PRAMANA
— journal of
physics

Vol. 75, No. 5
November 2010
pp. 901–906

On the operation of switch-less transversely excited atmosphere CO_2 lasers in the oscillator and amplifier configurations

GAUTAM C PATIL, PALLAVI RAOTE, J PADMA NILAYA and D J BISWAS*
Laser and Plasma Technology Division, Bhabha Atomic Research Centre,
Mumbai 400 085, India
*Corresponding author. E-mail: lpt@barc.gov.in

Abstract. The work presented in this paper deals with the triggering aspect of a switch-less laser. Many methods were utilized to affect the operation of two switch-less lasers in the oscillator–amplifier configuration. Most satisfactory performance in terms of the range and reliability of the delay was obtained with the LC inversion-based triggering option.

Keywords. Switch-less; TEA CO_2 laser; oscillator and amplifier.

PACS Nos 42.55.-f; 42.55.Lt; 84.30.Sk

1. Introduction

In the past, we have successfully operated self-switched transversely excited atmosphere (TEA) CO_2 lasers of varying discharge volumes utilizing different electrode geometries [1–3]. Here, the pre-ionizer, an integral part of the laser head, in addition to preconditioning the inter-electrode volume, performed the role of a switch as well. Simultaneous closure of the parallel gaps of the pre-ionizer was made possible by inductively ballasting each of the spark channels and then mutually coupling them through magnetic cores [4]. Synchronization of the operation of a laser with an event is of utmost importance and in the absence of a conventional switch, e.g., a spark gap or a thyratron, the triggering of such a switch-less laser is not straightforward. We have demonstrated the possibility of optically triggering a switch-less laser by transporting UV photons originating from another high voltage discharge (be it a spark gap or another mutually coupled parallel spark pre-ionizer) through an optical fibre into the vicinity of one of the gaps of its parallel spark pre-ionizer. This preconditions the gap causing its closure followed by the closure of the remaining gaps of the parallel pre-ionizer resulting in the operation of the self-switched laser in synchronism with the external high voltage discharge [5]. In this paper we experimentally demonstrate the satisfactory operation of two self-switched lasers in the oscillator–amplifier configuration wherein the delay between the two can be varied as desired to obtain the best results. Three different

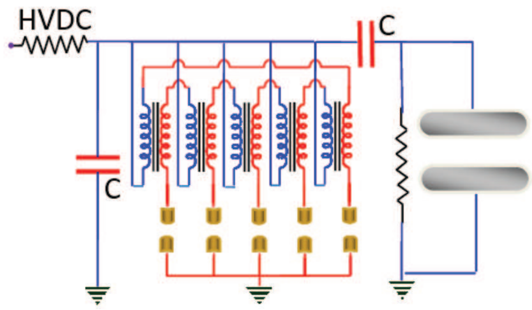

Figure 1. Schematic diagram of the excitation circuit used in the laser.

methods for obtaining the delayed operation of the oscillator with respect to the amplifier have been tested and are elaborated. The successful operation of the switch-less laser in the oscillator–amplifier configuration that allows obtaining high energy while maintaining a good spatial beam profile, further adds to its versatility.

The oscillator comprised of a pair of Ernst-profiled electrodes defining a discharge of 16 mm × 10 mm cross-section and 55 mm length enclosed in a Perspex chamber the two ends of which were 'O' ring-sealed with a 100% reflecting gold-coated mirror (1 m ROC) and a 95%R ZnSe mirror defining an optical cavity of ∼20 cm length. Under optimized conditions, 120 mJ coherent output at an electro-optic efficiency of ∼7% was obtained. The amplifier too comprised of Ernst-profiled electrodes that defined a discharge of volume 40 cc (25 mm × 16 mm × 10 mm) and enclosed in a Perspex chamber, the two ends of which were sealed with anti-reflection-coated optics. The pre-ionization chamber isolated from the main discharge chamber by means of LiF windows consisted of only two pairs of symmetrically placed aluminium pins in both the cases. The much higher efficiency of the mutually coupled pre-ionizer when compared with the conventional pre-ionizer [6] enabled the operation of the discharges in the glow mode with only two spark channels.

2. Optical fibre-based triggering

The LC inversion circuit typically utilized to energize a self-switched laser is depicted in figure 1 wherein the conventional switch is replaced by the mutually coupled parallel spark pre-ionizer. As the parallel gaps break, twice the supply voltage appears across the laser load in a time $\pi(\mathrm{LC})^{1/2}$.

