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Short laser-pulse generation based on self-injection in the CO_2 laser system

A. Dubicki, R. Jarocki

Institute of Plasma Physics and Laser Microfusion, 00-908 Warszawa, P.O. Box 49, Poland.

In this paper the CO_2 laser system for nanosecond pulse generation by the self-injection method is presented. The generation of single pulses of a few nanoseconds duration and 2 mJ energy level are obtained.

1. Introduction

A short pulse generation by using the method of self-injection has been developed especially in the solid state laser systems [1]–[6]. In these papers a detailed analysis of generation of this type is given [3], [4] as well as the laser systems enabling the generation of single subnanosecond [1], [2] and picosecond [5], [6]* pulses of energy much higher than those (of the same duration) obtained by using classical methods. Such small duration pulses were generated also in the dye lasers [7], [8] by using the self-injection method.

In this paper the preliminary results of the investigation concerning the CO_2 laser systems are shown. In Sect. 2 the concept of the generation process is given, while in Sect. 3 the experimental setup as as well the results obtained are described.

2. Generator operation principle

The operation principle of CO_2 generator with the pulse self-injection is shown in Fig. 1, being analogous to that suggested by Ewart [8].

In the initial phase of the laser action in the system presented, a voltage pulse of amplitude $U_{\lambda/4}$ ($U_{\lambda/4}$ – quarterwave voltage) and duration t_b' shorter than the resonator round-trip time: $T_R = 2L_R/c$ (L_R – resonator length) is applied to the Pockels cell (PC). The application of such a short voltage pulse to PC results in the fact that only a part of the radiation propagating inside the resonator is subject to twisting of the polarization plane by $\pi/2$ to be then emitted from the resonator due to reflection from the reflexion analyser (AN). On the other hand, the part remaining inside the resonator creates the so-called incipient pulse. If PC is located in the close

* In this case in the resonator there was additionally placed a nonlinear absorber.

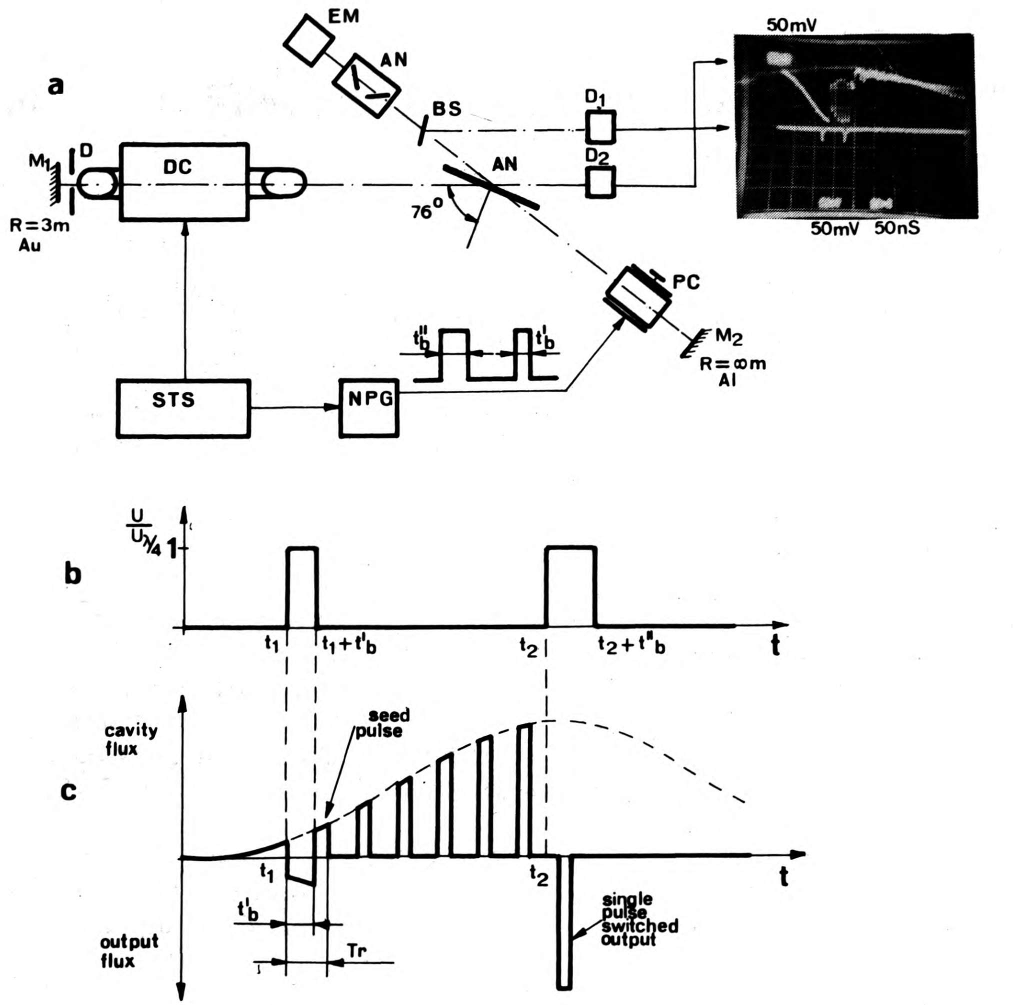

Fig. 1. Scheme of generator with self-injection of the pulse: **a** – experimental setup (DC – discharging chamber, D – diaphragm, STS – supply and triggering system, NPG – nanoseconds high voltage pulse (generator), PC – Pockels cell, EM – energy meter, AN – germanium analyser, BS – beam splitter, D_1, D_2 – photon detectors), **b** – time course of voltage on the Pockels cell electrodes, **c** – an illustration of the concept of generation development mechanism

