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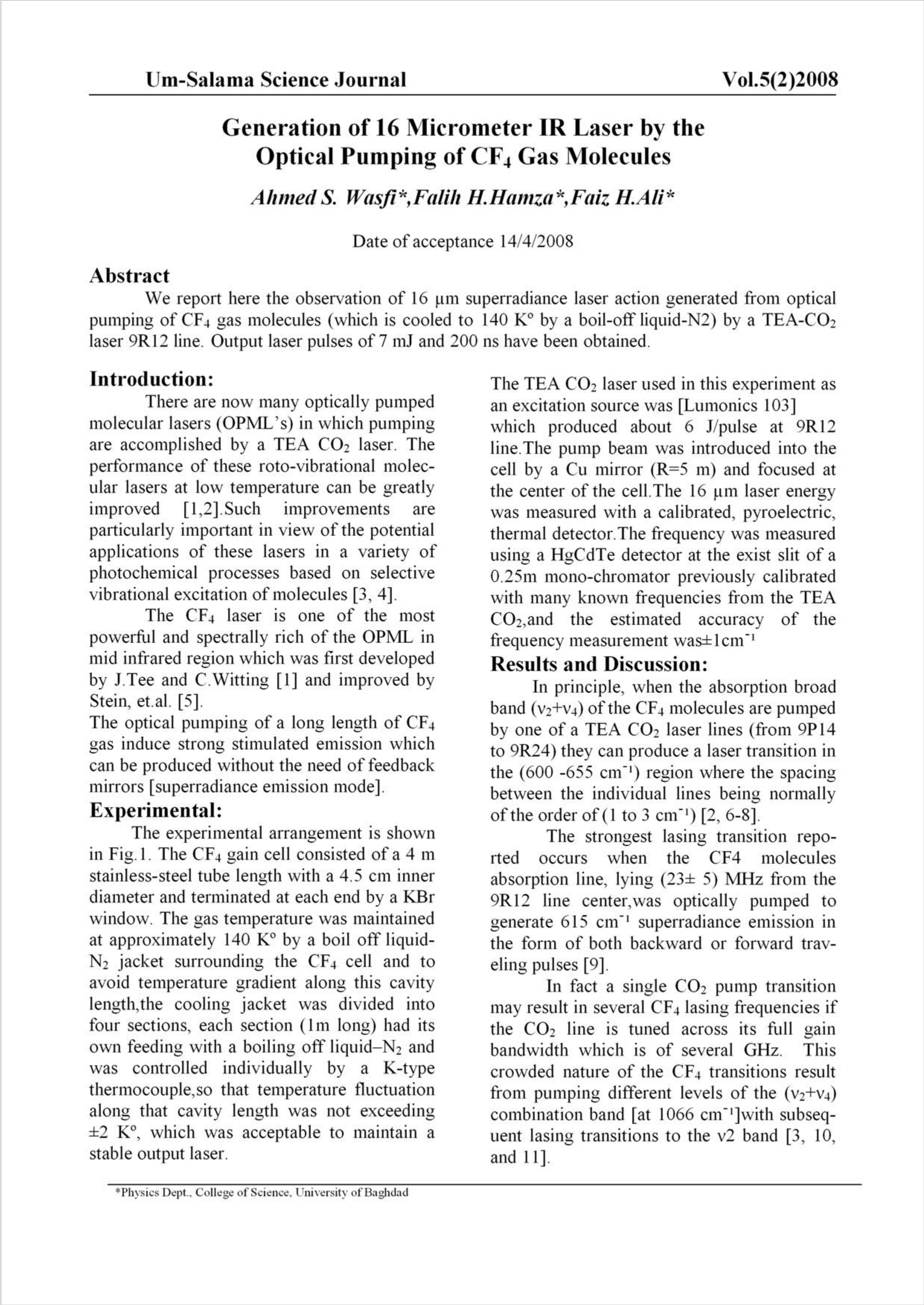

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Generation of 16 Micrometer IR Laser by the Optical Pumping of CF_4 Gas Molecules

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Abstract

We report here the observation of 16 µm superradiance laser action generated from optical pumping of CF_4 gas molecules (which is cooled to 140 K° by a boil-off liquid-N2) by a TEA-CO_2 laser 9R12 line. Output laser pulses of 7 mJ and 200 ns have been obtained.

