INTERNATIONAL ATOMIC ENERGY AGENCY
UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL CENTRE FOR THEORETICAL PHYSICS
34100 TRIESTE (ITALY) - P.O.B. 586 - MIRAMARE - STRADA COSTIERA 11 - TELEPHONES: 224281/2/3/4/5/6
CABLE: CENTRATOM - TELEX 460392-I

SMR/100 - 39

WINTER COLLEGE ON LASERS, ATOMIC AND MOLECULAR PHYSICS

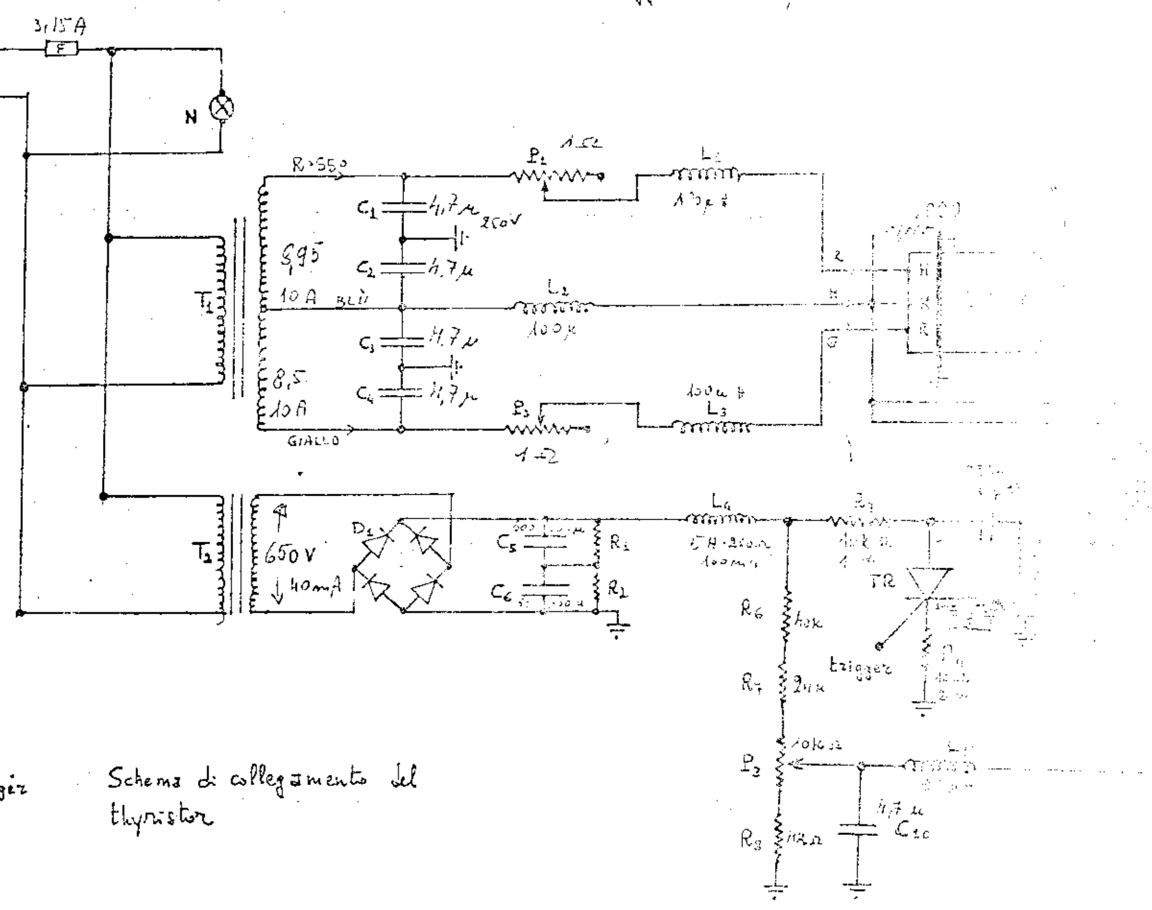
(24 January - 25 March 1983)

