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WINTER COLLEGE ON

ATOMIC AND MOLECULAR PHYSICS

(9 March - 3 April 1987)

(BASIC SPECTROSCOPY INSTRUMENTATION)

CONSTRUCTION OF SOME LASER SOURCES FOR SPECTROSCOPY

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BASIC SPECTROSCOPY INSTRUMENTATION : K. S. LOW

LECTURE 2 : CONSTRUCTION OF SOME LASER SOURCES FOR SPECTROSCOPY

2.0. Introduction

2.1. Nitrogen laser

Lecture notes - published in Proceedings of First Tropical College on Applied Physics, 1984, Kuala Lumpur

- C.H.Tan and K.S.Low

2.2. Nitrogen laser pumped dye laser and tuning

- C.H.Tan and K.S.Low

2.3. Flashlamp pumped dye laser

- Ignatius Rasiah and B.C.Tan

2.4. Other lasers to be constructed.

2.0 Introduction

Design and construction of lasers

building your own lasers
- technical job ?
- no physics ?

Answer: treat each laser you intend to build as a study of plasma physics + optics

Study electrical discharge characteristics optical properties.

Home build lasers are much cheaper ~ 10 to 20% cost of commercial units except for some

Easier to maintain & know exactly what goes wrong

Decide on the laser system, hunt for components, use your own hands, if necessary to get your own laser machined & assembled

- Weigh out complexities, costs & usefulness of the lasers

To make lasers, require

1. HV supply

   neon sign transformer

   10 → 12 kV , 30 mA

   · N_2 laser, CO_2 laser, He-Ne laser

2. Vacuum components

   rotary pump

3. Simple control electronics

   triggered spark gap

4. energy and laser detection

   energy meters can be home build also – thermopiles

5. Optics

   coating of Aluminium (or gold) front surface mirrors

   coating of dielectric coated mirrors

   Optics handling & cleaning

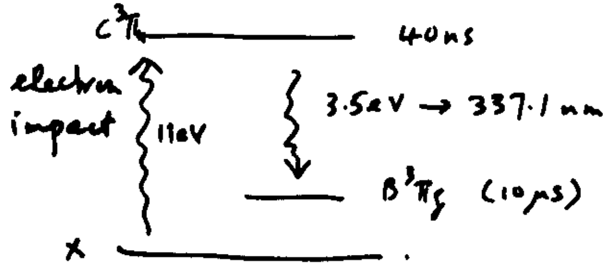
   alignment techniques

2.1: Nitrogen lasers (1963 – Heard)

- easiest & cheapest to build
- useful pump source for dye lasers
- relatively high peak power to 1 MW or more
- for laser induced fluorescence works
- narrow pulsewidth for time resolved spectroscopy → 1 → 10 ns pulsewidth

Basic Principles

3 level superradiant laser



In order to lase, must have very fast high voltage, high current discharge

Upper level ~ 40 ns

require very fast discharge ≲ 40 ns

Since lower level ~ 10 μs

can only have gain within time ≤ 40 ns

– very little gain amplification

No need to have mirrors to form resonator cavity – a super radiant laser

* ∴ no expensive optics & also alignment

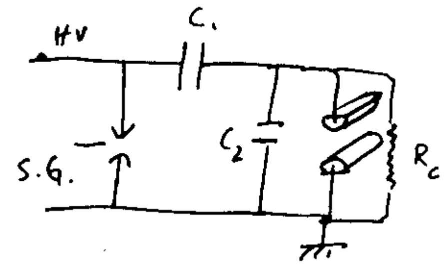
However, need very fast discharge

Normally, 2 types of fast discharge circuits

Blumlein or capacitor transfer or C to C type

– both circuits are also used for TEA-CO_2, Excimer & other pulse lasers systems.

A capacitor transfer circuit



HV → 10 to 20 kV

S.G. → spark gap to be triggered externally

C_1 → 20 to 50 nF main storage capacitor

C_2 → peaking or dumping capacitor that are mounted very close or across the channel to reduce inductance

Rise time of circuit

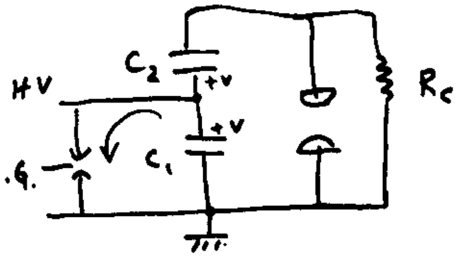
$t \sim \frac{1}{4} 2\pi\sqrt{LC}$

C_1 main storage capacitor – may have large circuit inductance

C_2 to reduce circuit inductance

Blumlein type circuit

- basically a voltage doubling unit



charging across the channel through R_c

When S.G. fires, C_1 discharges through S.G. & voltage ringing occurs

voltage across channel rises to about 2V provided $R_c C_2 \gg 40ns$

- more efficient than C-to-C circuits

Normally, parallel plates and/or some form of pulse forming circuit is used to obtain very low inductance

FIRST TROPICAL COLLEGE ON APPLIED PHYSICS

EXPERIMENT VI

THE NITROGEN LASER

C.H. Tan and K.S. Low

Content:

1. Introduction 134
2. Basic Physics of Nitrogen Laser 134
3. Construction of the Nitrogen Laser 135
4. Electrical Characteristics of Nitrogen Laser 143
5. Optical Characteristics of Nitrogen Laser 147

Proceedings of 1st Tropical College 1984, Kuala Lumpur

Ed. by S. Lee et al

EXPERIMENT VI

THE NITROGEN LASER

1. Introduction:

The write-up consists of four sections. The first and second sections deal with the actual design and construction of the nitrogen laser. The third section contains some basic theory of the blumlein electrical circuit and Experiment I where you are required to use a Rogowski coil to measure the various electrical parameters of the blumlein circuit. The final section deals with the optical characteristics of the nitrogen laser and it contains Experiment II where you are required to investigate some of the laser output characteristics.

2. Basic Physics of Nitrogen Laser:

The UV nitrogen laser is based on a three level pumping scheme. The ground state $X^1\Sigma^1g$ (level 1) and two electronically excited levels $C^3\Pi u$ (level 3) and $B^3\Pi g$ (level 2) are shown in Fig. 1. The vibrational and rotational splitting of these levels are omitted for simplicity.

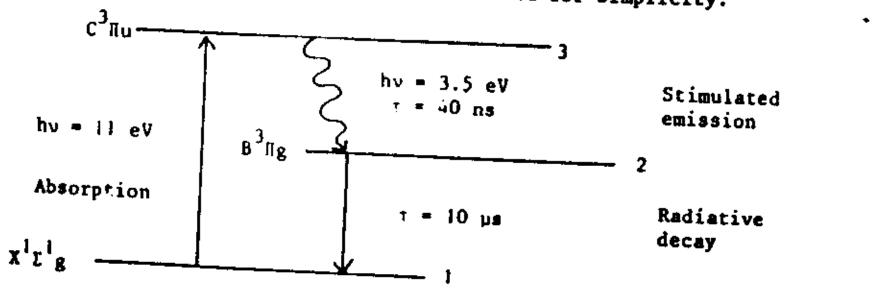


Fig. 1 Three levels pumping scheme of Nitrogen Laser.