Introduction:

There are now many optically pumped molecular lasers (OPML's) in which pumping are accomplished by a TEA CO_2 laser. The performance of these roto-vibrational molecular lasers at low temperature can be greatly improved [1,2].Such improvements are particularly important in view of the potential applications of these lasers in a variety of photochemical processes based on selective vibrational excitation of molecules [3, 4].

The CF_4 laser is one of the most powerful and spectrally rich of the OPML in mid infrared region which was first developed by J.Tee and C.Witting [1] and improved by Stein, et.al. [5].

The optical pumping of a long length of CF_4 gas induce strong stimulated emission which can be produced without the need of feedback mirrors [superradiance emission mode].

Experimental:

The experimental arrangement is shown in Fig.1. The CF_4 gain cell consisted of a 4 m stainless-steel tube length with a 4.5 cm inner diameter and terminated at each end by a KBr window. The gas temperature was maintained at approximately 140 K° by a boil off liquid-N_2 jacket surrounding the CF_4 cell and to avoid temperature gradient along this cavity length,the cooling jacket was divided into four sections, each section (1m long) had its own feeding with a boiling off liquid–N_2 and was controlled individually by a K-type thermocouple,so that temperature fluctuation along that cavity length was not exceeding ±2 K°, which was acceptable to maintain a stable output laser. The TEA CO_2 laser used in this experiment as an excitation source was [Lumonics 103] which produced about 6 J/pulse at 9R12 line.The pump beam was introduced into the cell by a Cu mirror (R=5 m) and focused at the center of the cell.The 16 µm laser energy was measured with a calibrated, pyroelectric, thermal detector.The frequency was measured using a HgCdTe detector at the exist slit of a 0.25m mono-chromator previously calibrated with many known frequencies from the TEA CO_2,and the estimated accuracy of the frequency measurement was±1cm^{-1}

Results and Discussion:

In principle, when the absorption broad band ($\nu_2+\nu_4$) of the CF_4 molecules are pumped by one of a TEA CO_2 laser lines (from 9P14 to 9R24) they can produce a laser transition in the (600 -655 cm^{-1}) region where the spacing between the individual lines being normally of the order of (1 to 3 cm^{-1}) [2, 6-8].

The strongest lasing transition reported occurs when the CF4 molecules absorption line, lying (23± 5) MHz from the 9R12 line center,was optically pumped to generate 615 cm^{-1} superradiance emission in the form of both backward or forward traveling pulses [9].

In fact a single CO_2 pump transition may result in several CF_4 lasing frequencies if the CO_2 line is tuned across its full gain bandwidth which is of several GHz. This crowded nature of the CF_4 transitions result from pumping different levels of the ($\nu_2+\nu_4$) combination band [at 1066 cm^{-1}]with subsequent lasing transitions to the ν2 band [3, 10, and 11].

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The lower lasing levels of this process are ν_2 rotational levels with energies in the range of 435cm^{-1}[12].Thus a significant improvement in the maximum operating pressure and energy output of this laser achieved by cooling the gas, which reducing the population of the terminal levels of the lasing transitions (at 150K° the fraction of CF_4 molecules is only 1.6% [1]) and also changes the initial thermal population of the lower level of the optically pumped transition [13].

The dependence of the laser output energy on the CF_4 gas temperature was studied, figure(2),it was found that gas cooling temperature around 140K° gave a maximum output energy of 7mJ at 615 cm^{-1} with a 200 ns pulse duration which consisted of 4-6 spikes, as can be shown in figure (3).

