Nonlinear Competing Processes in Multifrequency Raman Generation

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Abstract

Parametric and non-parametric nonlinear competing processes in ultra-broadband multifrequency Raman generation (UMRG) are investigated analytically and numerically. Results are also used to examine alternative experimental configurations in which UMRG is driven by detuned pump beams.

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Summary

Ultra-broadband Multifrequency Raman Generation (UMRG) is one of the most novel nonlinear optical processes to have emerged over the last few years. With H_2 gas as the Raman medium, we predicted that nearly 50 distinct frequencies of comparable energy may be generated [1-4]. For UMRG in air, beams containing around 150 waves may be attained [5]. Experimental results, that support our overall predictions, are appearing in the literature. However, some configurations exhibit competition between distinct Raman resonances. This feature may have serious consequences for many of the proposed applications for UMRG. Here, we present new analyses and simulations which take such nonlinear competing processes into account.

An effective gain-length product, Z^{eff}, for a *non-parametric* parasitic wave is introduced and its characteristics examined. For competing processes generated from background noise or amplified spontaneous emission, an analytical model is derived. Predictions of this model are found to be in good agreement with numerical simulations (see figure 1). The roles played by pump intensity, dispersion, transiency and the initial level of

the competing process are systematically investigated. The efficiency and character of UMRG, with resonant and symmetric pumping, is found to keep such nonlinear competing processes below threshold, $Z^{eff} < Z^{th} \simeq 25$. UMRG is also found to be robust when the competing signal grows from a strong seed, as could arise from the scattering of a pump beam off an optical element.

It is also possible that UMRG lines could *parametrically* generate a parasitic wave through scattering involving a distinct Raman transition. For such a process, the respective pump waves are detuned from the appropriate Raman resonance. We study a worst-case scenario, in which *only* the parametric competing process is driven, and examine the role of detuned pump beams in UMRG. Results are interpreted in terms of candidate competing transitions. We also use this data to investigate the effectiveness of alternative experimental configurations in which independent oscillator/amplifier chains generate the UMRG pump beams. Pump detuning is found to introduce new four-wave mixing processes and a mechanism to offset gain suppression effects. A surprising conclusion is that, in some cases, finite detuning may result in comparable or even greater bandwidth (see figure 2).

References

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Figure Captions

1. Effective gain-length, Z^{eff}, for a competing nonlinear process as a function of normalised distance, Z. The heavy solid curve is the analytic model for Z^{eff}. Other curves are calculated directed from simulation data.

2. Bandwidth of the multifrequency beam (in units of the Stokes shift) as a function of normalised distance, Z. Curves are for different pump beam detunings, δ. Heavy and light solid curves are for $|\delta| = 0$ and 2, respectively, while the corresponding dotted curves are for $|\delta| = 5$ and 10. Part (a) is for $\delta \geq 0$ and part (b) has $\delta \leq 0$.

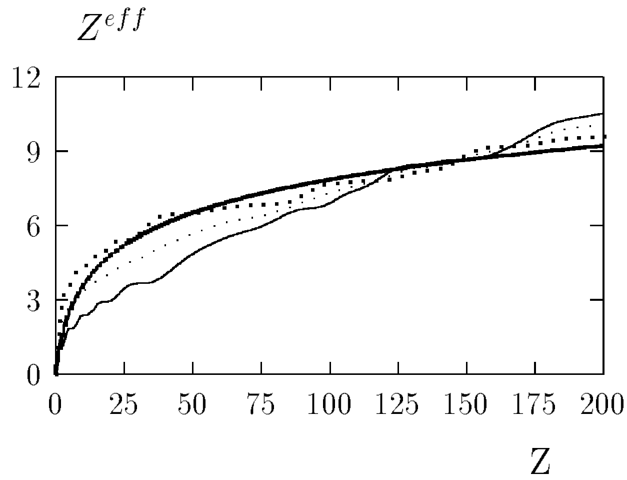

Figure 1

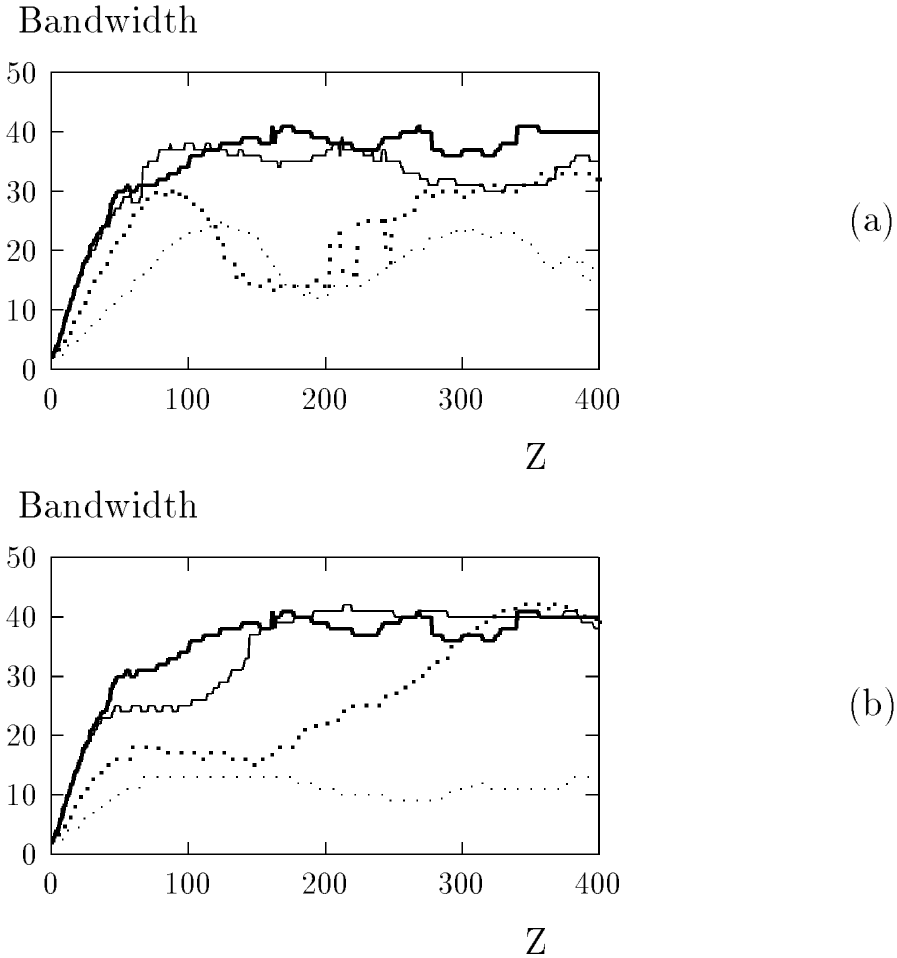
Bandwidth
50
40
30
20
10
0
0
100
200
300
400
Z
(a)
Bandwidth
50
40
30
20
10
0
0
100
200
300
400
Z
(b)

Figure 2