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Title: CALCULATION AND MEASUREMENT OF STIMULATED ROTATIONAL RAMAN SCATTERING IN ATMOSPHERIC OXYGEN

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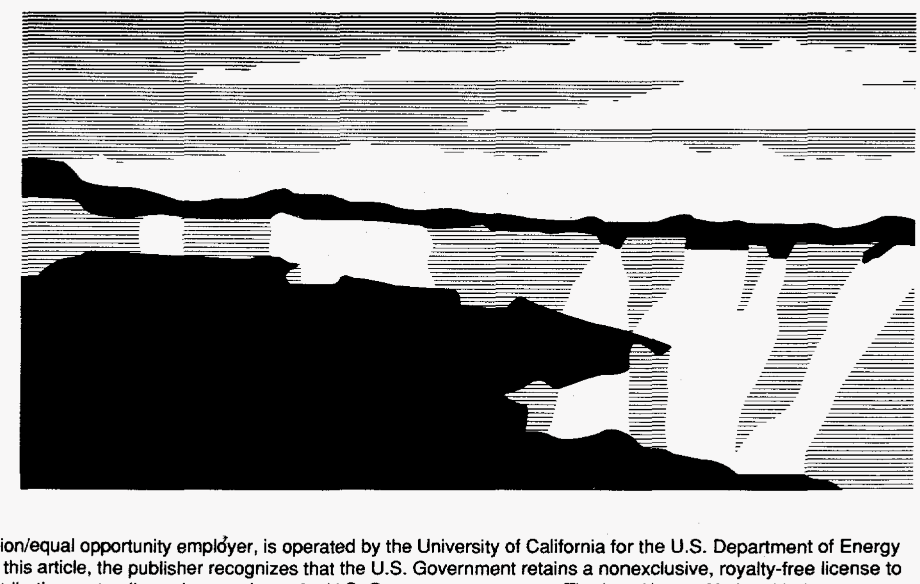

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Calculation and Measurement of Stimulated Rotational Raman Scattering in Atmospheric Oxygen

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Abstract

Calculations of the rotational Raman gain in atmospheric air that indicate that O_2 has more than 75% of the peak gain of N_2 have been substantiated by experiment.

Calculation and Measurement of Stimulated Rotational Raman Scattering in Atmospheric Oxygen

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It is well known that stimulated rotational Raman scattering (SRRS) in atmospheric nitrogen presents a limitation to the propagation of high intensity laser radiation through long air paths.[1-3] A method that has sometimes been proposed to mitigate this problem in laser fusion facilities is to replace part of the air path with a breathable mixture of oxygen and a monatomic gas such as argon. However, some earlier calculations,[4] which have now been extended and verified by experiment, indicate that the peak SRRS gain of oxygen in atmospheric air is approximately 77% that of nitrogen in air at the wavelength of Nd:glass lasers, and increases slightly, to about 80%, at the third harmonic.

A calculation of the rotational Raman gain in atmospheric nitrogen and oxygen at 1053 nm is indicated by the stick spectrum in Fig. 1. The lines are labeled by the rotational quantum number of the lower level as typically used for an S-branch transition, although the oxygen spectrum is actually more complicated, exhibiting fine structure caused by the multiplicity of the rotational levels of the $^3\Sigma_g^-$ ground state.[5] This splitting has almost no effect on the calculated spectrum for all but the lowest rotational levels, but was mistakenly assumed to lower the gain by a factor of three in a previously published calculation.[3]

The experiment carried out to validate these conclusions consisted of focusing up to 250 mJ of circularly-polarized 355-nm radiation first in an air path and then through a cell that could be filled with various mixtures of gases. Although it was possible to reach threshold in this way, the system was double-passed in order to further lower the threshold. With the cell filled with air, the typical rotational spectrum of nitrogen was observed. Filling the cell with a 600 Torr 20% O_2/80% Ar mixture produced the SRRS spectrum of O_2 shown in Fig. 2(a). The amount of ant-Stokes radiation observed was highly dependent on the degree of circular polarization that could be maintained after several turning mirrors. With the cell half-filled with the O_2/Ar mixture and half-filled with air, it was possible to obtain the mixed spectra shown in Fig. 2(b). It should be noted that because of optics losses the two focuses in the air path account for approximately 6% more gain than the two focuses in the cell. These results are in good agreement with the expected ratio of approximately 80% of the gain on the peak O_2 and N_2 lines. It should also be noted that some of the lines are very-nearly overlapped, particularly the N_2 S(9) and O_2 S(13) which differ by less than 0.25 cm^{-1} and which appears as one of the strongest lines in the spectrum when the gains are nearly equalized. This line has previously been observed in the SRRS spectrum of air and attributed to N_2.[2]

References

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Figure Captions

Fig. 1 Calculated rotational Raman spectrum of N_2 andO_2 in air.

