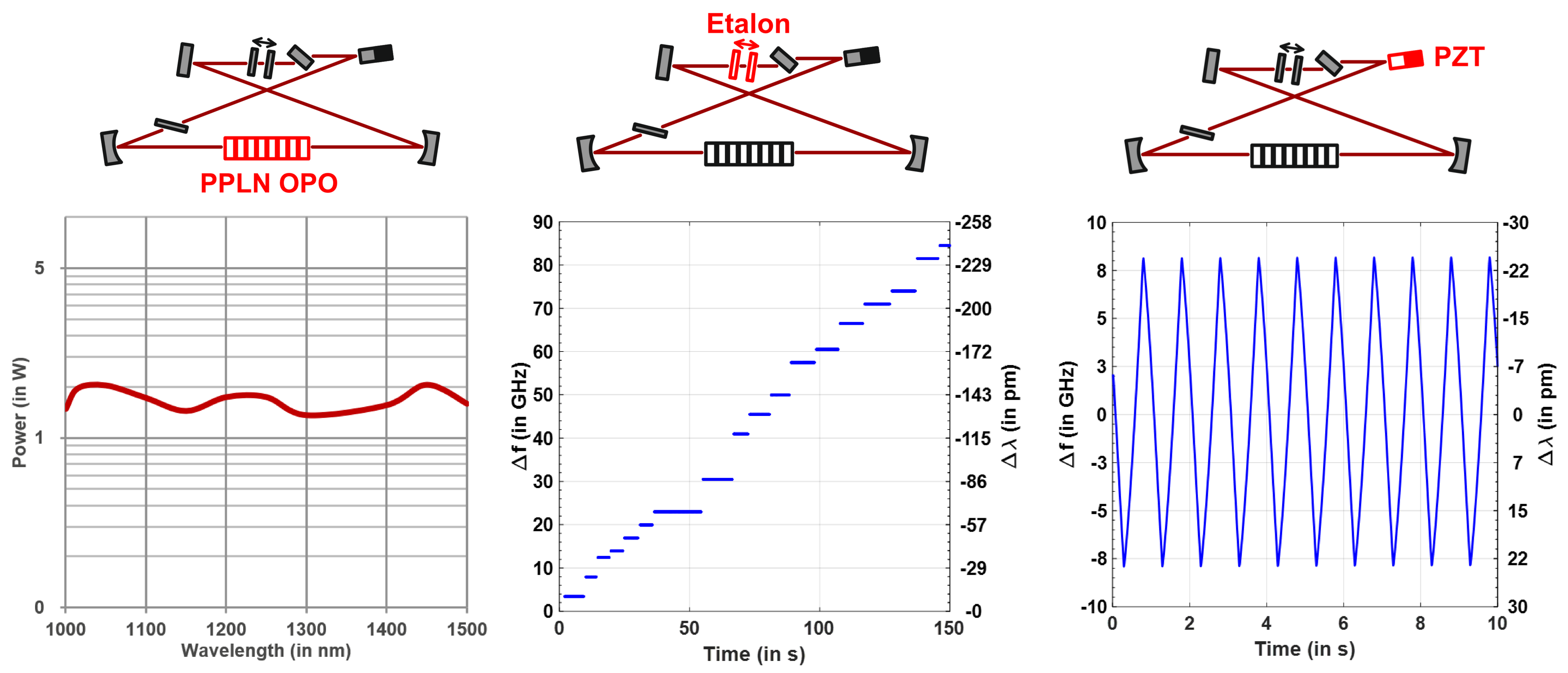
- *Two-Stage implementation combining longer wavelength pumping with second-harmonic generation (SHG) of primary OPO output*
- *Fiber-laser based pump delivering 7 W@ 780 nm*
- *Resonator layout for both OPO and SHG designed to match optimum OPO pump threshold and to maximize SHG conversion rates up to > 60% [2]*
- *Invoking an internal power stabilization scheme, a peak-to-peak power fluctuation of < 0.5 % over 30 min can be achieved*
- *Main wavelength tuning mechanisms:*
  - *Coarse tuning (crystal temperature)*
  - *Stepwise tuning (intra-cavity etalon)*
  - *Continuous tuning (piezo-scanning cavity length)*
- *System layout is general enough to be further adaptable, e.g. by power up-scaling or wavelength shifting of pump laser*







