GENERATION OF INTENSE SHORT FIR PULSES BY USE OF A PASSIVELY MODE LOCKED HIGH PRESSURE CO_2 LASER AS PUMP SOURCE

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ABSTRACT

We report operation of a passively mode-locked tunable high-pressure CO_2 laser and its use for generation of far-infrared laser pulses. Mode-locking of the CO_2 laser was performed with p-doped Germanium as saturable absorber. We obtained tunable radiation consisting of trains of short pulses of about 1 ns duration. By optical pumping of CH_3F gas superradiant emission resulted in generation of subnanosecond far-infrared laser pulses at a frequency of about 35 cm^{-1} .

INTRODUCTION

Short pulses in the infrared spectral region at fixed frequencies can be generated by use of a mode-locked TEA-CO_2 laser [1]. It has been demonstrated that by stimulated Raman scattering of CO_2 laser pulses short far-infrared (FIR) pulses can be obtained [1]. We report on the operation of a mode-locked high-pressure CO_2 laser and its use as a pump source for FIR laser emitting short pulses. Because of the tunability of the high-pressure CO_2 laser its frequency can be tuned to appropriate pump transitions of the Raman laser medium. As Raman laser medium we used CH_3F gas, which is well suitable for generation of FIR radiation by stimulated Raman scattering [2,3].

Our CO_2 laser (UV preionized, grating tuned, 20 atmospheres pressure), produces pulses of 150 ns duration and a spectral width of about 5 GHz (FWHM) [4]. Passive mode locking is achieved by a cooled nonlinear filter (saturable absorber) of p-type germanium, doped with gallium. Absorption in the filter takes place by broadband optical transitions between the heavy- and light-hole subbands [5]. The broad absorption spectrum permits in principle generation of short pulses in the whole tuning ranges of the high pressure CO_2 laser. This device, which is described elsewhere [5], was placed in the laser resonator close to the output coupler; the germanium plate had an antireflection coating.

CO_2 laser pulses were focussed into a FIR waveguide laser, length 115 cm, containing 11 mbar CH_3F , with a BaF_2 entrance and a TPX output window. CO_2 laser radiation passing the FIR laser was blocked with a plate of crystalline quartz. For pulse detection, fast detectors with response times of less than 1 ns were used. The signals obtained from the detectors were amplified (bandwidth of the amplifiers 1 GHz) and then recorded with a dual channel digital storage oscilloscope (Sampling rate 1 GS/s, input bandwidth 400 MHz).

RESULTS AND DISCUSSION

As nonlinear filters we tested germanium plates with lengths of 10 to 40 mm and gallium concentrations of $3 \cdot 10^{14}$ cm^{-3} to $3 \cdot 10^{15}$ cm^{-3}, optimum results have been obtained for a 20 mm long filter and a concentration of $8 \cdot 10^{14}$ cm^{-3} gallium. For this concentration the lifetime of the excited p-states is about 10^{-11} s. In Fig. 1 typical CO_2 laser pulse shapes are shown without (a) and with (b) the mode locking unit. Without passive mode locking the pulse is nearly smooth, showing weak structure due to self-mode locking effects. Passive mode locking produces short pulses, consisting of one or several pulse trains with a period given by the photon round trip time in the laser. The temporal shape of a single pulse is shown on an expanded time scale in the inset of Fig. 1b. The pulse duration appears to be less than 3 ns. The intensity of the single peaks must have been high compared to the pulse intensities obtained without the saturable absorber (1.6 MW for a 250 mJ pulse). We conclude this from the observation that damage of the NaCl Brewster windows of the high pressure tube occurred for pulse energies above 50 mJ when the saturable absorber was inside the resonator, while this damages occurred without saturable absorber only for pulse energies of more than 300 mJ. For germanium filters with lower concentrations than $8 \cdot 10^{14}$ cm^{-3} gallium more single pulses at a