The schematic diagram of the pulser circuit employed for the synchronized operation of the oscillator–amplifier discharges is shown in figure 2. The oscillator and the amplifier are powered by their respective LC inversion circuits. Once the pre-ionizer switch of the amplifier closes, a high voltage impulse appearing across its electrodes results in a glow discharge. Simultaneously, the spark gap SG in series with the amplifier discharge, operating in the over-voltage mode, too closes and the UV photons emanating from it are coupled into the vicinity of one of the spark channels of the pre-ionizer switch of the oscillator. The voltage across the pre-ionizer gaps of the oscillator is maintained less than their self-breakdown

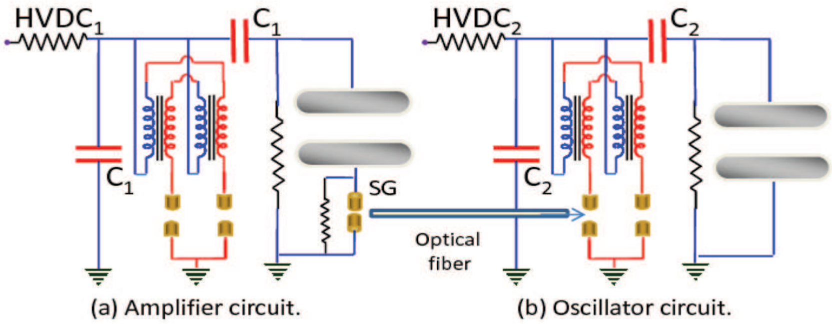

Figure 2. Schematic diagram of the experimental set-up for optical triggering of oscillator switch from amplifier.

voltage so that the gaps close only when they are preconditioned by these UV photons. This causes the switching of the oscillator after a time $\pi(LC_2)^{1/2}$ with respect to its pre-ionizer. The total delay between the amplifier and the oscillator discharges is the sum of $\pi(LC_2)^{1/2}$ and the closure time of the oscillator pre-ionizer gaps which can be varied by varying the DC voltage to which C_2 is charged. Closer it is to the self-breakdown voltage of the gap, smaller is the closure time after the gap is preconditioned and hence smaller will be the delay between the amplifier and the oscillator discharges and vice versa. In our experiments the oscillator discharge could be delayed from 280 ns to 500 ns with respect to the amplifier discharge reliably by this method. But, the pre-ionizer of the oscillator cannot be operated much lower than its self-breakdown voltage as it introduces jitter in its closure.

3. LC Inversion circuit-based triggering

Figure 3b shows an LC inversion circuit utilized exclusively for generating the trigger pulse for initiating the oscillator discharge. As the amplifier self-switches, the UV light emanating from its pre-ionizer is made to switch SG1 of the triggering unit which closes enabling the already charged C to discharge. SG2, in series with SG1, is overvolted. SG3 is so positioned that it is triggered by the UV photons generated due to the closure of SG2. As SG2 is overvolted to a great extent, there is very little jitter in its closure and as SG3 is used in the triggered mode the delay between their closures can be varied to any extent simply by changing the value of L in figure 3b, $\pi(LC)^{1/2}$ being the rise time of voltage across SG3. Figure 4 shows the variation in the rise time of the voltage across SG3 with changing L. As SG3 now can be operated close to its self-breakdown voltage, the jitter in its closure too is minimized. The UV photons from SG3 are coupled into the vicinity of the pre-ionizer switch of the oscillator by means of an optical fibre. This enables the oscillator to operate after a predecided delay with respect to the amplifier. By this method a satisfactory performance of the amplifier was possible by varying the delay with respect to the oscillator from 200 ns to $\sim$5 usec.

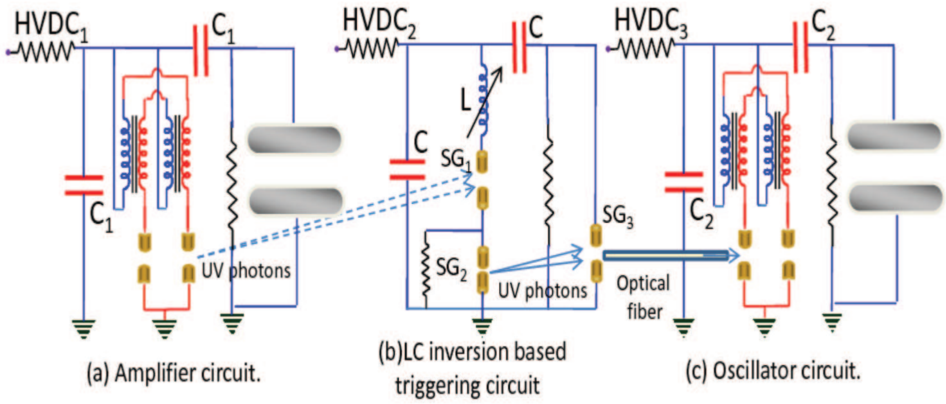

Figure 3. Schematic diagram of LC inversion-based optical triggering of an oscillator–amplifier system.

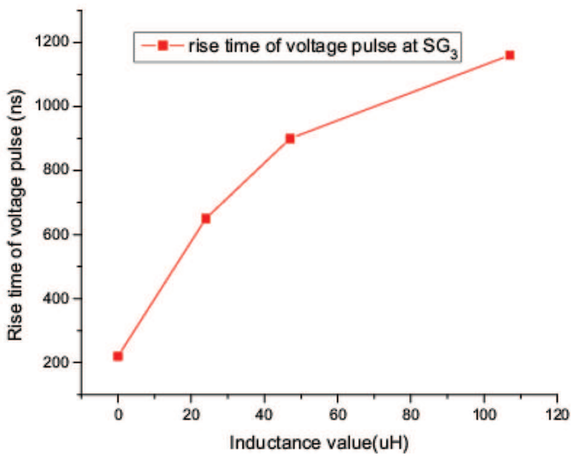

Figure 4. Rise time of voltage pulse as a function of inductance value.