During an electrical discharge, the nitrogen molecules are excited from the ground level to the upper level 3. The energy difference between level 1 and level 3 is of the order 11 eV. The transition from level 3 to level 2 corresponds to 3.5 eV giving rise to the 33.7 nm laser radiation. The upper laser level depopulates either radiationlessly via collision with electrons and other nitrogen molecules or through spontaneous or stimulated emission into the lower level 2 with a lifetime of 40 ns. Level 2, on the other hand, is a metastable state with a lifetime of about 10 μs. To avoid

depopulation by spontaneous emission, population inversion must be accomplished within a time shorter than 40 ns. This requires pumping by a rapid pulse discharge from a circuit with very low inductance e.g. in a blumlein circuit.

Due to the short life time of the upper laser level, the population inversion produced by such a discharge can be sustained for a short period only. However, during this time, the gain is sufficiently large that even in only one pass the laser radiation becomes so intense that the upper laser level is largely depopulated via stimulated emission. Therefore, an optical resonating cavity is not essential in the operation of this type of laser. It is called a "super-radiant" laser.

3. Construction of the Nitrogen Laser:

3.1 General Features of Nitrogen Laser:

In order to obtain a fast high voltage-high current discharge in a nitrogen laser, a low inductance high-voltage generator is needed. A blumlein high-voltage generator is used in this work and schematic diagram is shown in Fig. 2.

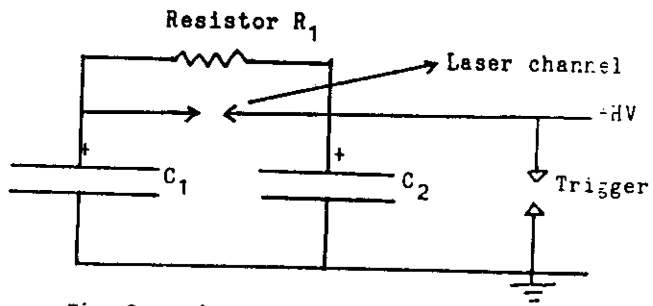


Fig. 2 Equivalent circuit for the blumlein high-voltage generator of the nitrogen laser

Initially, both the capacitors C_1 and C_2 are charged to the same high voltage when the high voltage supply is on, but there is no voltage drop across the laser channel. When the spark gap is triggered, causing a spark discharge and hence grounding one end of the laser electrode, an instantaneous high voltage develops at the other electrode connected to the capacitor C_1. Thus a blumlein circuit is a simple method of obtaining fast voltage switching. The criterion of fast switching is to have low inductance in the switching circuit, this is achieved in the usage of flat plate capacitors.

The physical construction of the laser is shown in Fig. 3 which consists of thelaser channel, the two parallel plate storage capacitors and the spark gap. The laser channel is connected electrically to the capacitors by the two soft copper sheet electrodes that extend from the middle of the laser channel; a 500 ohms resistor, R_1, is connected across the laser channel to both sides of the channel electrodes. Since the nitrogen laser is superradiant in nature, a simple front surface aluminized mirror is placed at one end of the laser channel that will roughly doubled the output power.

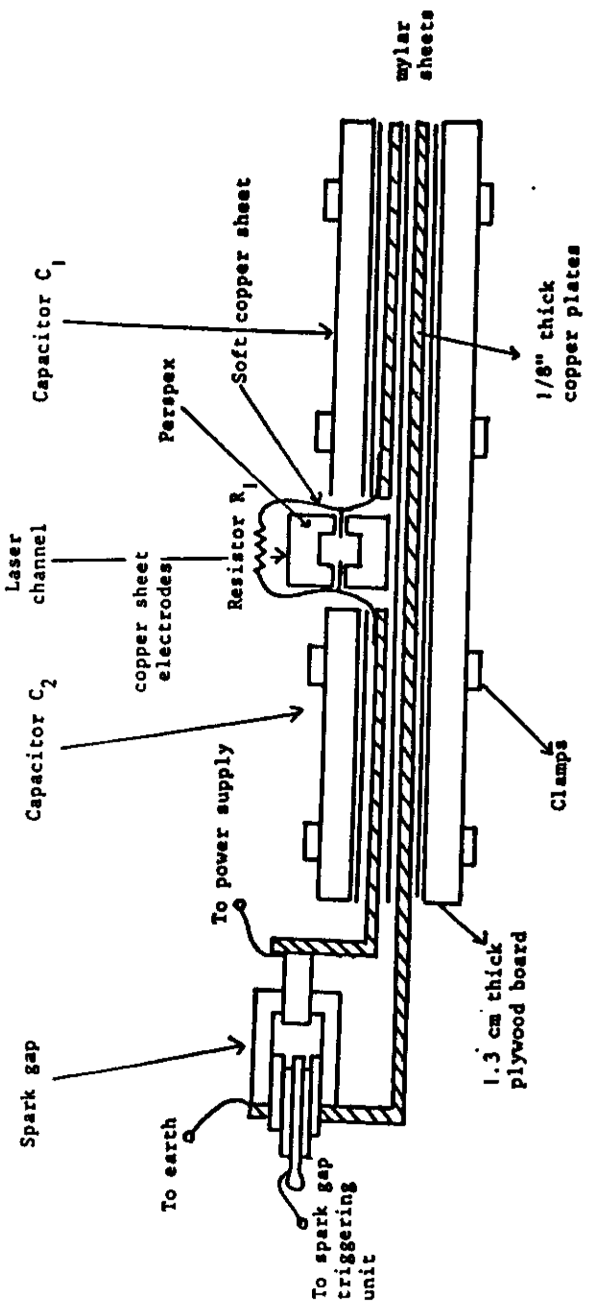


Fig. 3 A schematic diagram of the cross-section of Nitrogen Laser

Other components of the construction are a triggering unit for the triggering of the spark gap discharge and a high voltage power supply for the charging of the capacitors.

3.2 Details of Component Construction:

3.2.1 Laser Channel:

The laser channel is constructed using two soft copper sheets of thickness 1.6 mm and length 70 cm glued to two pieces of 1.3 cm thick and 2.5 cm width perspex rod using silicon rubber to form a rectangular laser channel of 1.5 cm width by 1 cm height by 70 cm length (internal measurement). The electrodes separation gap is 0.8 cm. The cross-section and layout of the channel are shown in Fig. 4. The ends of the tube are sealed using perspex caps fitted with quartz disc windows and O-rings.

The nitrogen gas is pumped longtitudinally along the tube i.e. the gas enter and leave from one end to another end of the tube through the gas inlet and outlet. A rotary pump is used and the pressure is monitored by a pressure gauge (0 - 250 mb), regulated by the gas flowmeter (0 - 150 SCFH).