vicinity of the mirror M_2, then for the jumping change of the voltage on PC the incipient pulse duration τ may be evaluated from the relation

$$\tau \approx T_R - t'_b.$$

In the course of successive passages through the active medium the incipient pulse is amplificated. Leading the other voltage pulse of amplitude $U_{\lambda/4}$ and duration $t''_b \geqslant t'_b$ to PC in the top phese of generation causes both a twisting by $\pi/2$ of the polarization plane of the pulse propagating inside the resonator and a pulse emission from the resonator. The extremal parameters of the generated pulses depend above all on the amplifying possibilities of the active medium, the switching time of the transmission of the electrooptic modulator and the duration of the voltage gate forming the incipient pulse.

3. Results of the experimental examinations

The experimental system was composed of the discharging chamber of the TEA CO_2 laser, germanium reflexion analyser and the electrooptic Pockels cell, all located in the plane-spherical resonator equipped with totally reflecting mirrors (Fig.1). In the presented system the discharging chamber CO_2 with UV preionization was exploited, in which the volume of the active medium was $25 \times 25 \times 280$ mm^3. The excitation of the active medium (gas mixture 1:1:6 – CO_2:N_2:He) was ensured by a two-stage Marx generator with capacities 2×20 nF charged to the voltage ± 27 kV.

The resonator length was ~ 1650 mm, which corresponds to $T_R = 10$ ns. The voltage pulses on the electrodes of PC were realized with the help of both the nanosecond pulse generator (NPG) and the respective forming lines. In the experiment the time parameters of the voltage gates, i.e., t'_b, t''_b applied to the PC and the distance between them $t = t_2 - t_1$ were changed. The results given below concern the cases $t'_b = 6$ ns, $t''_b = 12$ ns, $t = 50$ and 200 ns.

In the system the role of the reflexion analyser is played by a plane-parallel plate of germanium located under the Brewster angle with respect to the resonator axis.

The detection of the short pulses of radiation is carried out by exploiting the uncooled photon detectors (CdHgTe) cooperating with the wide-band oscilloscope.

The exemplified results of the experimental examinations are shown in Figs. 1**a** and 2. Figure 1**a** illustrates the idea of generation while the moment of creation of the incipient pulse inside the resonator has been retarded purposely to the top phase of generation to make it more readable which gives, in effect, a possibility of emission of two pulses to the outside of the resonator. From the oscillograms obtained it follows

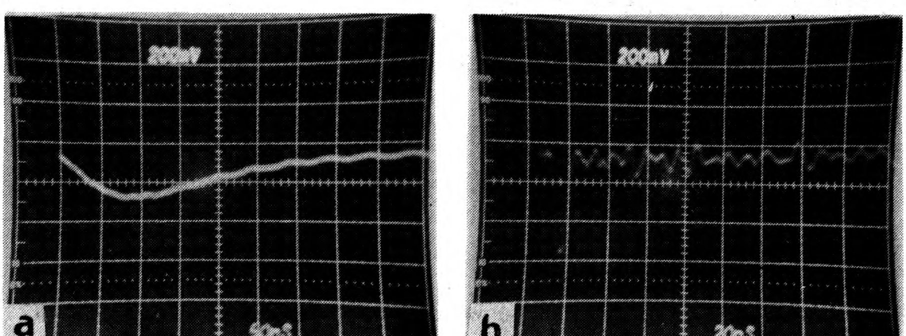

Fig. 2. Pulse oscillograms at the output from the resonator in the case of free generation (**a**) and in the case when the pulse self-injection is realized (**b**)

that after generation of the principal (second) pulse a free generation inside of the resonator is again developed but at lower level due to the active medium pumping. However, this generation has no serious influence on the characteristics of the emitted pulses. The oscillations appearing during the generation result from the multi-mode operation of the laser. Therefore, a modification of the resonator system is planned as well as an introduction of a longitudinal mode selector stimulating the generation of only one longitudinal mode by the same means.

In Figure 2, the oscillograms of pulses are shown, both in the case of free generation (**a**) and when self-injection is realized in the resonator (**b**). In order to expose the background of the pulse emitted from the resonator (Fig. 2**b**) the recording detector worked at high saturation state.

The single pulse (or two-pulse) energy obtained in the system amounted to about 2 mJ for the intensity contrast amounting to about 10^2. This contrast may be increased by a precise positioning of the germanium plate in the resonator under the Brewster angle and by application of the additional analyser in the output pulse trajectory.

4. Recapitulation

The experimental examinations carried out confirmed the possibility of short pulse generation of the radiation in the CO_2 laser system by using the self-injection method. We obtained the generation of single pulses of a few nanoseconds duration and 2 mJ energy. At present the studies on this kind of radiation generation in CO_2 laser systems are continued to determine the possibilities of pulse generation of a duration shorter than 2 ns and energy higher than 2 mJ.

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Генерация коротких лазерных импульсов методом самоинжекции в лазере CO_2

В работе представлена установка лазера CO_2 для генерации наносекундных импульсов методом самоинжекции. Получена генерация однократных импульсов длительностью в несколько наносекунд и энергией в 2×10^{-3} дж.