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S. Marchetti, S. Bartalini, R. Simili, M. Martinelli. Short (ns) single pulse FIR (70-500 μm) multi-kW Raman conversion, of a short pulse (25ns) broadband CO₂ Laser. Journal de Physique IV Proceedings, 1994, 04 (C4), pp.C4-747-C4-749. 10.1051/jp4:19944205 . jpa-00252667

HAL Id: jpa-00252667

<https://hal.science/jpa-00252667>

Submitted on 1 Jan 1994

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Short ($\sim$ ns) single pulse FIR (70-500 μ m) multi-kW Raman conversion, of a short pulse ($\sim$ 25ns) broadband CO₂ Laser

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Abstract

In this work a summary of many pulse compressed (< 10 ns), FIR, high power, Raman emissions produced by a short pulse (25 ns) broadband (2GHz) CO₂ laser is shown. Generally it has been always possible to obtain a single pulse ($\sim$ ns) conversion from a pulse train of a self-mode locked CO₂, also if it is not really reproducible. These emissions are interesting in pulsed high field EPR experiments.

Introduction

There is a large interest to produce short pulse FIR emissions to study the relaxation proprieties of solids and gases, and in in magneto-optics experiments. Recently short single pulses (ns) of few lines are produced by the OFID technique.⁽¹⁾ This method is only effective on like-resonant lines of strong absorbers. On the contrary a train of sub-ns pulses (total length > 50 ns) has been produced by pumping Raman lines with a tuneable broad band CO₂ laser⁽²⁾. An alternative method has been proposed by us, by using Raman scattering of a short pulse (~ 25 ns or less) tail-free, broad-band (~ 2 GHz) CO₂ laser He-free operating at few bar⁽³⁾. Resonant Raman scattering is efficient over few molecules but it can be obtained over many detuned-resonant lines (up to 20 GHz detuning) covering in principle the whole FIR spectrum. To obtain a large conversion also on large detuned transitions, high power CO₂ pump is necessary.

High pressure He-free mixtures have short gain lifetime⁽⁴⁾ so that, following a new design an auto synchronised high power CO₂ laser chain has been built which is also described here. The broadband Raman scattering starts before the superfluorescent emission and it is modulated as the mode locked pump, giving few FIR ns spikes. In principle a single spike can be always obtained.

Experimental, results and discussions.

The laser chain is shown in fig 1. It is a modified design of a discharge system

Fig1: P=preionization, C=13.5nF, C₁=4.6nF, cp=1.15nF, L=0.4 μ H, LL=0.8 μ H, R=10K Ω

originally described in (5). All the capacitors are suitably charged at plus or minus High voltage (HV) by the same supply and the SG spark gap discharge allows to produce a nominal 4V pulse and fast current pulses (~ 25 ns) simultaneously ($\sim$ zero ns delay) in both the oscillator (right discharge) and amplifier (left discharge) when suitable pressures are used, also if the laser heads are different. Normally 2.3 and 1.8 bar pressures are used in the oscillator and amplifier heads respectively. Typical pump pulses were 200mj in 25 ns. The experimental set up for FIR generation and detection is shown in fig2. A Brewster angle Quartz window allows to extract both the FIR and the residual pump. Home made PbSe fast photon drag is used to detect the residual pump, a home made Sb photon drag is used to detect the 70-300 μ m FIR radiation, while a more sensitive home made MOM diode has been used for $\lambda > 300\mu$ m

Fig2: FIR generation experimental set-up

Generally all the emissions are Raman dominated as shown by the transferred mode -locking from the laser pulse (fig 3 up trace, with sign reversed)to the FIR one (bottom trace), also if only the large detuned transitions are showing a pulse compression also in high conversion regime(fig3)

Fig 3a : BOTTOM = 320 CH₃F line (5KW/div)

Fig3b: 385 μ m D₂O line (1KW/div)

UP= residual pump (1MW/div, sign reversed), time scale = 10ns

In all the cases we have observed that by using a suitable large gas pressure and a suitable large pump power we can transfer the Raman scattering onset in the tail of the laser pulse, and a short

FIR pulse can be produced. A sequence of 6 different lines is reported in fig 4. In some cases a sub-ns pulse (square panel of fig 4F) at the oscilloscope limit are detected. The peak power is ranging from 150 KW (NH_3 , $90\text{ }\mu\text{m}$) to 2 KW (CH_3F , $496\text{ }\mu\text{m}$). The well detuned Raman lines allows to obtain a single ns spike, But in general this condition is not reproducible shot-to-shot.

Fig4: sequence of some short FIR pulses. Time scale 5ns/div, λ and power scale are under figure.

Conclusions

In this work we have reported a large number of multiKW FIR pulses ranging in a wide part of the spectrum. The long-wave emissions ($> 400\text{ }\mu\text{m}$) are particularly interesting in pulsed high field EPR with ns resolution.

*)Work supported by the Progetto Finalizzato TECNOLOGIE ELETTRONICHE of the Italian National Research Council.

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