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A High Power N_2 Laser Using Water Filled Strip Lines

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Abstract. A fast Blümlein circuit with a water strip line having an impedance of Z = 0.078 Ω is used to excite a TE high power nitrogen laser at $\lambda = 337$ nm. A pseudospark switch works as a high power switch. The laser operates without any preionization and delivers an energy of 15 mJ per pulse (7.5 ns FWHM) at 10 kPa nitrogen pressure. The shot to shot reproducibility is better than 5%.

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The $N_2(C) \rightarrow N_2(B)$ nitrogen laser is a rather simple device for obtaining high-power radiation in the ultraviolet at 337 nm. The upper laser level $N_2(C)$ has a lifetime of $\tau = 36/[1+(p/0.76)]$ (p: nitrogen pressure in bar, τ in ns) [1], while the lower level $N_2(B)$ is long lived. Therefore, the laser may be described by a three-level scheme and hence a fast excitation circuit is necessary.

For high-power lasers [6] usually strip lines with low impedance are used to achieve a fast excitation. The impedance Z [Ω] of a strip line is given by $Z = 377 \times (s/w)(\epsilon_r)^{-1/2}$ Ω, where s represents the gap and w the width. Since geometrical parameters are fixed by the length of the laser and the operating voltage, a large dielectric constant ϵ_r is highly desirable. Water seems to be the ideal medium. It has a large dielectric constant of $\epsilon_r = 81$ and a high breakthrough field strength.

In the present paper the properties of a nitrogen laser operating with water filled strip lines will be described. While previous constructions [3, 5] work with a capacitor transfer circuit, the present construction uses a Blümlein circuit as a power source.

Figure 1 shows the basic electrical network. After the spark gap has been fired, the energy of the storage capacitor $C_s = 120$ nF is transferred into two strip lines C_1 and C_2. The transfer time is about 300 ns. In the Blümlein circuit the voltage at C_2 is reversed by the second switch and the laser discharge is initiated.

Each of the capacitors C_1 and C_2 consists of three stainless steel plates measuring 80×11 cm² with a separation of 0.3 cm (Fig. 2). The middle plates are connected to the laser electrodes, which have a length of 80 cm. The whole device is submerged in distilled water, which gives an ideal impedance match at the interface of capacitors to electrodes. The voltage reversing switch is attached just above the water surface (Fig. 2). An ion exchanger maintained the resistivity of the water at better than $4 \cdot 10^3$ Ω·cm, which corresponds to an energy storage time of 3 μs. The impedance of the strip line amounts to Z = 0.078 Ω. For the reversing switch of the Blümlein circuit a thyratron (HY-1102) or a pseudospark switch [2] was used. Both switches have about the same properties. When no breakthrough in the laser channel occurred, the risetime of the voltage reversal was deter-

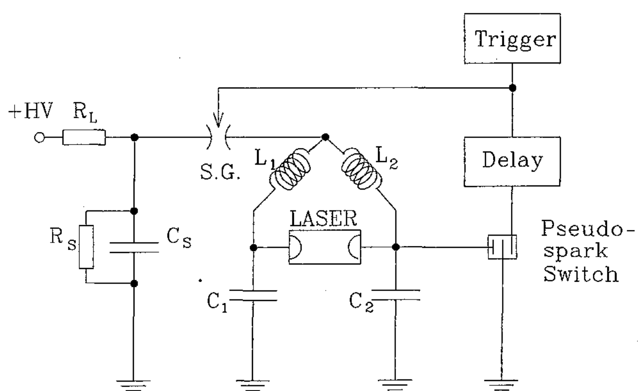

Fig. 1. Basic electrical setup. After the Spark Gap (S.G.) has been fired the energy stored in C_s is transferred into the capacitors C_1 and C_2 of the strip lines. Once the pseudospark gap switch has been closed the voltage of the strip line C_2 is reversed and an electrical wave initiated, causing breakdown in the laser channel (see also Fig. 2)

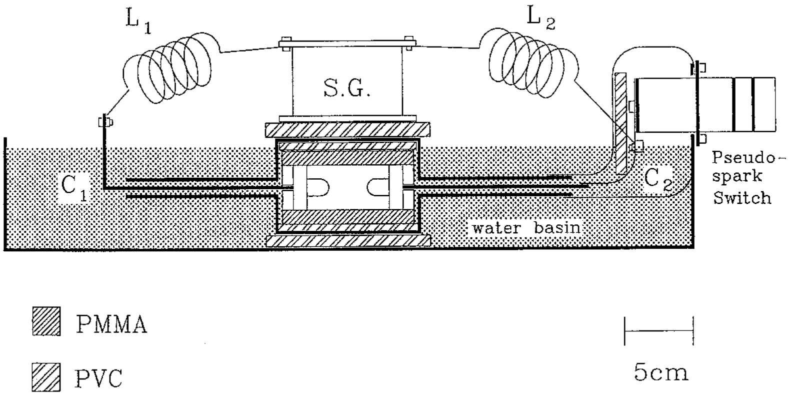

Fig.2. Sectional drawing of the experimental setup

mined to be 78 ns. Owing to the ohmic losses of the switches during firing, the reversed voltage was measured to be 70% of the charging voltage. Experiments using a four-gap pseudospark switch led to a faster risetime by the reduction of the inductance by about a factor of 2. However, the ohmic losses increased because four channels had to be established. So only a slight improvement of the laser performance was achieved.

The laser channel had an electrode separation of 3 cm and a width of 0.5 cm. The best performance of the laser was observed with a charging voltage of 20 kV and a N_2 pressure of 10 kPa. Visible inspection showed an extremely smooth discharge, leading to a shot to shot reproducibility of better than 5% in energy. When the same laser head was operated with distributed capacitors, filamentation and beginning of arcing occurred already at 5 kPa. Since the energy transport in water is nine times slower than in air the coupling between pulseline and electrodes in water prevents energy rubbing along the electrodes. This explains that the laser works reproducibly without preionization at a rather high pressure.

The output energy was determined to be 15 mJ per shot using a pyroelectric detector. This leads to an efficiency of 0.68%. The pulse width, measured with a fast photodiode, was 7.5 ns (FWHM).

An increase in energy on adding SF_6 gas to the N_2 gas was reported by several researchers [3, 8-10, 12]. Increased output may also be expected for He/N_2 gas mixtures [11]. A large number of mixtures were tried in the present laser and a slight increase of the laser output energy was observed, but only in cases where the laser was operated with parameters (pressure, voltage) far from the optimum. Passive preionization of the discharge using a silicon electrode (ρ = 400Ω·cm) parallel to the main discharge electrode as proposed by Papadopoulos and Serafidinides [4] led to an energy increase of about 20%.

In conclusion, water as the dielectric in the strip lines improves the performance of the nitrogen laser. Besides its low impedance, water has a high breakthrough field strength. Breakthroughs heal immediately. The disadvantage of the ohmic conductivity can be overcome by charging the strip line within 1 μs before firing the laser. The performance of such a laser is demonstrated to lead to a very good shot to shot reproducibility. The energy per pulse and the efficiency of the laser are among the highest ever achieved with nitrogen lasers.

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