Generation of nanosecond radiation pulses in a small-size CO_2 laser using a sealed-off e-beam pump source

E.S. Kovalenko, A.E. Mandel', V.M. Orlovskii, V.A. Panarin, and S.N. Sharangovich

Institute of High-Current Electronics, Siberian Branch of the Russian Academy of Sciences, Tomsk

Received September 2, 1999

We present data on formation of nanosecond radiation pulses in a small-size CO_2 laser using a sealed-off e-beam pump source operated in the mode-locking mode. A train of pulses each about 1-ns long with the total energy of 50 mJ and pulse repetition frequency of 4 Hz was obtained in the $CO_2:N_2$ = 1:1 gas mixture at atmospheric pressure.

Small-size electroionization CO_2 lasers employing a sealed-off e-beam source are now being actively developed. Such lasers, delivering relatively small energy, have found wide application in such fields as ranging, detection, remote gas analysis, medicine, etc. Wide application imposes a lot of requirements on the power and time characteristics of such lasers.

This paper presents some results of investigation into the generation of ultrashort pulses in CO_2 lasers with the electric discharge initiated with a nanosecond electron pulse.

The pulse duration in electroionization CO_2 lasers depends mainly on the regime of formation of radiation pulses. At a long duration of pumping ($t > 10^{-5}$) the radiation power follows the corresponding parameters of the volume discharge. At a shorter t the shape and duration of the emission pulses are affected by the "switch-on" effect. That means that, during the time interval between the onset of pumping and the emission of noticeably high optical power substantial amount of energy is accumulated at the upper lasing level, whose depletion is accompanied by the formation of a high-power emission peak. In this case the radiation characteristics depend on the size and composition of the active medium, pressure, pump power and duration, cavity length and Q-factor. The pulse duration under such conditions of excitation can vary from 10^{-8} to 10^{-4} s depending on the above-listed parameters.[1,2] In the regime of mode locking, such a laser can generate the emission pulses with the duration from 10^{-9} to 10^{-10} s.

The setup we used in studying the formation of nanosecond pulses is shown in Fig. 1. The $CO_2:N_2$ = 1:1 active medium with the volume of 0.7×1.5×12 cm and pressure of 1 atm was produced in the process of independent pulsed discharge initiated with an electron beam (duration of 10 ns and current of 600 A) from four IMA–150 E vacuum diodes connected in parallel. The diodes were supplied with power from a standard MIRA–3D X-ray apparatus. The voltage across the spark gap was about 50 kV applied to a capacitor battery of 15 nF capacitance (Ref. 3). The active medium was bounded by a plane mirror from steel *1* on the one side, and by ZnSe plate *3* set at the " rewster angle on the other side.

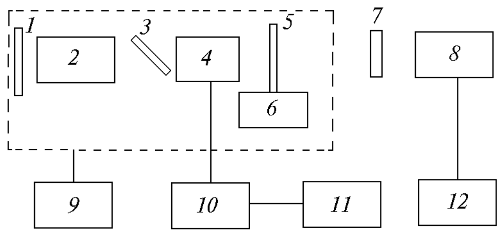

Fig. 1. Functional block-diagram of the setup: steel mirror *1*, active medium *2*, ZnSe plate *3*, acoustooptical modulator *4*, output external mirror *5*, micrometer table *6*, NaCl lens *7*, photodetector *8*, power supply *9*, VCh GZ–19 oscillator *10*, ChZ–34A frequency meter *11*, and oscilloscope *12*.

The laser cavity was formed by the steel mirror and mirror *5* made from Ge plate with a multilayer coating providing for 94% reflection. The mirror was set on a micrometer table, thus allowing the cavity length to be slightly changed.

To obtain mode locking, an acoustooptical modulator *4* made from 10×10×20 mm Ge crystal was set inside the laser cavity. Standing ultrasonic waves were excited in the Ge crystal with a generator and a piezoelectric transducer made from a Y+35 crystal cut of a 60-μm thick lithium niobate plate. The piezoelectric transducer was stuck to a delay line with cyacrin. The frequency of the high voltage applied across the modulator was measured with a frequency meter. The laser radiation in our experiments propagated along the direction [1 1 0] of the Ge crystal, while the ultrasonic wave propagated along the direction [1 1 0] of the crystal. The maximum value of the effective diffraction was 20% per 1 W of the power at the modulator. It was achieved in the ultrasonic frequency range from 42 to 47 MHz. To decrease the losses introduced by the modulator into the laser cavity, the faces of the Ge crystal were coated with an antireflection coating.

The FP–1 Ge crystal-based photodetector was used as a detector *9* of the laser radiation. The signal from the photodetector was entered into S9–4A oscilloscope *12*. The shape and duration of laser pulses were recorded on a photographic film from the oscilloscope display. The resolution of the receiving instrumentation was about 0.2 ns.

For mode locking to take place, the modulation frequency and the laser intermode beat frequency must coincide. In the experiment the precision tuning was achieved by varying the cavity length when slightly moving the output external mirror.

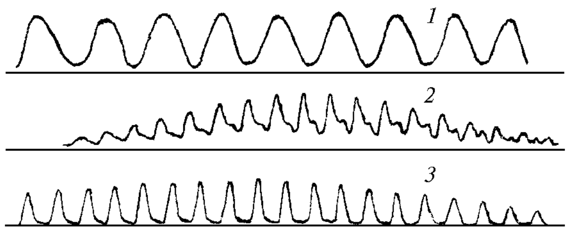

Fig. 2. Oscillograms: mark pulse generator, period of 10 ns (*1*), radiation pulse at the AOM switched-off (*2*), radiation pulse at the AOM switched-on (*3*).

At the switched-off modulator, self-mode locking was observed due to a strong nonlinearity of the active medium. The typical oscillogram of the laser emission delivered in this regime is shown in Fig. 2 (curve *2*). Ultrashort pulses under mode-locking conditions are unstable both in duration and amplitude.

As the acoustooptical modulator (AOM) was switched on, the stimulated mode locking was observed. The typical oscillogram of the laser emission in this case is also shown in Fig. 2 (curve *3*). Under conditions of stimulated mode locking, the duration of a laser pulse is markedly stabilized. The duration of an ultrashort pulse in a train was about 1.2 ns at a good repeatability of the results.

Since the duration of an ultrashort pulse in a train is inversely proportional to its spectral width, we can estimate the number of modes generated under conditions of stimulated mode locking. In our experiments the number of modes generated was equal to six.

Thus, generation of a train of pulses with the duration at halfmaximum about 1 ns, total energy of 50 mJ, and pulse repetition frequency of 4 Hz was obtained under conditions optimal for a small-size CO_2 laser employing a sealed-off e-beam source.

References

1. V.M. Karpov, Yu.G. Konev, V.M. Orlovskii, et al., Kvant. Elektron. **15**, No. 3, 465–470 (1988).
2. Yu.I. Bychkov, V.P. Kudryashov, Yu.A. Kurbatov, et al., Zh. Tekh. Fiz. **49**, No. 7, 1572–1574 (1979).
3. Yu.I. Bychkov, V.M. Orlovskii, V.V. Osipov, et al., Prib. Tekh. Eksp., No. 5, 185–186 (1983).