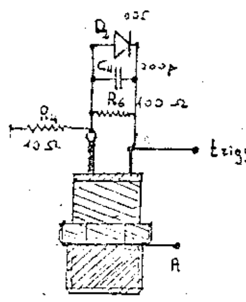
Laser Laboratory Notes

L. PALLARO

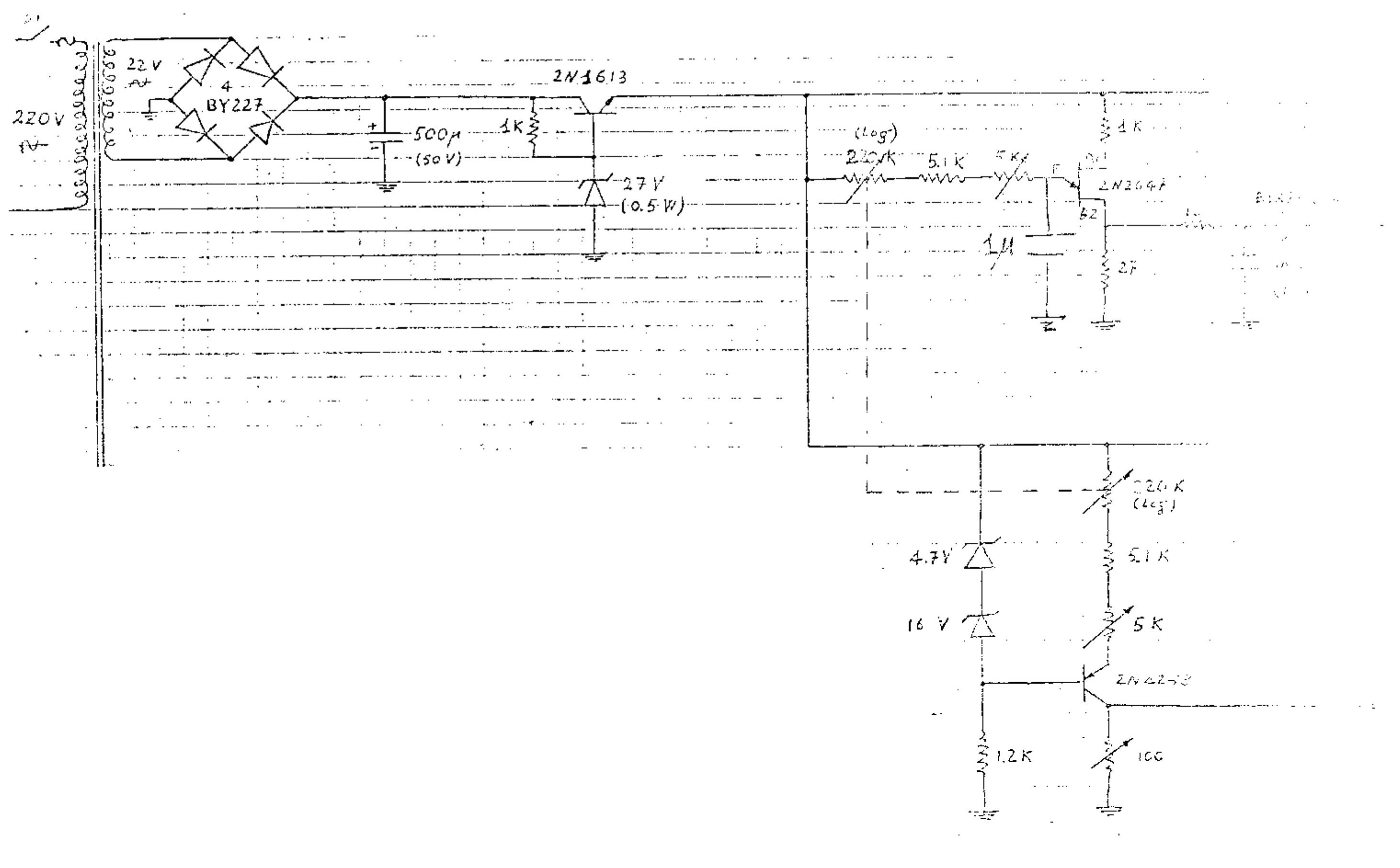
Centro di Elettronica Quantistica
e Strumentazione Elettronica
Istituto di Fisica del Politecnico
Piazza Leonardo da Vinci, 32
20133 Milano
Italy