3.2.2 Flat-plate Storage Capacitors:

The storage capacitors are constructed using parallel copper plates with both 10 mil and 20 mil mylar sheets acting as the dielectric as shown in Fig. 3. The mylar dielectric has a breakdown rating of 2 kV/mil and a dielectric constant of 1.8. The measured values of the constructed capacitors are as follows:

Capacitors	10 mil mylar (nF)	20 mil mylar (nF)	Dimension (cm^2)
C_1	18.0	14.2	70 x 46
C_2	7.0	4.2	70 x 21

The copper plates are carefully polished with the edges well rounded to reduce corona discharge. The capacitor plates are firmly held together between two pieces of 2.5 cm thick plywood boards in order to maintain a uniform spacing and to prevent mechanical flexing of the dielectric during charging and discharging of the capacitors. Thick 20 mil mylar sheets are placed in between the copper plates and plywood boards for insulation.

3.2.3 High Voltage Power Supply:

The nitrogen laser is known to operate best around 10 to 25 kV. A 35 kV variable high voltage charger has been constructed. It is shown in Fig. 5. A high voltage transformer is used to step up the voltage from a 0 - 250 V variac connected to the mains rms voltage of 230 V. The high

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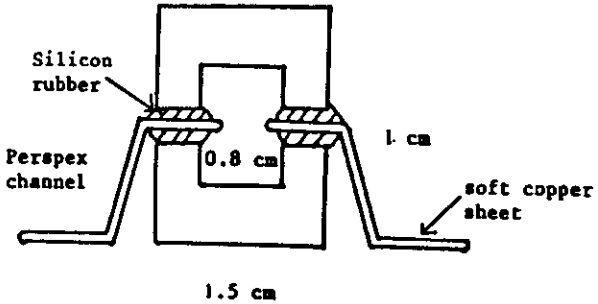


a) Cross-section

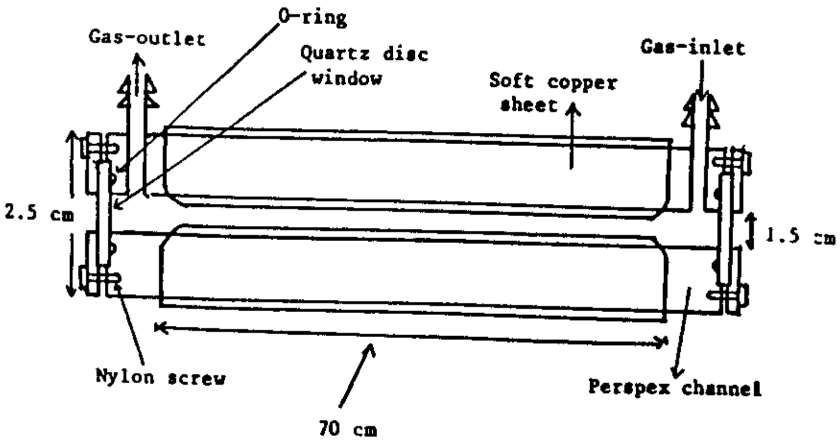


Fig. 4 Schematic diagrams of the Laser Channel

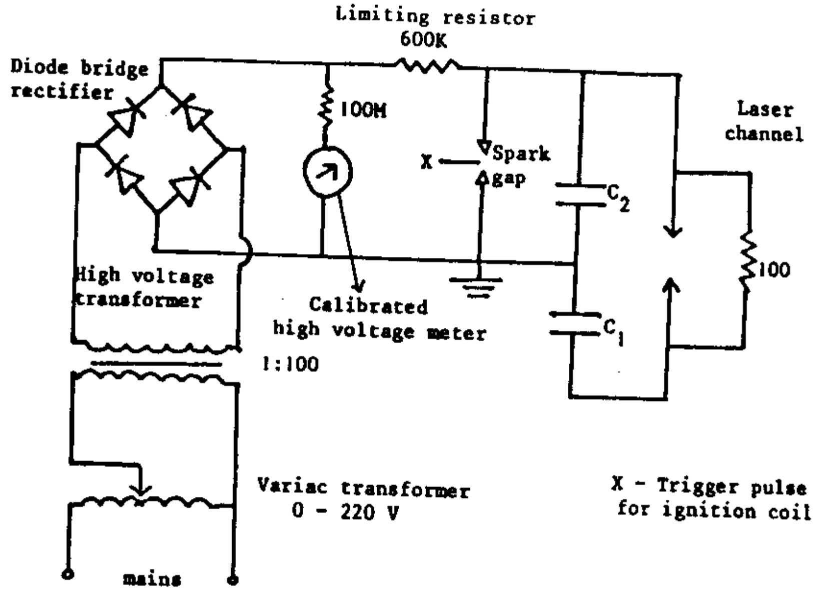


Fig. 5 High Voltage Power Supply for Nitrogen Laser

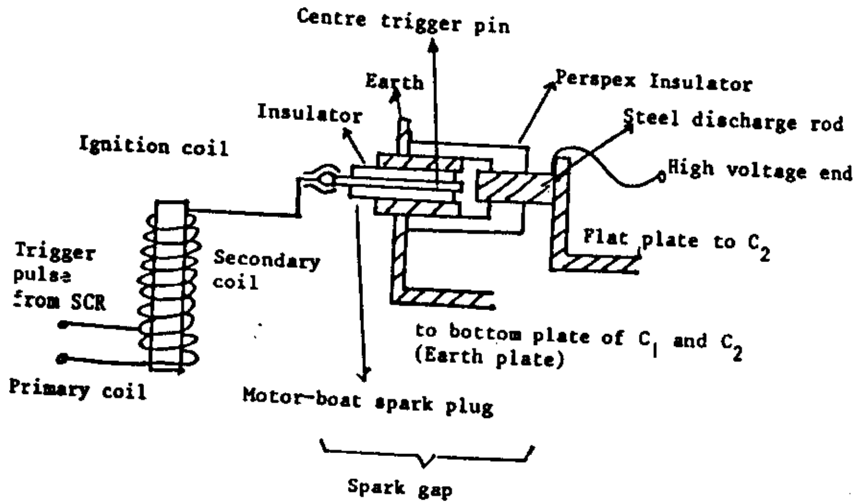


Fig. 6 Motor-boat spark plug triggered spark gap

voltage output from the transformer is then full-wave rectified using a diode bridge consisting of 4 x 41 pieces of IN4007 diodes in parallel each with a 4.7 MΩ dividing resistor. The charging current is limited by six pieces of tubular power wire wound 100 KΩ resistors in series giving a charging current of 17 to 42 mA when the charging voltage is operated from 10 to 25 kV. (The maximum current rating of the transformer is 50 mA). The high voltage output is read out on a microammeter in series with a 100 MΩ resistor chain calibrated using an electrostatic voltmeter.

3.2.4 Spark Gap and Triggering Circuit:

A non-pressurised air spark gap triggered by a motor-boat spark plug was used as shown in Fig. 6. The spark plug has its centre triggering pin insulated from its outer metallic body by a gap requiring a firing voltage of 5.5 kV. An ordinary motor car ignitron coil (CIZ-500) was used to generate the necessary high voltage triggering spark.

