Ultra-Broadband Light Generation in Air

G.S. McDonald and G.H.C. New,
Laser Optics and Spectroscopy Group, Blackett Laboratory,
Imperial College of Science, Technology and Medicine,
Prince Consort Road, London SW7 2BZ, UK
Tel. : +44 171 594 7659 – Fax : +44 171 594 8376
Email : g.mcdonald@ic.ac.uk
–
L.L. Losev and A.P. Lutsenko,
P.N. Lebedev Physical Institute,
Leninsky Prospekt 53, 117924 Moscow
–
M.J. Shaw,
Rutherford Appleton Laboratory,
Chilton, Didcot, Oxfordshire OX11 OQX, UK

Abstract

We predict that ultra-broadband light (containing nearly 100 distinct frequencies of comparable amplitude) can be generated in air through stimulated Raman scattering by using resonant symmetric pumping. Results for cooled nitrogen will also be presented.

Ultra-Broadband Light Generation in Air

G.S. McDonald and G.H.C. New,
Laser Optics and Spectroscopy Group, Blackett Laboratory,
Imperial College of Science, Technology and Medicine,
Prince Consort Road, London SW7 2BZ, U.K.
Tel. : Tel. : +44 171 594 7659 – Fax : +44 171 594 8376
Email : g.mcdonald@ic.ac.uk
–
L.L. Losev and A.P. Lutsenko,
P.N. Lebedev Physical Institute,
Leninsky Prospekt 53, 117924 Moscow
–
M.J. Shaw,
Rutherford Appleton Laboratory,
Chilton, Didcot, Oxfordshire OX11 OQX, U.K.

Summary

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 beams whose frequency difference is resonant with the Raman transition and which are temporally symmetric (pulses 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].

In addition to full numerical simulations, we have derived and tested an exact analytic solution which predicts the bandwidth generated in steady-state multifrequency gener-

ation [1]. We will firstly report on the generalisation of this analytic work to include transient effects. Our new result includes finite Stokes shift, polarisation dephasing time and arbitrary input pulse shapes. The dependence of bandwidth generated on these and other system parameters will be presented.

The possibility of using air as the Raman medium has obvious attractions. Experimental work has been published in which bandwiths of 2% of the pump frequency were generated [2]. However, only single beam pumping was implemented and their results can be explained as being mainly due to multiple (non-parametric) Stokes cascade processes. Our analyses predict that the resonant symmetric pumping of a single rotational transition of atmospheric nitrogen will lead to the generation of bandwidths of the order of 100 Stokes shifts. Furthermore, we find that the necessary input intensities are one or two orders of magnitude lower than those used in [2]. Simulations support these predictions (see Fig 1-3). A full evaluation of the use of air and cooled nitrogen will be presented.

References

[1] L. L. Losev and A. P. Lutsenko, Kvantovaya Electron. (Moscow) **20**, 1054 (1993), G.S. McDonald, G.H.C. New, L.L. Losev, A.P. Lutsenko and M.J. Shaw, Opt. Lett. **19**, 1400 (1994), G.S. McDonald, Opt. Lett. **20**, 822 (1995).

[2] D. Eimerl, D. Milam and J. Yu, Phys. Rev. Lett. **70**, 2738 (1993).

Figure Captions

1. Frequencies generated ($\omega_n = \omega_0 + n\omega_R$) as function of air path L (in metres) for two CW input beams ($n = 0$ and $n = -1$) which each have an intensity of $5 GW cm^2$.

2. Time-integrated spectrum at $L = 150m$ for $1ns$ input pulses.

3. Growth of generated bandwidth during propagation for input pulsewidths of (a) $1ns$, (b) $130ps$ and (c) $30ps$.