Circuito di alimentazione e di trigger del Thyristor





Schema di collegamento del thyristor



SUBNANOSECOND AMPLIFIED SPONTANEOUS EMISSION PULSES BY A NITROGEN PUMPED DYE LASER

R. CUBEDDU, S. De SILVESTRI and O. SVELTO
Centro di Elettronica Quantistica e Strumentazione Elettronica del C.N.R., Istituto di Fisica del Politecnico di Milano, Milano, Italy

Received 8 February 1980
Received manuscript received 5 May 1980

Pulses of 100 ps duration and peak power up to 100 kW are obtained with a dye laser pumped by an atmospheric pressure nitrogen laser of 0.5 ns duration. The shortening of the dye laser pulses is attributed to amplified spontaneous emission.

1. Introduction

Several techniques have been proposed for generating subnanosecond pulses from a nitrogen (N_2) pumped dye laser. Most of them use an N_2 laser with a duration of a few nanoseconds [1–8]. Only in a few cases have high pressure N_2 lasers been used. Salzmann et al. [9], using a 4 atm N_2 laser pump with pulses of 100 ps duration, obtained dye laser pulses shorter then 10 ps. They used the controlled resonator transient technique first proposed by Roess [10]. The dye laser cavity was 40 μm long with a cavity lifetime of 0.04 ps. The peak power was not quoted. In our experience however, the generation of N_2 laser pulses of 100 ps duration is quite difficult to achieve, because it requires a very stable discharge at a nitrogen pressure of ≈4 atmospheres. In addition, the very high ratio (~ 2500) of the pumping pulse duration over the cavity lifetime, which applies to the experiment of Salzmann et al., should provide a single pulse only at a pump level very near to threshold [9,10]. More recently [11], an atmospheric pressure N_2 laser (0.6 ns pulse duration) was used to generate pulses of 30–40 ps duration with peak power of up to 30 kW in a Hansch type cavity, followed by an amplification stage (pumped by one of the two outputs of the N_2 laser). However, even in this case the peak power from the main oscillator is very low (~ 1 kW). Moreover, the use of a Hansch type resonator is critical, and the stability of this laser is not very high [12].

In this work, we report on a simple configuration of a nitrogen-pumped dye laser in which pulses of ~ 100 ps duration and peak power of ~ 100 kW were obtained. For this purpose, an atmospheric pressure N_2 laser of our specific design [13] was used and only one of the two output beams of this laser was employed to pump a specially designed dye laser. Amplitude fluctuations are less than 10%, and arise from the N_2 laser fluctuations.

2. Experimental

A schematic diagram of the experimental set-up is shown in fig. 1. As a pump source, we used an atmospheric pressure N_2 laser that provides pulses of 500 ps

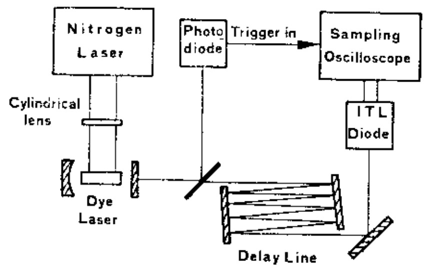


Fig. 1. Block diagram of dye laser arrangement and detection apparatus.