periode of 26 ns and less contrast between the pulses were obtained. For higher concentrations, laser action vanished. For generation of the short FIR pulses we made use of Raman transitions in the R(20) tuning branch of CH_3F , which has high Raman gain [4]. The highest pulse energies (about 100 μJ) were found, as without the saturable absorber, for a pump frequency of 1079 cm^{-1}, causing FIR laser emission at a frequency of 35 cm^{-1}. Pumping with short pulses (Fig. 2a) of the mode locked CO_2 laser leads to generation of still shorter FIR pulses (Fig. 2b). Single CO_2 laser and FIR pulses are shown on an expanded time scale as insets of Fig. 2. While the CO_2 laser pulse has a measured duration of 2 ns (FWHM) the duration of the FIR pulse has a measured duration of 1 ns. Taking account of the bandwidth of the measuring system (detector and amplifier) we find that the true width of the FIR pulses must be below 1 ns. We should note that the pulse generation in both the mode locked CO_2 laser and the FIR Raman laser are not reproducible with respect to pulse sequence and pulse intensity -as it is typical for such highly nonlinear processes. A better controlled laser action of the high pressure CO_2 laser should improve the reproducibility.

SUMMARY

Our study demonstrates for the first time generation of frequency-tunable intense infrared radiation pulses in the nanosecond time regime by mode-locking a high pressure CO_2 laser using p-doped germanium as a saturable absorber. These pulses were transferred into the FIR region via stimulated Raman scattering of the CO_2 laser radiation in CH_3F resulting in subnanosecond FIR laser pulses.

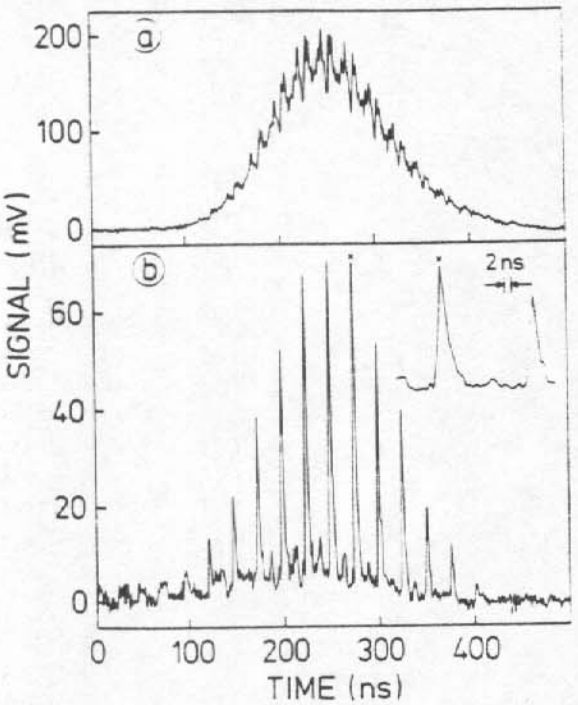

Fig. 1. Pulses of the high pressure CO_2 laser without (a) and with mode locking unit (b)

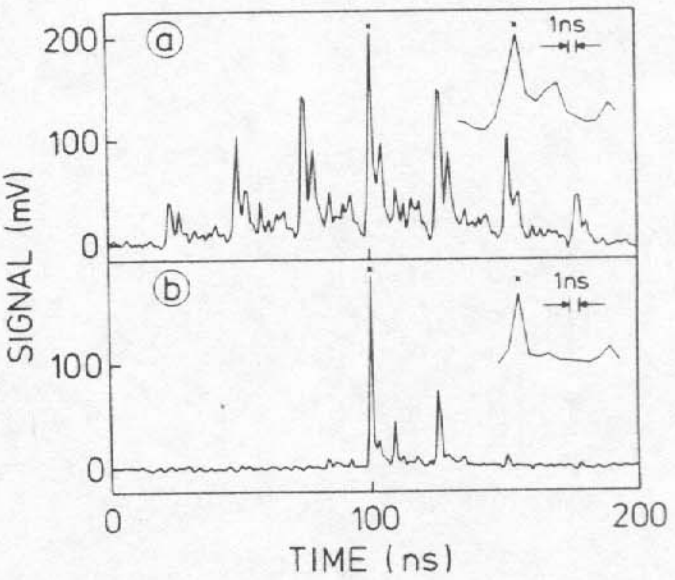

Fig. 2. Pump pulse train of the CO_2 laser (a) and emission from the FIR CH_3F Raman laser (b); insets: single pulses in an extended scale

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