Highlights

Advanced materials and techniques for organic electronics, biomedical and sensing applications - 2018

Phase-matching-free parametric oscillators based on two dimensional semiconductors

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LIGHT: SCIENCE & APPLICATIONS 7 (2018) 5

Optical parametric oscillators are widely used as pulsed and continuous-wave tunable sources for innumerable applications, such as quantum technologies, imaging and biophysics. A key drawback is material dispersion, which imposes a phase-matching condition that generally entails a complex design and setup, thus hindering tunability and miniaturization.
We have obtained the new and unexpected result that micro-resonators embedding monolayer transition metal dichalcogenides (ML-TMD) produce doubly resonant parametric oscillations with unprecedentedly small cavities of few microns thanks to the strong nonlinearity of these materials and their atom-sized thickness, which circumvent the ubiquitous phase-matching condition of state-of-the-art quadratic nonlinear optics. Bearing in mind that nonlinear optics ignited in 1961 with the discovery of second-harmonic generation (a parametric effect ruled by phase-matching) by Peter Franken et al. at University of Michigan, we envisage that the extent, importance and impact of our findings can be enormous since they dismiss a paradigm standing ever since fifty years. In addition, electrical voltage gating of two-dimensional material provides our setup with a further external control parameter that can be used to modulate the parametric radiation emission.

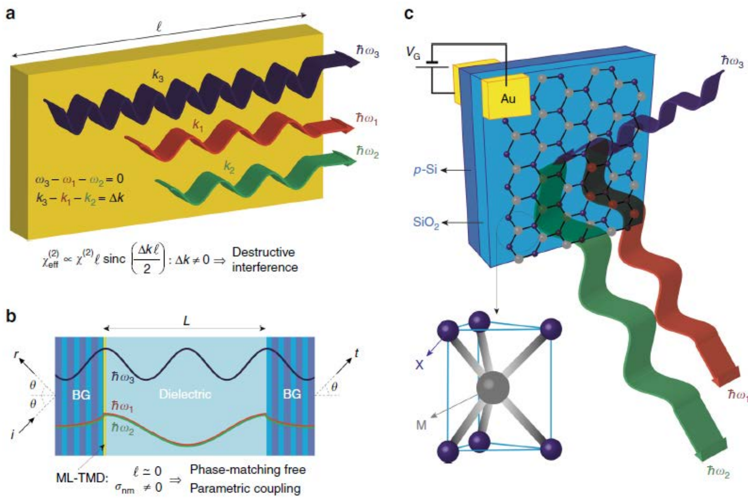

Fig. 1 **a.** Schematic illustration for conventional three-wave parametric coupling in bulk nonlinear crystals. The effective quadratic susceptibility $\chi^{(2)}_{\rm eff}$ is heavily affected by the mismatch Δk among the wavevectors $k_m = n_m \omega_m / c$ of the pump (3), signal (1) and idler (2) waves, whose destructive interference $\Delta k \neq 0$ hinders parametric coupling. **b.** Sketch of the ML-TMD based parametric oscillator. The cavity is assembled using two Bragg mirrors separated by a dielectric layer, and the ML-TMD is placed onto the left mirror. The incident (i) pump field produces both reflected (r) and transmitted (t) pump, signal and idler fields by means of the ML-TMD quadratic surface conductivity $\sigma_{nm} \neq 0$. The mutual dephasing $\Delta\phi = \Delta k l$ among these three waves becomes negligible within the atomic thickness of the nonlinear ML-TMD ($\Delta\phi \approx 10^{-2}$) because $l = \lambda$, thus enabling phase-matching-free (*i.e.*, free from the momentum conservation requirement ($\Delta k = 0$) parametric coupling. **c.** Sketch of the geometry of MX_2 ML-TMDs. Fast modulation is enabled by extrinsic doping by a gate voltage, with gold contacts applied between the ML-TMD and the Bragg mirror.