The triggering circuit as shown in Fig. 7 was used. It consists of a UJT trigger pulse circuit to trigger the 'gate' of a SCR which is holding a peak mains voltage of 340 V across its anode and cathode. Both continuous switching and manual switching are selectable by the two-way switch of S1 and S2 respectively. In continuous switching, a pulse repetition rate of more than 10 Hz can be obtained by adjusting the RC time-constant of the UJT circuit. The manual switch is operated using the press-switch S3. In both manual and repetition switching, a trigger pulse would appear across the primary of a 1:1 pulse transformer. This will trigger the SCR which then produces a voltage pulse of approximately 340 V peak. The SCR output trigger pulse appears across the primary of the ignition coil which then gives an output pulse of 17.5 kV peak. As shown is Fig. 6, this high voltage will cause the spark plug to fire, hence inducing the high voltage discharge across the spark gap. For more information on the control electronics, refer to Experiment IV of this volume.

3.3 Operation of the Nitrogen Laser:

In the operation of a nitrogen laser, there are two important factors to be taken into consideration. Firstly, the radio frequency radiated into the surroundings due to the spark discharge must be effectively shielded. To do this, a metal casing is constructed to enclose the laser channel leaving only an outlet and another outlet for the high voltage and triggering lines as well as the gas inlet and outlet rubber tubings. The outlets are constructed in the form of wave guides that will attenuate the emission of radio frequency. Also, all connections of electrical wires from outside the casing to the laser, e.g. the high voltage and triggering lines, are made using coaxial cables to prevent propagation of RF along the wire to the outside. Secondly, the grounding of the high voltage to the earth line during spark gap breakdown will cause a rapid transient high voltage in the earth circuit and also a transient high voltage wave reflected back into the mains circuit. Any electrical instrument using the mains supply will then be affected. To overcome these problems, the earth line of the laser discharge is connected to the waterpipe instead as shown in Fig. 8. In addition, all earth lines are distributed from a single point to the various laser components to prevent earth looping. A line filter for the mains with an attenuation of 100 db at frequency from 14 kHz to 10 GHz is placed before the mains supply to the input of the variac

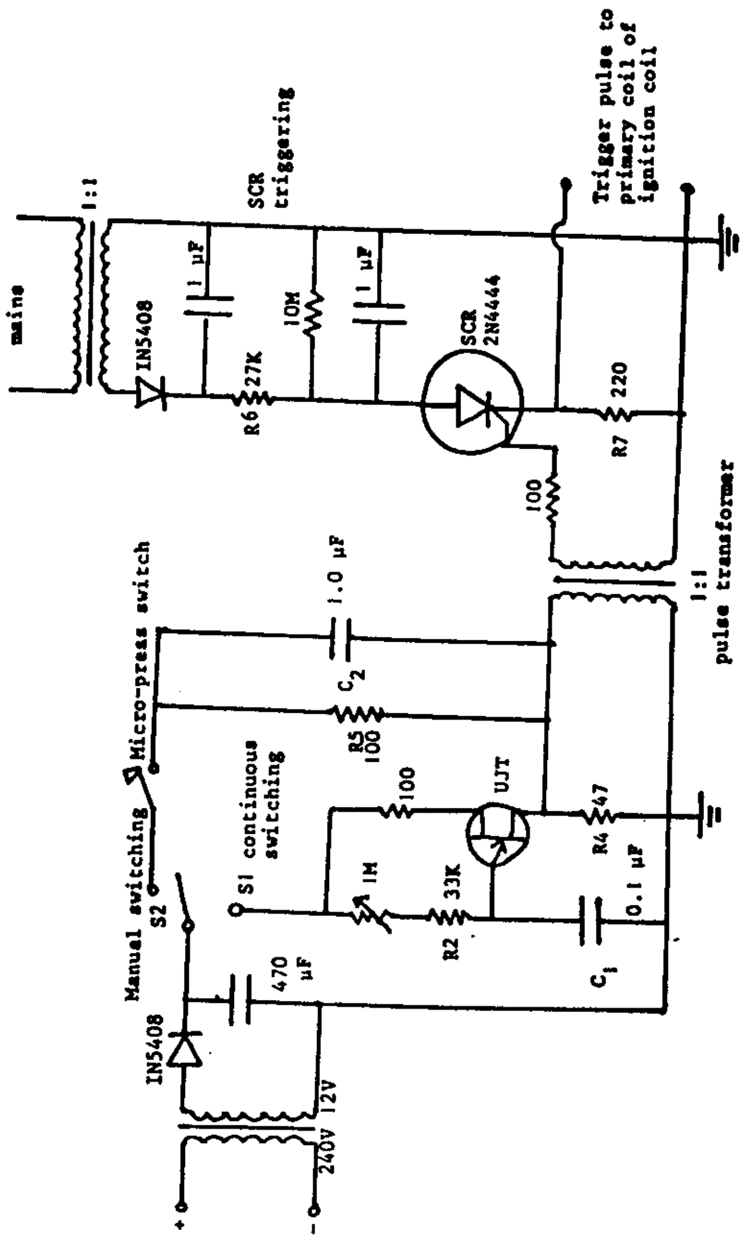


Fig. 7 Triggering circuit for motor-boat spark plug spark gap

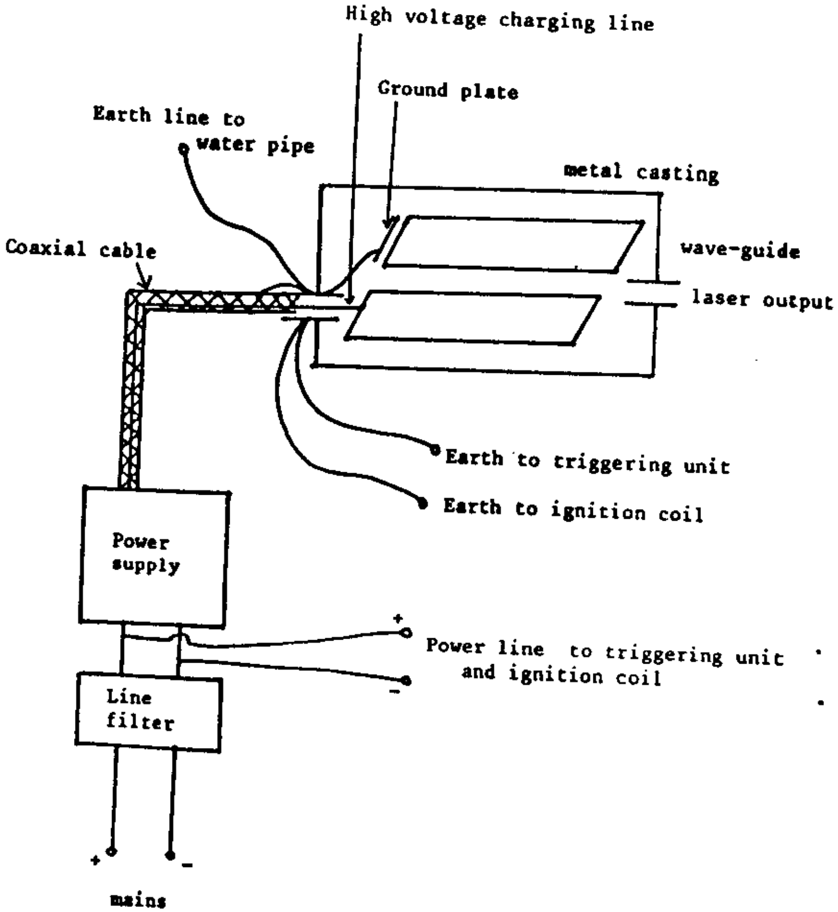


Fig. 8 RF shielding, line filtering and electrical connection to avoid earth looping and transient earth floating.

transformer.

