



Full length article

Control of laser pulse waveform in longitudinally excited CO₂ laser by adjustment of excitation circuitKazuyuki Uno^{a,*}, Takahisa Jitsuno^b^a Graduate Faculty of Interdisciplinary Research Faculty of Engineering, University of Yamanashi, 4-3-11 Takeda, Kofu, Yamanashi 400-8511, Japan^b Institute of Laser Engineering, Osaka University, 2-6 Yamada-oka, Suita, Osaka 565-0871, Japan

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ABSTRACT

In a longitudinally excited CO₂ laser that had a 45 cm-long discharge tube with a 1:1:2 mixture of CO₂/N₂/He gas at a pressure of 3.0 kPa, we realized the generation of a short laser pulse with a spike pulse width of about 200 ns and a pulse tail length of several tens of microseconds, control of the energy ratio of the spike pulse part to the pulse tail part in the short laser pulse, the generation of a long laser pulse with a pulse width of several tens of microseconds, and control of the pulse width in the long laser pulse, by using four types of excitation circuits in which the capacitance was adjusted. In the short laser pulse, the energy ratio was in the range 1:14–1:112. In the long laser pulse, the pulse width was in the range 25.7–82.7 μs.

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1. Introduction

CO₂ lasers exhibit high output powers at wavelengths of 9.6 μm and 10.6 μm. CO₂ lasers are characterized by the flexibility of the laser pulse shape. For instance, a CO₂ laser can produce a tail-free short pulse with a width of 10 ns to several hundreds of nanoseconds, a short laser pulse with a spike pulse and a pulse tail, a long laser pulse with a width of several tens of microseconds to several milliseconds, or CW laser light, depending on the structure of the discharge tube, the discharge type, and the oscillation type. For example, a CO₂ laser pumped by a DC discharge and an RF discharge produces CW laser light [1,2]. A CO₂ laser can also produce a long laser pulse by electrical control of the discharge and mechanical chopping of CW laser light [1,2], as well as a tail-free short laser pulse by Q switching [3,4]. A transversally excited atmospheric (TEA) CO₂ laser using a pulse discharge produces a short laser pulse with a pulse tail because a fast discharge is typically used [5,6]. And a TE-CO₂ laser has been reported to produce long laser pulse oscillation by controlling the discharge time [7].

An ideal CO₂ laser would be a device in which the laser pulse waveform can be easily controlled. Therefore, we focus on a longitudinal excitation scheme in which the excitation discharge and the laser axis are in the same direction [8–13]. In a longitudinally excited CO₂ laser, the discharge tube is typically made of a dielectric pipe with a length of 30–80 cm and an inner diameter of 1–2

cm and two metallic electrodes attached to the ends of the pipe [11–13]. This type of CO₂ laser operates at a low gas pressure of less than 10 kPa because the long discharge length provides a high discharge starting voltage of more than 20 kV at a low gas pressure. The low-gas-pressure operation and the long discharge length affect the laser pulse shape. Recently, we have reported that longitudinally excited CO₂ lasers produced a tail-free short pulse with a pulse width of about 100 ns and a short pulse with a spike pulse width of about 100 ns and a pulse tail length of about 10–100 μs [11–13]. In addition, a long, small-diameter discharge at a low gas pressure is formed uniformly by a minute spark discharge and optical ionization. In this regard, the scheme does not require strong preionization or a fast gas flow system. A low gas pressure discharge without preionization may also place fewer demands on the excitation circuit. Therefore, this scheme has the possibility of fine control of the laser pulse waveform by adjusting the excitation circuit electrically.

In this work, we describe control of the laser pulse waveform by using four excitation circuits and adjustment of the capacitance, in a longitudinally excited CO₂ laser with a 45 cm-long discharge tube and 1:1:2 mixture of CO₂/N₂/He gas at a pressure of 3.0 kPa.

2. Experimental setup

Figs. 1 and 2 show longitudinally excited CO₂ lasers for producing short and long laser pulses, respectively. All longitudinally excited CO₂ lasers that we used had the same laser tube. The laser tube was constituted of a discharge tube and an optical cavity. The

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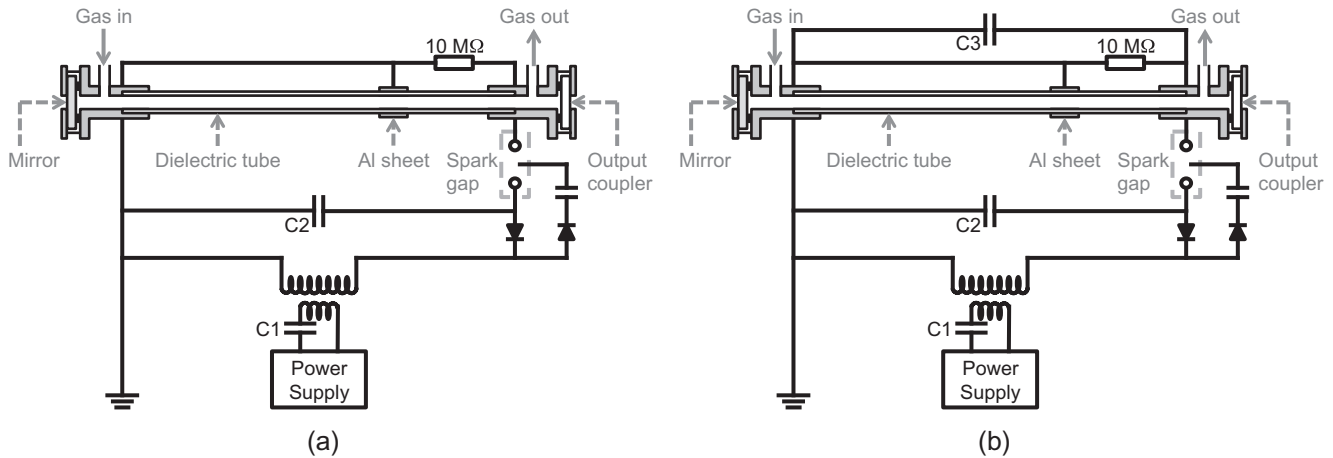


Fig. 1. Schematic diagrams of longitudinally excited CO₂ lasers with fast-discharge circuits.

