RAMAN GENERATION OF ULTRA-BROADBAND LIGHT USING NITROGEN

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The phenomenon of ultra-broadband multifrequency Raman generation (UMRG) has only recently been discovered and presents a goldmine of new physics with a wealth of possible uses. In addition to frequency conversion, sensing and spectroscopy, a key application lies in the field of inertial confinement fusion. Our previous work has concentrated on the case of hydrogen as the Raman medium and we have predicted that a multifrequency beam with a bandwidth of nearly 50 waves of comparable energy may be generated[1a)]. The proposed technique involves using two collinear input beams, with matching temporal profiles, which resonantly drive a rotational transition of the gas (resonant symmetric pumping). For nominal parameters, say a pressure of 1 atmosphere hydrogen and a propagation length of 2 metres, one can maximise the bandwidth of the multifrequency light by varying the pulsewidth and the intensity of the pump beams[1a)]. During the last year we have been continuing to extend the understanding of UMRG in hydrogen through the development of analytical models coupled with numerical simulation of the full model equations. Our earlier analysis[1b)] yielded a model for the parametric gain which is applicable to dispersionless UMRG under cw conditions. This work has now been extended to incorporate the transient effects which arise from the pulse profiles of the constituent light waves and the dephasing time, T_2, of the polarisation wave in the medium[1c)].

We have also extended our investigations to consider the use of nitrogen as the nonlinear medium. The resonant driving of a number of candidate rotational transitions and the optimal conditions under which each can be exploited has been examined. The use of air as the nonlinear medium has very obvious attractions and in this brief communication we report some results on this subject. Experiments demonstrating Raman frequency generation in nitrogen and air have already been performed. However, the configurations that were used are highly non-optimal for bandwidth production. In one case[2a)] only around 15 sidebands were generated because a single pump beam was employed; new frequencies had to grow from background noise - a relatively inefficient process. In another set of experiments, Dangor et al[2b)] investigated the propagation of two light beams in air and rotational Raman scattering was observed to be the dominant effect. Their configuration generated several sidebands even though the frequency difference of their input beams was around 10 linewidths aways from resonance.

We consider here the resonant symmetric pumping of a single rotational transition (J=8 to 10) of atmospheric nitrogen; defining a Stokes shift of $76cm^{-1}$. The pump beam of higher frequency is the second harmonic of a Nd:YAG laser ($18900cm^{-1}$). We predict that this configuration can lead to a multifrequency beam consisting a number of distinct waves which is 1 to 2 orders of magnitude higher than those previously observed[2)]. In Fig 1 we show the role that input pulsewidth plays in determining the growth in bandwidth of the multifrequency beam as it propagates. We generally find that input pulsewidth can have an important limiting effect since, for shorter pulses (of width around, or less than, T_2=130ps), the bandwidth tends to fall off at larger distances. In Fig 2 we consider relatively long input pulses (1ns) and the role that their intensity plays. In contrast to the effect of shorter pulsewidth, for lower intensity beams the bandwidth continues to grow with distance. For example, after propagating a distance of 150 metres (not shown) case (b) grows to approximately 180 Stokes shifts while case (c) reaches a bandwidth of around 90 waves. In common with our results for UMRG in hydrogen[1a)], we find that input pulsewidths of around an order of magnitude greater that T_2 are optimal. At difference with those results, we find that the highest available input intensities will be optimal (provided that this is not at the expense of having to use highly focused beams[1b)]). This new feature has been the subject of analytical investigations and we have found that the explanation lies in the rather sensitive dependence of Raman gain suppression on the Stokes shift. This, in turn, leads to an optimal normalised mistuning parameter[1a)] which is orders of magnitude smaller than that found for hydrogen. The experimental confirmation of these predictions presents an exciting task.

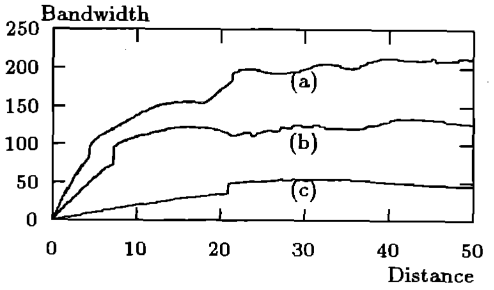

Fig 1 Bandwidth (in units of the Stokes shift) as a function of propagation distance in air (in metres). Square input pulses of intensity $30GWcm^{-2}$ are considered. Input pulsewidths are (a) 1ns, (b) 130ps and (c) 16ps.

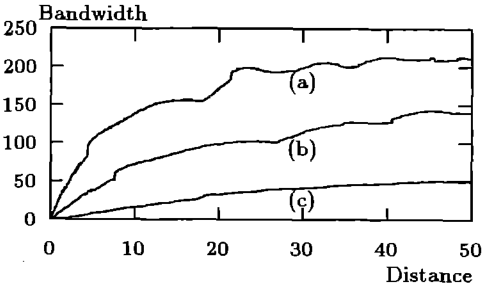

Fig 2 Bandwidth generated as a function of propagation distance in air for 1ns input pulses. The intensity of the launched pulses is a) $30GWcm^{-2}$, (b) $10GWcm^{-2}$ and (c) $2GWcm^{-2}$.

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