Since the nitrogen laser is operated at high voltage, a few safety precautions must be taken into account during the operation. An "earthing roc" connected to the earth is used to discharge the capacitors prior to any manipulation of the laser components. During charging and discharging of the laser, close contact with the laser must be avoided and the laser output must be carefully guided on its path.

Following the above precautions, the nitrogen laser is safe for operation and use in experimental work.

4. Electrical Characteristics of Nitrogen Laser:

4.1 Electrical Characteristics of the Blumlein Pulse Forming Circuit:

The blumlein circuit is a simple means to obtain a high voltage pulse which could then be applied across the laser channel. This is shown again in Fig. 9 together with the equivalent circuit when the spark gap breaks down.

The RLC circuit of the spark gap breakdown is composed of the capacitance C_2, the spark gap inductance L_2 (including stray inductances) and the breakdown spark resistance R_2. When breakdown occurs, the circuit begins to oscillate as defined by the following equation:

$$L_2 \frac{dI_2}{dt} + R_2 I_2 = V_o - \frac{1}{C_2} \int_o^t I_2 dt \qquad (1)$$

where I_2 is the current flowing across the spark gap. Terms on the left-hand side represent the voltage that develops across the spark gap during the discharge.

The equation has a damped sinusoidal solution is the form of

$$I_2 = Ae^{-\gamma t} \sin \omega_1 t \qquad (2)$$

where $\omega_1 = (\omega_o^2 - \gamma^2)$ is the oscillating frequency

$\omega_o = \surd(\frac{1}{L_2 C_2})$ is the natural oscillation frequency

and $\gamma = \frac{R_2}{2L_2}$ is the damping factor.

The voltage across the spark gap during the spark gap breakdown can be shown to be

$$V_2 = V_o e^{-t/\tau} (\frac{R_2}{2\omega_1 L_2} \sin \omega_1 t + \cos \omega_1 t) \qquad (3)$$

where $\tau = \frac{1}{\gamma}$ is the damping time constant.

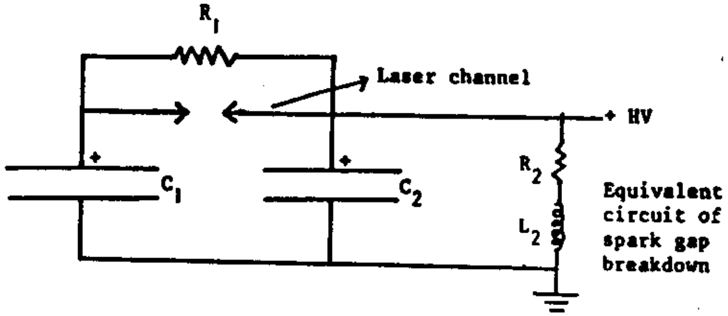


Fig. 9 Equivalent blumlein circuit when spark gap breakdown.

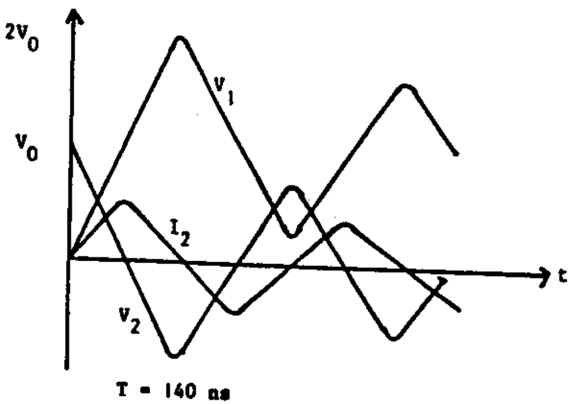


Fig. 10 Sketches of spark gap current I_2 and voltage V_2 waveforms, and the open circuit voltage waveform V_1 of the Laser channel.

Since the voltage at the capacitor C_1 remains at V_o during the spark gap breakdown (the characteristic time scale of spark gap discharge is in the order of nanoseconds which is much faster than the 10 μs (R_1 = 500Ω; C_1 = 20 nF) discharge constant of C_1), the open circuit voltage across the laser channel is then given by

$$V_1 = V_o - V_2$$

$$= V_o\{1 - e^{-t/\tau}(\frac{R_2}{2\omega_1 L_2}) \sin \omega_1 t + \cos \omega_1 t)\} \quad (4)$$

The empirical parameters of the oscillating circuit are obtained by measuring the discharge current waveform of the spark gap using a Rogowski coil wound around the anode of the spark gap. By operating at atmospheric pressure so that no laser channel breakdown occurs, a sinusoidal current waveform can be obtained. It is a slightly damped RLC oscillating waveform. Using Eqn. (2) by substituting the values of period T and damping constant γ obtained from the waveform, various values of ω_1, ω_o, L_2, R_2 and γ can be determined.

These parameters are important factors for optimum operation of the laser and are discussed in Section 4.2. For simplification, assume $\omega_1 \sim \omega_o$. Eqns. (3) and (4) become

$$V_2 = V_o\, e^{-t/\tau} \cos \omega_o t \quad (5)$$

and $$V_1 = V_o\, (1 - e^{-t/\tau} \cos \omega_o t) \quad (6)$$

A sketch of the waveform I_2, V_2 and I_1 are shown in Fig. 10. Thus, when the spark gap breaks down, the voltage across the laser channel begins to oscillate with the same fequency ω_o, rising towards a maximum value $2V_o$. In actual operation the breakdown voltage fo the laser channel is between V_o and $2V_o$.

4.2 Electrical Considerations for Optimum Laser Discharge:

Since the laser output power is directly proportional to the dicharge current I_D across the laser channel, this discharge current can be taken to be approximately proportional to the short-circuit current I_{SC} between the two storage capacitors. Thus

$$I_D \simeq I_{SC} = V_b/Z_L \quad (7)$$

where V_b is the breakdown voltage of the laser channel;
Z_L is the characteristic impedance of the storage capacitors.

An increase in laser output is therefore expected by operating at higher breakdown voltages across the laser channel. The breakdown voltage is generally also a function of the rate of voltage rise. The more rapidly the voltage increases, the higher the breakdown voltage. The voltage rise time T_r is dependent on the inductance and capacitance of the switching circuit given approximately by one quarter of the periodic time,

$$T_r = \tfrac{1}{4}T = \frac{\pi}{2}\sqrt{(L_2C_2)} \quad (8)$$

A fast switching can thus be effected by reducing the values of L_2 and C_2. The value of C_2 is fixed from the power requirement for the discharge and can only be reduced marginally. The contribution of L_2 comes from various sources. In the case of the flat plate storage capacitors, the values of L, C and Z can be estimated by considering a flat plate transmission line, i.e.

$$\text{Capacitance} \quad C = \varepsilon\varepsilon_o wl/d \quad (9)$$

$$\text{Inductance} \quad L = \mu\mu_o dl/w \quad (10)$$

$$\text{and Impedance} \quad Z_L = \sqrt{(L/C)} = \left(\frac{\mu\mu_o}{\varepsilon\varepsilon_o}\right)^{\frac{1}{2}} d/w \quad (11)$$

where l and w are the length and width of the parallel plates; and d is the thickness of the dielectric.