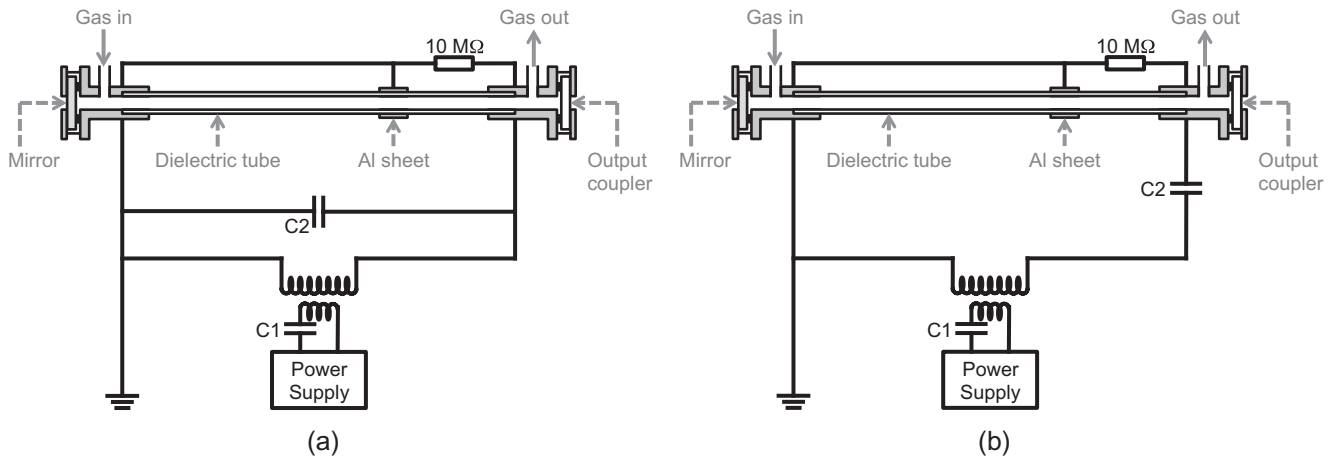


Fig. 2. Schematic diagrams of longitudinally excited CO₂ lasers with slow-discharge circuits.

discharge tube was made of an alumina ceramic pipe with an inner diameter of 9 mm, an outer diameter of 13 mm, and a length of 45 cm, and two metallic electrodes were attached to the ends of the pipe. An optical cavity was formed by a ZnSe output coupler with a reflectivity of 85% at a wavelength of 10.6 μm and an Au-coated high-reflection mirror with a reflectivity of 99% and a radius of curvature of 20 m at a wavelength of 10.6 μm . The optical cavity length was 54 cm. In all systems, CO₂:N₂:He mixed gas with a ratio of 1:1:2 and a pressure of 3.0 kPa was flowed through the discharge tube.

All longitudinally excited CO₂ lasers had the same pulse power supply operating at a repetition rate of 1 Hz. A -600 V pulse was generated by the power supply using a low-voltage silicon-controlled rectifier and was fed to a step-up transformer with a primary capacitance C1, which defined the electrical energy of the high-voltage pulse. The high-voltage pulse was composed of a main negative voltage pulse part and a positive voltage pulse part generated by the overshoot of the transformer.

Fig. 1 shows fast-discharge circuits that have a spark gap as a fast-current, high-voltage switch and apply a voltage with a rise time of about 100 ns to the discharge tube. In Fig. 1(a), the high-voltage pulse from the step-up transformer was divided into a negative voltage pulse and a positive voltage pulse by two high-voltage rectifiers [10–13]. The negative voltage pulse was used to charge a secondary capacitance C2. The positive voltage pulse was applied to a trigger electrode of a spark gap through a small

capacitance. When the spark gap was switched, the charging voltage was applied to the discharge tube. Fig. 1(b) shows a capacitor-transfer circuit, in which a buffer capacitance C3 is added to the circuit in Fig. 1(a) [10,11]. The spark gap was switched, and then the high voltage was transferred to the buffer capacitance. When the voltage reached the breakdown threshold of the discharge tube, a discharge took place in the discharge tube and was sustained by charge from this buffer capacitance C3.

Fig. 2 shows slow-discharge circuits that do not have a spark gap and apply a voltage with a rise time of several tens of microseconds to the discharge tube. Fig. 2(a) is the circuit in Fig. 1(a) without the spark gap [9]. In the circuit in Fig. 2(a), the discharge tube and the secondary capacitance C2 are connected in parallel. In the circuit in Fig. 2(b), on the other hand the discharge tube and the secondary capacitance C2 are connected in series, forming a capacitor-coupled circuit. In the slow-discharge circuits in Fig. 2, the high-voltage pulse from the step-up transformer charged the secondary capacitance C2. When the voltage reached the breakdown threshold of the discharge tube, a discharge took place in the discharge tube. A long-duration current from the step-up transformer flowed to ground through the discharge tube.

The laser pulse was measured with an energy detector (Gentec, QE12LP-H-MB-D0), a photon drag detector (Hamamatsu Photonics, B749) and an oscilloscope (Tektronix, DPO7054). The voltage pulse was measured with a high-voltage probe (Tektronix, P6015A) and the oscilloscope.

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