Fig. 2. a) Observed spectrum of O_2 with O_2/Ar in cell. b) Spectrum with mixtures in cell to give nearly equal gain on O_2 and N_2.

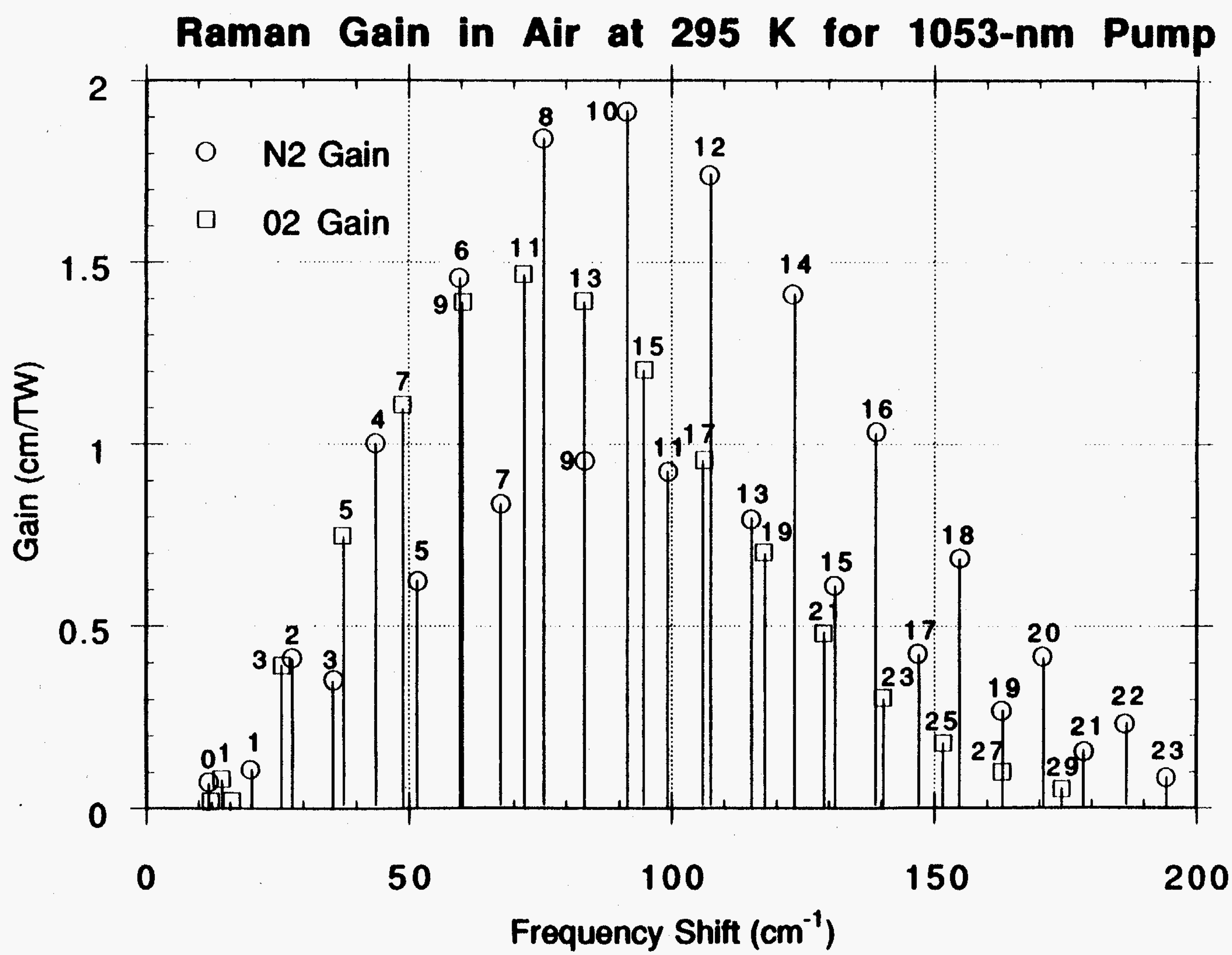
Raman Gain in Air at 295 K for 1053-nm Pump
N2 Gain
02 Gain
Gain (cm/TW)
Frequency Shift (cm-1)
0
50
100
150
200
0.5
1
1.5
2
0 1 1 3 2 3 5 4 7 5 9 6 7 11 8 9 13 10 15 11 17 12 13 19 14 21 15 16 23 17 18 25 19 27 20 29 21 22 23