In most case, the switching inductance is largely contributed by the spark gap itself. This inductance is proportional to the flux linkage of the switching current loop. The spark gap should therefore be placed across the capacitor plates with minimum cross-section area for the current loop which is often restricted by constructional design.

Referring again to Eqn. (7), the optical power is also increased if the characteristic impedance of the storage capacitor transmission line is reduced. Since the value of the impedance Z_L (Eqn. 11) is directly proportional to the thickness of the dielectric, a thinner dielectric would result in higher optical power than a thicker one. But there is an optimum thickness of dielectric to be used due to the breakdown voltage rating of the dielectric. For mylar dielectric (breakdown rating is 2 kV/mil), the optimum thickness of dielectric is therefore given by V_b/2kV mil where V_b is the breakdown voltage in kV. For most cases, breakdown voltage is between V_o and $2V_o$, thus a mylar thickness of $V_o \times 10^{-3}$ mill will avoid dielectric breakdown. In this case, the thickness of the dielectric is fixed according to the operation voltage range. The impedance of the laser is then necessarily reduced by having a larger width of capacitor (Eqn. 11) instead, this means a longer laser channel as well.

We can also consider the following circuit equation across the laser channel when the laser gas breaks down.

$$V_b = L\frac{dI}{dt} + Z_L I + R_g(t)I \quad (12)$$

where I is the discharge current of the gas breakdown;
L is the inductance of the capacitor transmission line circuit;
Z_L is the characteristic impedance of the transmission line;
and $R_g(t)$ is the time varying resistance of the discharge plasma.

The first term represents the voltage across the circuit inductance, the second and third terms represent the voltage drop across the source and plasma impedance respectively. To maximise laser output power. the value of the last term must be increased, i.e. the power fed into the gas during the time of breakdown discharge must be increased. This can be done by minimizing the values of both the first term and the second term which means having a low inductance and low impedance circuit. This criterion is in fact normally best met by using a parallel-plate capacitor design.

4.3 Experiment I - Electrical Characteristics Measurement:

By operating at atmospheric pressure so that no laser channel breakdown occurs, obtain the current waveform from the oscilloscope by using a Rogowski coil wound around the anode of the spark gap. Then calculate the following electrical parameters of the blumlein switching circuit as shown in the table below where Z_2 is the impedance of the RLC circuit.

T =	ns	$\omega_1 = \omega_2$ =		Hz
γ =		τ =		s
L_2 =	nH	R_2 =		Ω
Z_2 =	Ω			

5. Optical Characteristics of Nitrogen Laser:

The output of the nitrogen laser is ultraviolet but can be observed visibly through its blue fluorescence on a piece of white paper. The laser pulse is detected using a fast photodiode (EG & G FND-100 with a rise time of less than one nanosecond) and displayed on a 400 MHz Tektronix 7834 oscilloscope. This is shown in Fig. 11 indicating a laser pulse width (FWHM) of 5.0 ± 0.6) ns.

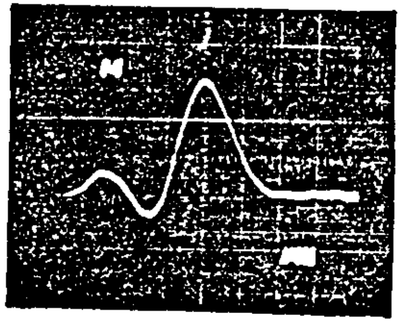


Fig. 11 A nitrogen laser output pulse detected by the FND-100 photodiode and displayed on the Tektronix 7834 oscilloscope.

Laser pulse width
= (5.0 ± 0.6) ns.

The divergence of the laser beam was estimated by measuring the dimension of the flourescence spot on a white paper at different distances. Since the laser is superradiant, the divergence is approximately given by the raio of the width to the length of the laser channel. However, in the presence of a backmirror, the horizontal divergence will be reduced. This can be understood from the longer gain path of the output beam in the presence of the backmirror.

5.1 The Characteristics of Nitrogen Laser Output Power:

The average output power of the laser was measured using a Scientech 36-001 thermopile. The peak power is then obtained using the average power divided by the pulse rate and the pulse width.

The growth of ionization in the laser plasma is a function of value of E/P where E is the electric field across the laser channel and P is the gas pressure in the laser channel. There is thus an optimum value of E/P where the laser power is maximum. In general, maximum laser power occurs when E/P = 80 to 250 V/cm torr. For example, in Fig. 12, laser power as a function of the laser channel pressures are obtained. The optimum laser power is found to be maximum at pressures of about 145 mb. The E/P values for curves I and II are 120 V/cm torr and 120 V/cm torr respectively. These are the minimum estimated values since the breakdown voltage is taken to be equal to the charging voltage.

The overall efficiency of the laser system is defined as the ratio of the average optical power to the electrical input power from the supply.

i.e. $$\text{overall efficiency} = \frac{\text{average output power}}{V_o^2/R} \times 100$$

where R is the limiting resistance.

The optical efficiency of the laser system is defined as the ratio of the optical energy per pulse to the electrical energy $CV_o^2/2$ stored in the capacitor.

i.e. $$\text{optical efficiency} = \frac{\text{laser pulse energy}}{\text{capacitor stored energy}} \times 100$$

In this experiment, the nitrogen laser constructed has an overall and optical efficiency of 0.2 % and 0.05 % respectively. In the majority of such designs the optical efficiency is less than 0.1 %.

5.2 Experiment II - Optical Characteristics Measurement:

a) Measure the various optical ouput parameters of the nitrogen laser as shown below:

Average optical power at 5 Hz (V_o = 10 kV)	mW
Peak optical power (optimum value)	kW
Laser pulse width (FWHM)	ns
Laser pulse energy	mJ
Beam divergence (horizontal and vertical)	mrad

b) Plot a graph of laser output amplitudes against the laser channel pressures. The laser output is detected using the photodiode with output connected to the Tektronix 7834 oscilloscope.