[illegible] kW at a [illegible] of 100 Hz. One of the two outputs of the N_2 laser was focused through a cylindrical lens into a 1 cm-long, 100 μm thick dye cell, with transverse flow. To increase the pumping efficiency, the back surface of the cell was made of reflecting stainless steel. The cell axis was rotated by about 20° from the resonator axis to avoid back reflections at the cell end faces. The dye laser cavity of hemifocal design consisted of a spherical 100% reflecting mirror of 2-cm focal length and a 10% reflecting-plane output mirror. Several dyes (Rhodamine 6G, 7D4MC, α-NPO, Stilbene and POPOP) were used as laser medium. The duration of the dye laser pulses was measured by a fast photodiode ITL (rise time 100 ps) directly connected to a sampling head S4 (rise time 25 ps) of a Tektronix 7904 oscilloscope. An optical delay line of ~ 60 ns was used to overcome the internal delay of the sampling oscilloscope (see fig. 1).

3. Results and discussion

A typical dye laser pulse obtained with 7D4MC is shown in fig. 2. The FWHM of the pulse is seen to be ~ 150 ps. Once the finite response time of our detecting system is taken into account (~ 100 ps), we infer a width for our pulse of ~ 100 ps (FWHM). No changes in the pulse duration were observed with out detection system when the cavity was lengthened from 2 cm up to 30 cm, and when the spherical mirror was replaced by a plane mirror or a diffraction grating. In these last two configurations, however, a decrease of 30% in the out[illegible] was measured. Similar results were obtained with all the dyes used.

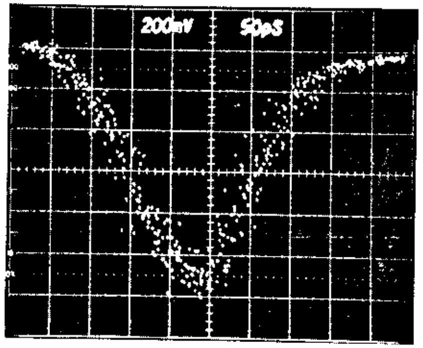


Fig. 2. Observed dye laser pulse. Time scale, 50 ps div^{-1}.

On the basis of these experimental results, it seems to us that the pulse shortening observed cannot be explained in terms of controlled resonator transient theory. In fact, according to Roess [10], at a given pumping level, the pulse shortening depends on the ratio between the pump duration and the cavity lifetime τ_c. In our experiment no appreciable changes of the dye laser pulse duration were observed when τ_c was varied by as much as a factor of 15 by lengthening the cavity up to 30 cm. Following this last observation, we therefore suggest that our pulse stems from transient shortening due to amplified spontaneous emission. Indeed, when the spherical mirror of fig. 1 is moved 30 cm away from the cell, the spatial length of the 100 ps pulse observed becomes one order of magnitude smaller than the cavity length. In this case, the oscillation can be considered as resulting from a two-pass process, as follows. First, when the threshold for amplified spontaneous emission is reached [19], a short pulse is generated in the dye-plane mirror system. This pulse leaves the dye single pass gain G_0 well below the threshold level which, according to ref. [19], is calculated in our case to be $G_0 \simeq 866$. The pulse then travels to the far spherical mirror and it is reflected back to the dye cell. Since the gain left in the dye cell, although smaller than G_0, may still be appreciable, amplification and further shortening will occur. The amplified beam then passes through the plane mirror to provide the output beam. As a comment on our suggestion, we would point out that pulses appreciably shorter than the dye fluorescence lifetime and arising from amplified spontaneous emission have, in fact, already been observed to occur in several organic dyes, when pumped by picosecond pulses [14–18]. Of course, the shortening is expected to depend on the available gain, the fluorescence lifetime, and the population rise time. Indeed, in our case, pulses of 100 ps duration were obtained only in the optimum pumping configuration previously described: i.e., where a 100 μm thick cell with a back-reflecting surface was used. By contrast, a pulse duration of 400 ps was observed when our dye cell was replaced by a 10 mm-thick standard spectrophotometric cell. In this arrangement, in fact, the same pump power is absorbed in a larger active volume, thus resulting in a lower gain.