Fig. 1

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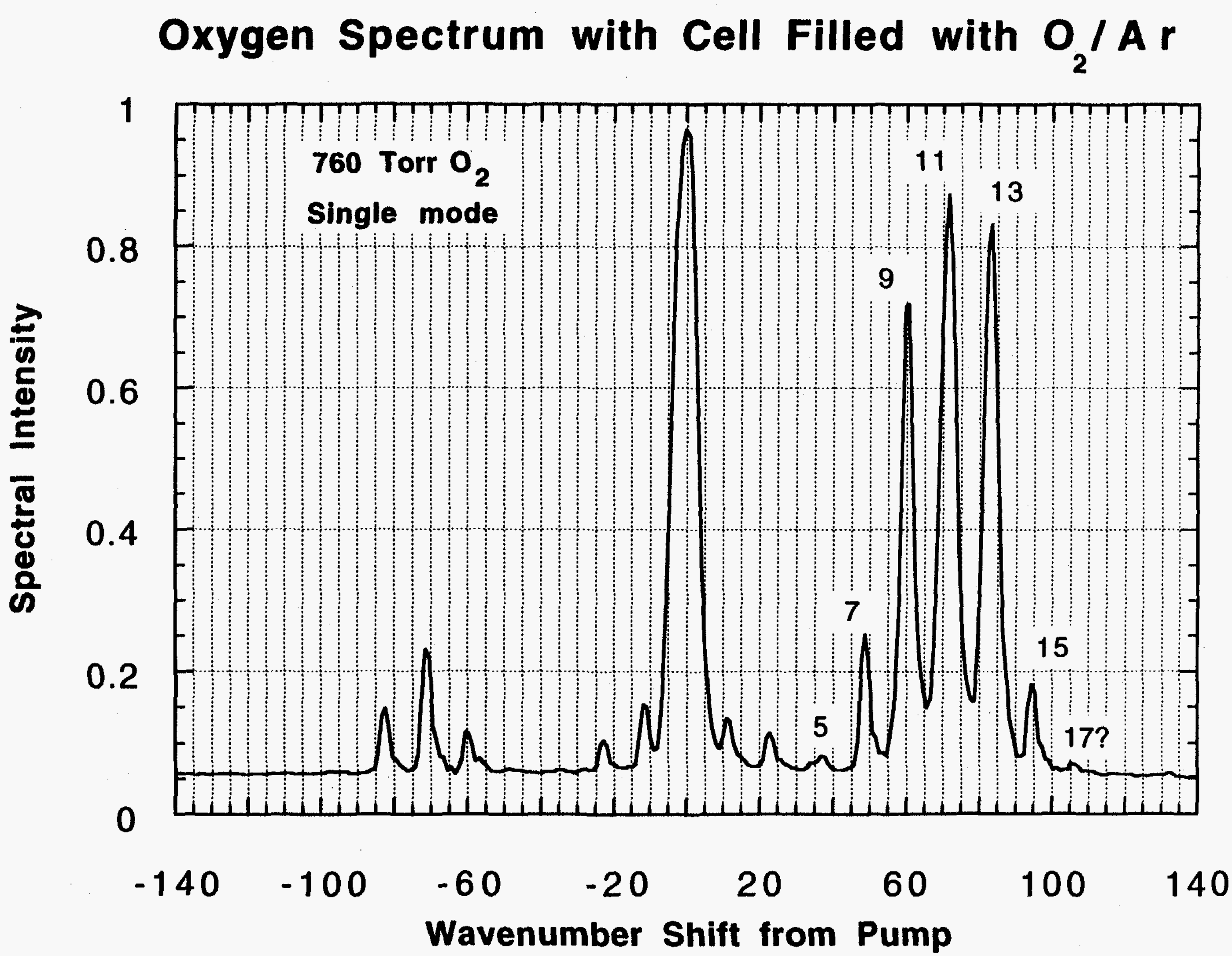

Fig 2(a)

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Spectra With Gas Mixtures In Cell