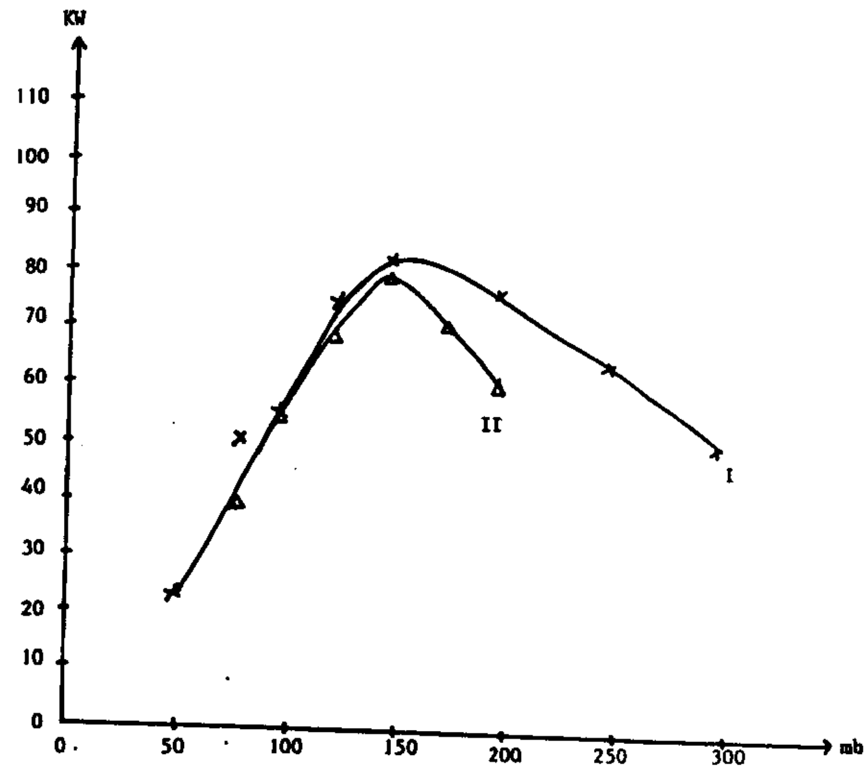


Fig. 12 Laser output peak power versus Laser channel pressure
I) 10 mil dielectric capacitors with charging voltage 10 kV
II) 20 mil dielectric capacitors with charging voltage 10 kV

Above simple N_2 laser can be assembled for less than U.S. $1000.

However, relatively low power → 100 KW

Can build other higher power N_2 laser

eg. a 2'×2' double Blumlein laser yield 500 KW at 14 KV charging

- can be used for pumping 2 dye cells oscillator - & amplifier system for spectroscopy

(S. Sapan, C.K. Lee & K.S. Low)

1 MW → 3 MW can also be scaled up & would be the limit of N_2 lasers

(C.K. Lee, C.H. Tan & K.S. Low)

To go higher, need excimer lasers & especially for Raman shifters.

2.2. Construction of a nitrogen pumped dye laser and its tuning

The following notes describes the construction of a nitrogen laser pumped dye laser system. The system has been used for the measurement of ambient nitrogen dioxide using differential absorption Lidar techniques.

Fig.1 is a schematic diagram of the dye laser oscillator-amplifier system based on the Hansch type (1). Instead of using beam expander telescope, a 4-stage prism linear beam expander is used. The basic system consists of two dye cells, transversely pumped by a 800 kW home built nitrogen laser, a 600 lines/mm grating blazed at 500 nm, a partial output mirror with 30% transmission.

Fig. 2 shows how the beam is expanded approximately 2.1 times at an incident angle of 67 degrees. With the cascade of 4 prisms, a linear expansion of 20 times can be achieved.

Fig. 3 shows the sine drive on which the grating is rotated. By choosing the appropriate arm length, drive shaft thread and reducing gear ratios, fine tuning of the laser output can be achieved. One could then use a microcomputer to operate the turning of the steppermotor for computer controlled tuning of the laser output.

Fig. 4 shows a typical dye laser output with a pulse width of 5 ns.

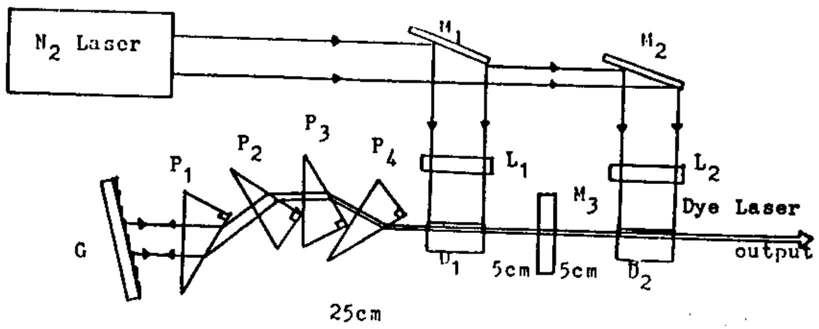


Fig.1. Schematic diagram of the simultaneous tunable double-wavelength dye laser. M1 & M2 are plane mirrors. L1 & L2 are cylindrical lens. M3 is partial feedback mirror. D1 & D2 are the dye cells. P1,P2,P3 & P4 are the prisms. G is the diffraction grating.

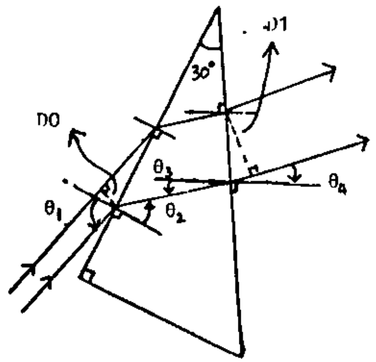
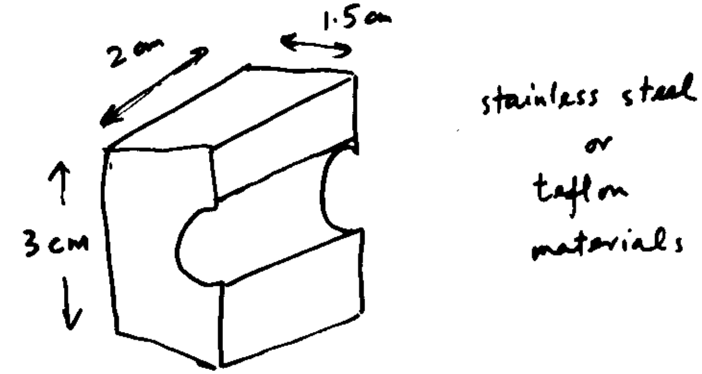
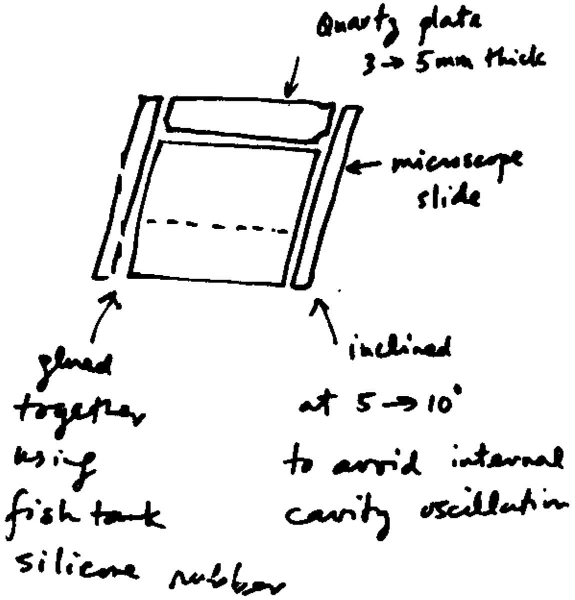


Figure 2. Ray diagram of light passing ahe single prism expander.