Short Communication

A simple and reliable atmospheric pressure nitrogen laser

Due to the interest in the nitrogen laser as a suitable pump source for dye lasers, extensive experimental work has been carried out on this subject. For application in the sub-nanosecond time domain, it has been shown that it is possible to reduce the nitrogen laser pulse duration by increasing the gas pressure. Atmospheric pressure N_2-lasers have been reported by several authors [1–8].

In this communication we describe the construction of a very compact and reliable atmospheric pressure N_2-laser which provides pulses of 0.5 ns duration, with a peak power of 100 kW at a repetition rate of 100 Hz.

The laser is excited by a conventional flat-plate Blumlein system short circuited by a spark gap. The transmission line is made of a thin layer of Cu evaporated onto a 0.4 mm thick mylar sheet pressed on an aluminium plate. It has a total storage capacitance of 2.2 nF and a characteristic impedance of $\sim 0.4\ \Omega$. The discharge electrodes, 200 mm long, are made from aluminium of 10 mm thickness and 20 mm width with a semi-circular profile ($R = 5$ mm) and are pressed onto the Cu plate by two plexiglass plates held by screws (Fig. 1). One electrode is connected at both ends to a couple of screws which allow it to be aligned carefully from outside. The overall dimensions of the assembled laser head are 220 mm × 200 mm × 40 mm. The electrode separation is ~ 2 mm, the nitrogen pressure 760 torr and the charging voltage 16 kV.

The electric discharge in atmospheric nitrogen lasers usually gives rise to arc formation along the laser channel, especially at high repetition rate, and consequently the laser action turns out to be very unstable. Several methods have been proposed to prevent this effect (e.g. pre-ionization, electric field modification, etc.). With our electrode design arcing is completely eliminated by a suitable choice of the gas flow. The nitrogen flows into the discharge chamber through three holes equally spaced in the fixed electrode, as shown in Fig. 1, which ensure a fast and efficient gas replacement.

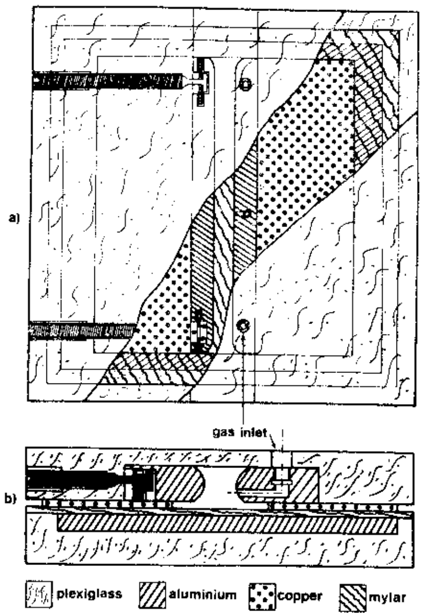


Figure 1 (a) Top view of the laser and (b) cross-section of the channel.

A small number of inlets produce gas stagnation zones which favour arc formation. At 100 Hz repetition rate and 12 ℓ min^{-1} gas flow the

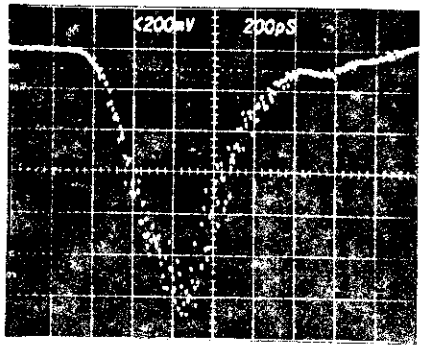


Figure 2 Observed nitrogen laser pulse. Time scale 200 ps div^{-1}.