4. Plasma shutter-based triggering

The triggering circuit here is as shown in figure 5a. Capacitor C when charged to an appropriate voltage discharges through SG1 and in the process overvolts SG2. SG1 is positioned in the optical path inside the oscillator as shown in figure 5b and therefore its closure results in the formation of an arc plasma. The pre-ionizer cum switch of the oscillator is optically triggered by transporting UV photons originating from the closure of SG2 into the vicinity of one of its gaps (figure 5a). Although the oscillator discharge is affected within several hundreds of nanoseconds, owing to the formation of plasma the onset of lasing in the oscillator is seen to be delayed. The amplifier, on the other hand, is triggered in synchronism with the oscillator by deriving UV photons from the same source and hence a delay is created between

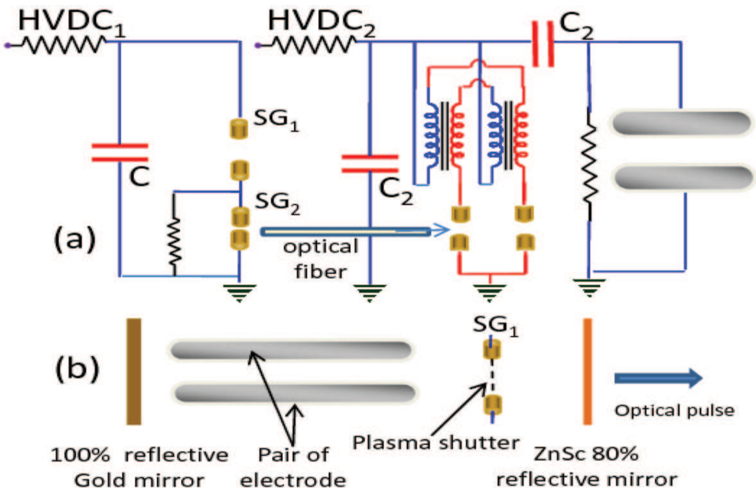

Figure 5. Schematic diagram of the plasma shutter-based triggering. (**a**) Excitation circuit, (**b**) experimental arrangement.

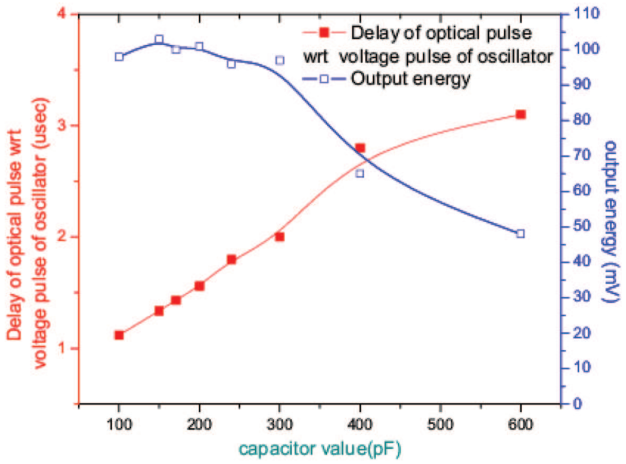

Figure 6. Output energy of oscillator and delay of the optical pulse as a function of capacitance C.

the operation of the oscillator and the amplifier. By varying the energy deposited in the plasma by way of changing the value of the capacitor C (figure 5a) the delay could be changed from hundreds of nanoseconds to ∼3 ms. Unduly large delay, however, results in a poor operating efficiency of the oscillator (figure 6) as the stored energy begins to leak through spontaneous emission.

With all the above methods, satisfactory amplification of the oscillator output commensurating with the length and gain of the amplifier was obtained. Most satisfactory performance in terms of the range and reliability of the delay, however, was obtained with the LC inversion-based triggering option.

References

[1] D J Biswas, J P Nilaya, M B Sai Prasad and P Raote, *Opt. Express* **13**, 9636 (2005)
[2] J P Nilaya, P Raote, G Patil and D J Biswas, *Opt. Express* **15**, 129 (2007)
[3] P Raote, G Patil, M B Sai Prasad, J P Nilaya and D J Biswas, *Opt. Commun.* **281**, 2213 (2008)
[4] P Raote, G Patil, M B Sai Prasad, J P Nilaya and D J Biswas, *Appl. Phys. Lett.* **93**, 031103 (2008)
[5] G Patil, P Raote, J P Nilaya, M B Sai Prasad and D J Biswas, Towards a triggerable switch-less laser, in: *Proceedings of the Seventh DAE-BRNS National Laser Symposium*, vol. 91 (2007)
[6] G Patil, P Raote, J P Nilaya and D J Biswas, *Opt. Commun.* **282**, 4100 (2009)