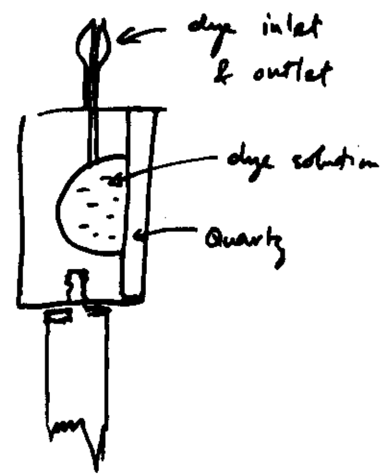
Simple dye cells



Top view



side view



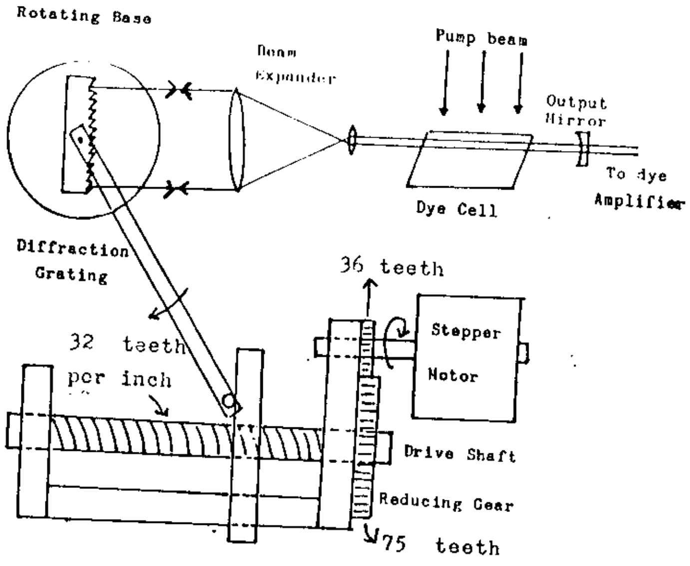


Fig 3 Schematic lay-out of a microcomputer controlled sine driven Grating for tuning dye laser output.

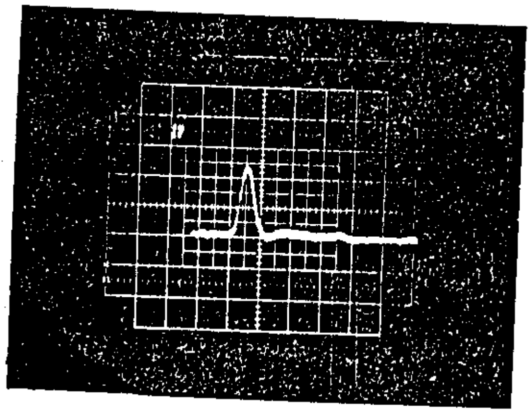


Fig. 4 Dye laser output pulse.
Time scale: 5 ns per smaller division.

Dye laser output

5 ns

10 → 50 KW for 500 KW input

0.5 Å resolution

Used for laser LIDAR techniques
& especially for differential absorption Lidar or DIAL for monitoring of NO_2 at 445 → 450 nm absorption spectra

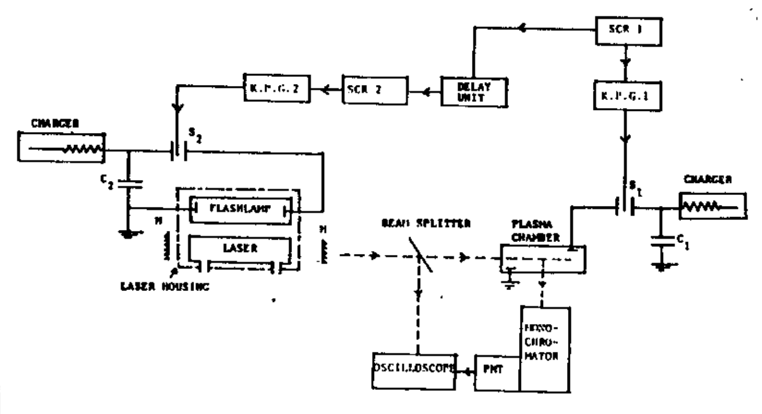
Backscattered Lidar signal

Fig.6 Backscattered signal return from the fixed target. First peak is the elastic return from the atmosphere, second peak is the signal return from a building 2.4 Km away. Each horizontal division represents a flight path of 300 m.

2.3. Flashlamp pumped dye laser

The following describes briefly the operation of a flashlamp pumped dye laser system. The cavity is elliptical with the flashlamp made from quartz tubes and filled with air at low pressure. The laser is used for the resonant absorption spectroscopy of hydrogen plasmas as a diagnostic technique.

Fig. 5 shows a sketch of the lay-out of the system.



SCHEMATIC DIAGRAM OF THE EXPERIMENTAL ARRANGEMENT

KEY: M Mirror
—•— Light beam

System characteristics

- using R640 dye in methanol at about 4×10^{-4} M/l.
- Cavity - chrome plated with major axis 4.5 cm and minor axes 2.5 cm, length is 20 cm.

-flashlamp - air filled quartz tube at about 0.6 torr, discharged using a 5 uF capacitor at 13 kV, triggered using an ignitron which is in turn triggered by a krytron pulse generator.

-tunable between 647 and 659 nm, H-alpha line at 656.3 nm.

-output - 800 mJ with a pulsewidth of 2 us.

2.4. Other lasers to be constructed

A. Gas Lasers

Since nitrogen lasers are the simplest and cheapest to construct, one should obtain sufficient working experience with them before proceeding to construct other types of gas discharge lasers.

Amongst various gas lasers, the CO2 lasers, either the pulsed or the CW type, would be the most useful lasers to consider. In this case, infrared optics and windows could then be the major cost of the system. High voltage power supplies and capacitors have also now to be higher rated to 40 kV or so (instead of only 20 kV for the nitrogen lasers). Corona associated with higher working voltages will have to be taken into considerations. Some of the electrical components may have to be immersed in transformer oil. IN essence, the TEA-CO2 laser operates much the same way as a nitrogen laser does, requiring fast discharge and some form of preionising scheme to ensure uniform discharge along the laser channel. On the other hand, since the CO2 laser has much higher gain, it can be made to lase rather easily.

Another type of gas discharge laser to be considered would be the excimer lasers. In this case, expensive inert gases like xenon and krypton are required. Highly toxic fluorine or chlorine gases are used. Optics are also very expensive and high voltage requirements also exceed those of the nitrogen lasers. For both the excimer and TEA-CO2 lasers, electrode design and preionisation are more critical and has to be designed correctly. Otherwise, both types of lasers are straight forward extension of the simple nitrogen laser discussed in details earlier on.

Solid State Lasers

Nd-YAG or glass lasers can also be constructed rather easily. Here, the major cost would be in the laser rod. The design of the laser cavity is more or less the same as in the flashlamp pumped dye laser discussed earlier on. Here, commercial xenon or krypton flashlamps are used and are placed either in an elliptical cavity or in a collinear configuration. The switching of the flashlamp is much the same as in the case of the dye laser. However, with the commercial flashlamps, lower charging voltage and capacitances are needed.

Frequency doubling and quadrupling to obtain higher order visible and UV output involves using expensive non-linear crystals like the KDP. Nevertheless, due to the simplicity in operation and the ruggedness of the Nd-YAG lasers, many spectroscopy experiments are based on such commercial laser systems.

References

1. T.W. Hansch, Apl. Opt., 11,895, 1972.