4. Conclusions

In conclusion, we can say that our system provides a simple and reliable way of generating dye laser pulses of 100 ps duration and high peak power. The phenomenon responsible for the generation of these short pulses seems to be amplified spontaneous emission.

References

[1] B.J. von Gutfeld, Appl. Phys. Lett. 18 (1971) 481.
[2] C. Lin and C.V. Shank, Appl. Phys. Lett. 26 (1975) 389.
[3] L.W. Braverman, Appl. Phys. Lett. 27 (1975) 602.
[4] S.A. Borgström, Phys. Scripta 14 (1976) 92.
[5] R. Cubeddu, P. Polloni and C.A. Sacchi, Appl. Phys. 13 (1977) 109.
[6] S. Mory and R. König, Exp. Techn. d. Phys. 25 (1977) 581.
[7] R. Wyatt, Optics Comm. 26 (1978) 429.
[8] Zs. Bor, Optics Comm. 29 (1979) 103.
[9] H. Salzmann and H. Strohwald, Phys. Lett. 57A (1976) 41.
[10] D. Roess, J. Appl. Phys. 37 (1966) 2004.
[11] G. Veith and A.J. Schmidt, Optics Comm. 30 (1979) 437.
[12] S.M. Curry, R. Cubeddu and T.W. Hänsch, Appl. Phys. 1 (1973) 153.
[13] R. Cubeddu and S. De Silvestri, Opt. Quant. Electr. 11 (1979) 276.
[14] M.E. Mack, Appl. Phys. Lett. 15 (1969) 166.
[15] E.G. Arthurs, D.J. Bradley and A.G. Roddie, Appl. Phys. Lett. 20 (1972) 125.
[16] C.V. Shank, E.P. Ippen and A. Dienes, Appl. Phys. Lett. 21 (1972) 125.
[17] C. Lin, T.K. Gustafson and A. Dienes, Optics Comm. 8 (1973) 210.
[18] A. Penzkofer and W. Falkenstein, Opt. Quant. Electr. 10 (1978) 399.
[19] G.J. Linford, E.R. Peressini, W.R. Sooy, and M.L. Spaeth, Appl. Optics 13 (1974) 379.

discharge is perfectly homogeneous along the channel. Due to the small volume of the laser the gas consumption is relatively small.

The pulse width has been measured using an ITL fast photodiode (FWHM 150 ps) connected to a Tektronix 7904 sampling scope with a S-4 sampling head. The overall FWHM was ~ 200 ps. The detected laser pulse is shown in Fig. 2. The time scale is 200 ps div^{-1}.

In conclusion, we have reported a very simple and low cost atmospheric pressure nitrogen laser particularly suitable for pumping dye lasers, for application in time-resolved spectroscopy and fast dynamic processes. The system described has been working for several months in our laboratory without any damage.

References

1. H. M. VON BERGMANN, V. HASSON and P. PREUSSLER, *Appl. Phys. Lett.* 27 (1975) 553–55.
2. H. M. VON BERGMANN, V. HASSON and D. PREUSSLER, *ibid* 28 (1976) 17–18.
3. V. HASSON and H. M. VON BERGMANN, *J. Phys. E.: Sci. Instrum.* 9 (1976) 73–76.
4. H. SALZMANN and H. STROHWALD, *Opt. Commun.* 12 (1974) 370–72.
5. W. HERDEN, *Phys. Lett.* 54A (1975) 96–98.
6. E. E. BERGMANN, *Appl. Phys. Lett.* 28 (1976) 84–85.
7. H. STROHWALD and H. SALZMANN, *ibid* 28 (1976) 272–74.
8. R. K. BAUER and A. KOWALCZYK, *Opt. Commun.* 23 (1977) 169–70.

Received 6 December 1978

R. CUBEDDU
S. DE SILVESTRI
Centro di Studio per l'Elettronica Quantistica e la Strumentazione Elettronica del CNR
Istituto di Fisica del Politecnico di Milano
Italy