Ultra-Broadband Light Generation in Air and Cooled Nitrogen

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Non-parametric stimulated Raman scattering is well-established as a simple and efficient method of converting laser radiation to one or more lower (Stokes) frequencies. However, parametric Raman conversion to higher frequencies, or the simultaneous generation of multiple Raman lines, has generally been found to be much less efficient. We have shown that the collinear generation of higher orders using two input beams, whose frequency difference is resonant with the Raman transition and which are temporally symmetric (of matching intensity and shape), has much greater potential. Considering hydrogen gas, the generation of a single multifrequency beam consisting of nearly 50 waves of comparable energy is feasible [1].

Previously, we derived and tested an exact analytic solution which predicts the bandwidth generated in steady-state multifrequency generation [1]. We will firstly report on the generalisation of this analytic work to include transient effects. Our new result incorporates finite Stokes shift, polarisation dephasing time and arbitrary input pulse shape. The possibility of using air as the Raman medium has obvious attractions. Experimental work, in which only single beam pumping was implemented, has shown that bandwidths of 2% of the pump frequency are possible [2]. Their results can be explained in terms of multiple (non-parametric) Stokes cascade processes. Our mathematical and numerical analyses predict that the resonant pumping of a single rotational transition of atmospheric nitrogen leads to a multifrequency beam consisting of 200-250 distinct waves of comparable energy (see Fig 1). The necessary input intensities are an order of magnitude lower than those used in [2].

A full evaluation of the optimal conditions for multifrequency generation using air and cooled nitrogen will be presented. For the latter case, we predict that a bandwidth of 300 waves can be generated in a chamber of length 3m and that the optimum bandwidth increases to over 500 waves for longer propagation lengths (see Fig 2). Finally, the key results of a further analysis which explains the fundamental differences in bandwidth optimisation requirements for hydrogen, air and cooled nitrogen will be reported.

[1] LL Losev and AP Lutsenko, Kvant Elect (Moscow) **20**, 1054 (1993), GS McDonald, GHC New, LL Losev, AP Lutsenko and MJ Shaw, Opt Lett **19**, 1400 (1994), GS McDonald, Opt Lett **20**, 822 (1995). [2] D Eimerl, D Milam and J Yu, Phys Rev Lett **70**, 2738 (1993).

Fig 1 Bandwidth generated in air for (a) 1ns, (b) 130ps and (c) 16ps input pulses.

Fig 2 Output spectrum for cooled N_2. Frequencies are $\omega_n = \omega_0 + n\omega_R$ (where ω_0 is the pump, ω_R=Stokes shift).