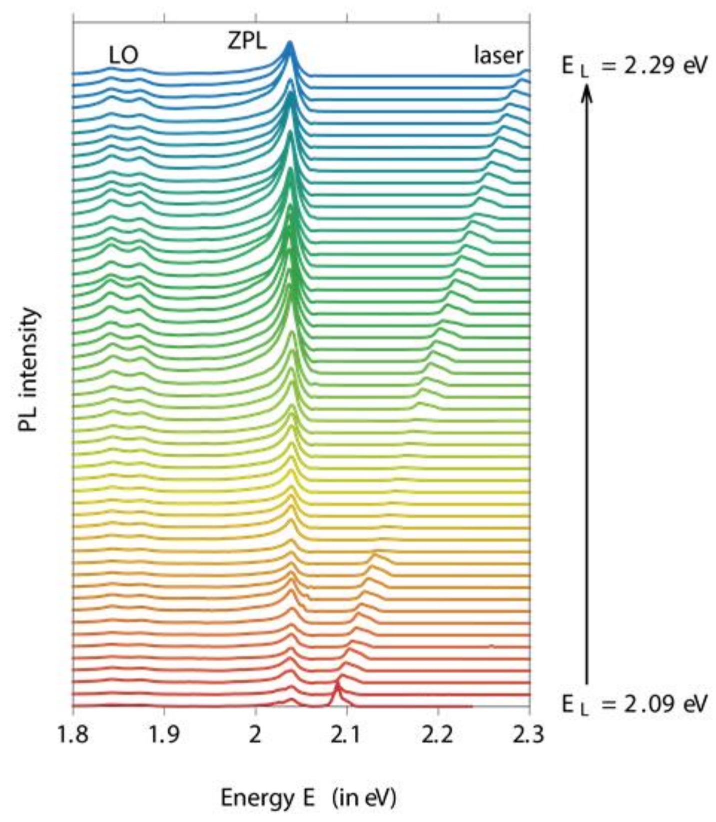
LEFT: *OPO pump power threshold as a function of OPO signal wavelength. Optimization is crucial to gain highest efficiency from the OPO process [2].* **MIDDLE:** *Output power vs. wavelength of fundamental OPO outputs and SHG output.* **RIGHT:** *Power fluctuation of 600 nm SHG output on a 30 min timescale, deploying an internal active power stabilization scheme.*



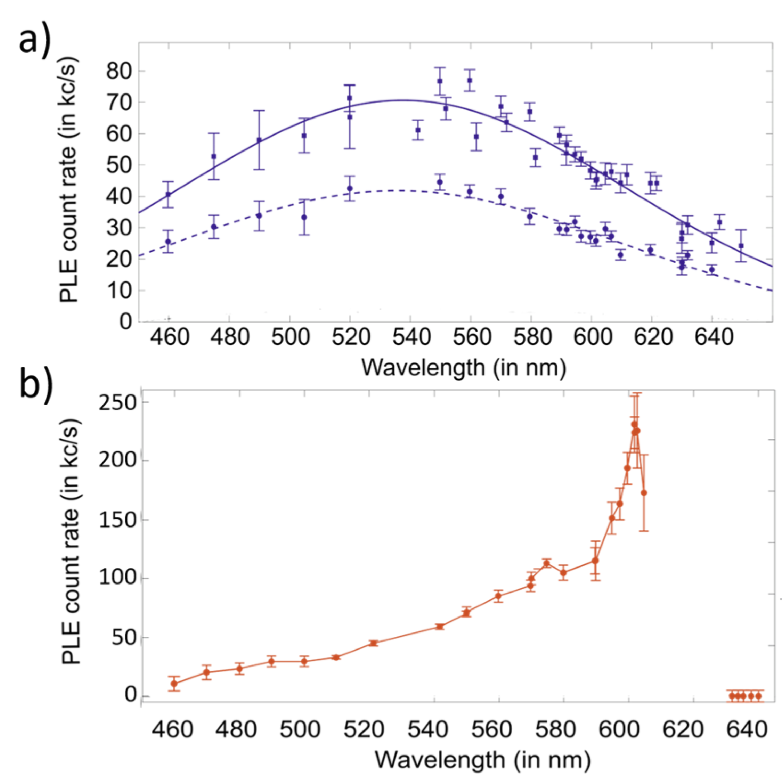
LEFT TO RIGHT: *Power of the OPO signal output recorded for a coarse scan, frequency stepping at 940 nm by stepping the intra-cavity etalon, and a truly continuous mode-hop free scan at 940 nm. The overlapping tuning ranges of the three mechanisms provide gap-free wavelength coverage over > 250 nm in VIS.*

TUNABLE CW OPOs AT WORK: CHARACTERIZING SINGLE-PHOTON EMITTERS

- *Experimental studies frequently necessitate tuning the laser frequency throughout a wide spectral range, while high finesse spectral resonances require sufficiently narrow linewidths*
- *For illustration, datasets on two different kinds of single-photon emitters are shown here (adapted with permission from ref. [3] and [4]).*



LEFT: *Photoluminescence spectra of a single defect center in hBN recorded under laser excitation energy tuning from 593 nm to 541 nm [3].* **RIGHT:** *(a) Photoluminescence excitation spectra of an ensemble of Si-V centers recorded at two excitation powers. (b) Photoluminescence excitation spectrum of an ensemble of Ge-V centers recorded at 0.25 mW excitation power [4].*



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[2] R. Sowade et. al., "Influence of the pump threshold on the single-frequency output power of singly resonant optical parametric oscillators", Appl. Phys. B, 96, 25 (2009)
[3] D. Wigger et. al., "Phonon-assisted emission and absorption of individual color centers in hBN", 2D Mat. 6(3), 035006 (2019)
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