The performance of the CF_4 laser has been investigated in terms of the pumping energy of the TEA CO_2 laser, where the threshold pumping energy was found at a CF_4 gas pressure of 7mbar and temperature of 150 K°, figure (4).

A significant energy fluctuation was noticed from pulse to pulse.This unstable behavior resulted from the action of the TEA CO_2 laser in many longitudinal and transverse modes, and as the output of a normal multimode CO_2 laser varies erratically in frequency range of 1-2 GHz around the pump laser line center,several of the close lying CF_4 absorption transitions can be pumped simultaneously.The output from the CF4 laser contained the remainder of the pumping CO_2 laser radiation (1073cm^{-1}).Although it is a difficult to separate the output wavelength from the pumping wavelength without special filters, the monochromator dispersive element itself is used in our experiment to separate them but with great losses in the detected CF_4 output energy.

Conclusion:

To prevent the CF_4 laser jumping from one emission frequency to the other, the output of the pump laser has to be frequency narrowed and stabilized. A simple way to do this is the insertion of a hot CO_2 low-pressure gain cell into the laser resonator, and the fine frequency tuning can be done by changing the pressure in the hot CO_2 cell. We believe that the output of the CF_4 laser can be improved with better pumping design and more serious attention paid on the engineering of a CF_4 laser device.

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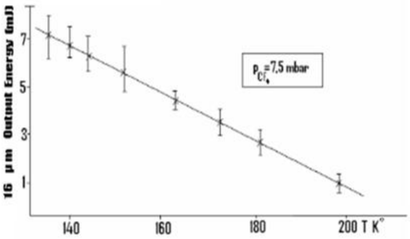

FIG.2 COOLING TEMPRETURE DEPENDANCE OF CF_4 LASER OUTPUT ENERGY.

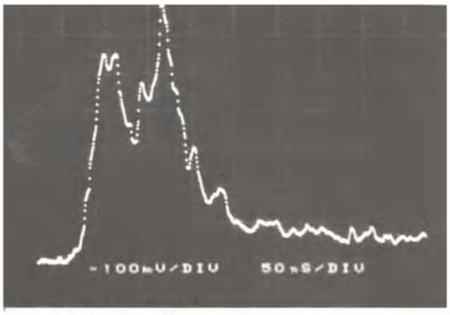

FIG.3 CF_4 LASER OUTPUT PULSE.

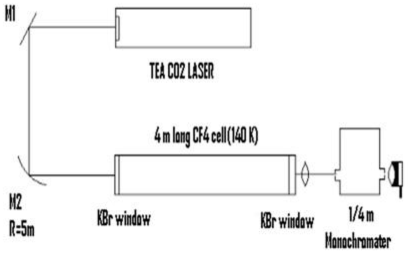

Fig.I SCHEMATIC DIAGRAM OF EXPERMINTAL ARRANGEMENT

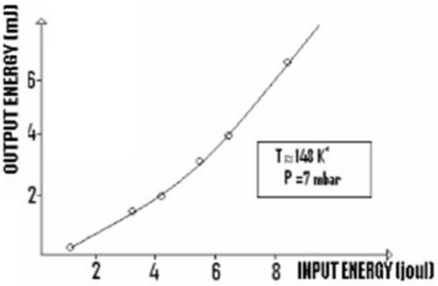

FIG.4 pumping energy dependance of the CF_4 laser output energy.

توليد أشعة الليزر تحت الحمراء 16 مايكروميتربواسطة الضخ الضوئي لغاز رابع فلوريد الكاربون

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الخلاصة

تم الحصول على الطول الموجي (16) مايكروميتر بطريقة الاشعاعية المفرطة بضخ غاز رابع فلوريد الكربون (المبرد الى درجة 140K بواسطة بخار سائل النتروجين) بليزر ($TEA\ CO_2$) والذي تمر أشعته مرة واحدة فقط في فجوة الليزر ، وكانت طاقة اشعة الليزر الخارجة بحدود(7mJ) وبعرض نبضة (200 ns).