Complete energy conversion by autoresonant three-wave mixing in nonuniform media

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Three-Wave Mixing (TWM) processes appear in many fields of physics e.g. nonlinear optics, plasma physics, acoustics and hydrodynamics. Recently, a general theory of autoresonant three-wave mixing in a nonuniform medium has been derived analytically and demonstrated numerically [1]. It has been shown that due to the medium nonuniformity, a stable phase-locked evolution is automatically established. For a weak nonuniformity, the conversion efficiency between the interacting waves can reach almost 100% of the pump energy. We have shown that due to mechanisms different from those previously reported, it is possible to establish an autoresonant state in wave-mixing processes, resulting in pump-depletion, also in the absence of self-phase and cross-phase modulation effects. Our work generalizes previous studies about two-wave mixing processes in spatially-varying media [2,3] and TWM in the undepleted pump regime (which is effectively a two-wave mixing process) [4].

One of the potential applications of our theory is the design of highly-efficient $\chi^{(2)}$ Optical Parametric Amplifiers (OPAs) allowing complete pump depletion. This kind of OPAs is expected to have a very large amplification bandwidth with a flat amplification spectral profile, similarly to what have been suggested and demonstrated in the case of four-wave mixing in tapered optical fibers [5].

References: