Research on iodine stabilized lasers in the metrology laboratory of Eindhoven University of Technology

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REASEARCH ON IODINE STABILIZED LASERS IN THE METROLOGY LABORATORY OF EINDHOVEN UNIVERSITY OF TECHNOLOGY.

P. SCHELLEKENS

WT Rapport Nr. 0 384

Dit rapport is geschreven voor onderzoekers werkzaam op het gebied van golflengtestabilisatie van He-Ne lasers. Het rapport is de schriftelijke weergave van een voordracht door de auteur gehouden te Braunschweig op 11 februari 1977.
Het geheel wordt in deze vorm gepubliceerd in het blad P.T.B.-Berichten, een uitgave van de Physikalisch-Technische Bundesanstalt te Braunschweig, West-Duitsland.

RESEARCH ON IODINE STABILIZED LASERS IN THE METROLOGY LABORATORY OF EINDHOVEN UNIVERSITY OF TECHNOLOGY.

P. SCHELLEKENS

SUMMARY

This report consists of four parts. The first is a short description of our iodine stabilized lasers. Next we have given a description of our manufacturing process for making plasmatubes and a method for determining optimum filling pressure and dischargecurrent. Finally, the results are summarized.

A. WORK ON IODINE LASERS

Research on iodine stabilized lasers has started in 1974 as we felt a need for a more stable laser than the Spectra-Physics 119 available. The latter is used as a light source in our line standard interferometer and limits its accuracy. Our plan was to built a small compact light source which was easily transportable. From the beginning we tried to build our own plasmatubes as well as the iodine cells. For this part there was an extremely good cooperation between our laboratory and the technical service department (CTD, THE)*).

In principle our lasers consist of a mechanical structure of steel in which Zerodur bars are mounted. On these bars the mirror adjustment plates are supported in such a way that the length of the cavity is determined solely by the Zerodur bars (Fig. 1). Even if no external stabilization system is used this results in a good frequency stability.

The plasmatube is of the so called side-arm type. It is entirely home made, has a long life time and a noise level comparable with commercial tubes.

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*) Section Glasstechnology: J.C. Hendriks.
Section Optics: J.W. Versteeg.

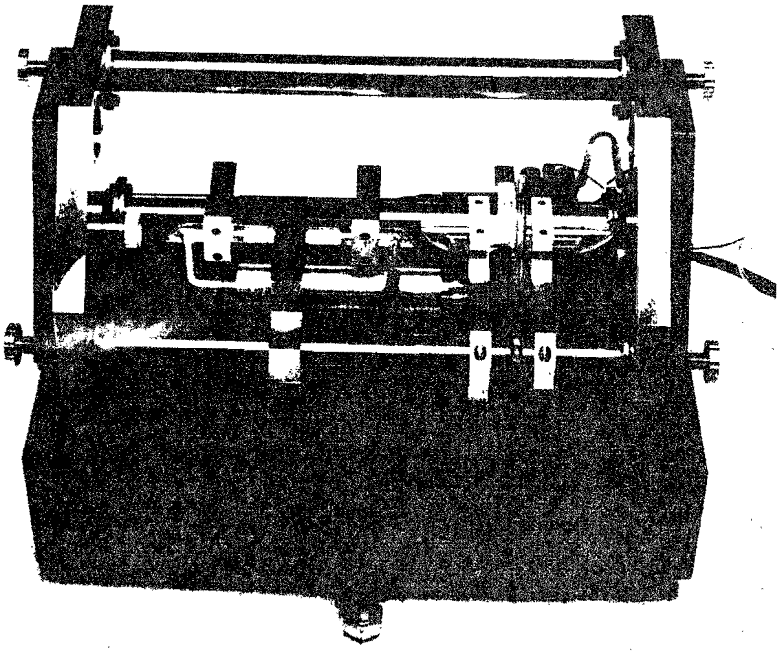

Fig. 1.

Quartz is used as material for the iodine cells because the windows are fused on with "glass transfer tape" [1,2]. We cannot recommend this method for sealing windows onto plasmatubes as the danger of contamination of the small windows is too high. Until now we have used piezo-electric cylinders supplied by Jodon (MD-44), the lasermirrors are supplied by Spectra-Physics.

Maximum output power is around 300 μW using a plasmatube with 135 mm gain length and a 100 mm absorbtioncell, total mirrordistance is 230 mm. The electronic circuit is based on the third derivative method [3]. We are using commercial P.S.D.'s (PAR) with home made oscillators supplying f and 3f. In April 1976 a comparison was made between NPL and THE lasers. Using Wallard's integrators we have measured a stability of 2×10^{-11} for 10 sec averaging time. Reproducibility seems better than 1×10^{-10}. At this moment we are working on improved electronics and another mechanical structure. By this means we hope to improve stability and reproduciblity. We have planned new intercomparisons in the second half of this year.

B. PRODUCTION OF PLASMATUBES

During the recent meeting at PTB many people seemed interested in the process of making plasmatubes. So it may be usefull to describe our methods here. Further we think it is advisable to use not only commercially available plasmatubes in experiments with iodine stabilized lasers.

At this moment we are only making side-arm tubes as we have very good results with them.

The plasmatubes consists of a capillary part and a kathode part, both made of pyrex. Side-arms are fused on the capillary part, the planes for the brewsterwindows are made by a sawing process and afterwards roughly polished.

The kathode part has a diameter of 25 mm and a length of around 130 mm. The kathode is turned from pure aluminium (99,9%) using a diamond cutting tool and a continuous flow of water around the cutting tool. In this way a good oxide layer is formed on the surface which is very resistant against sputtering. The anode pin and the kathode supportpin are made of tungsten which is heated to 1000 °C before sealing in.

The connection between kathode supportpin and kathode is made by a nickel wire on which a barium getter is mounted.

Before fusing together the glass parts are cleaned by usual techniques and dried in a dustfree oven. After the fusing process the plasmatube, still without brewsterwindows, is placed in a tube-oven and heated to 400 °C for 5-10 hours under rough vacuum (10^{-3} Pa). The next step is to mount the windows.

The brewsterwindows are made of fused silica with a thickness of 2 mm. Generally the window is polished before use. After cleaning carefully the windows can be mounted on the plasmatube.

Since we are using a low viscosity cement we have to clamp the windows onto the plasmatube (Fig. 2).

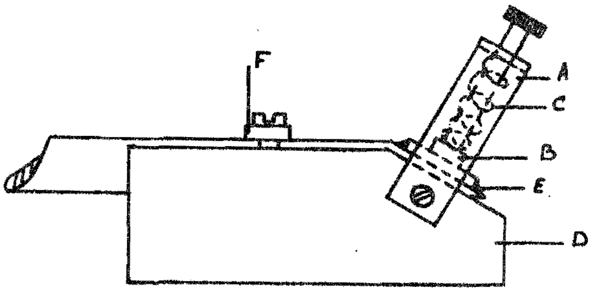

Fig. 2.

A: Rotatable holder
B: Pressurepen for brewsterwindo
C: Spring
D: Plasmatubeholder
E: Cement
F: Clamb screw plasmatube

We have experienced good results with a two component cement called APCO-313*). This cement remains elastic and therefore it seems to be better than Torr-Seal which cracks easily. After putting on the cement the plasmatube is put in an oven at 80 °C for a few hours. Then the filling procedure can be started. The pumping system consists of a forepump and a high-vacuumpump and is connected with the filling station onto which the plasmatube has been fused.

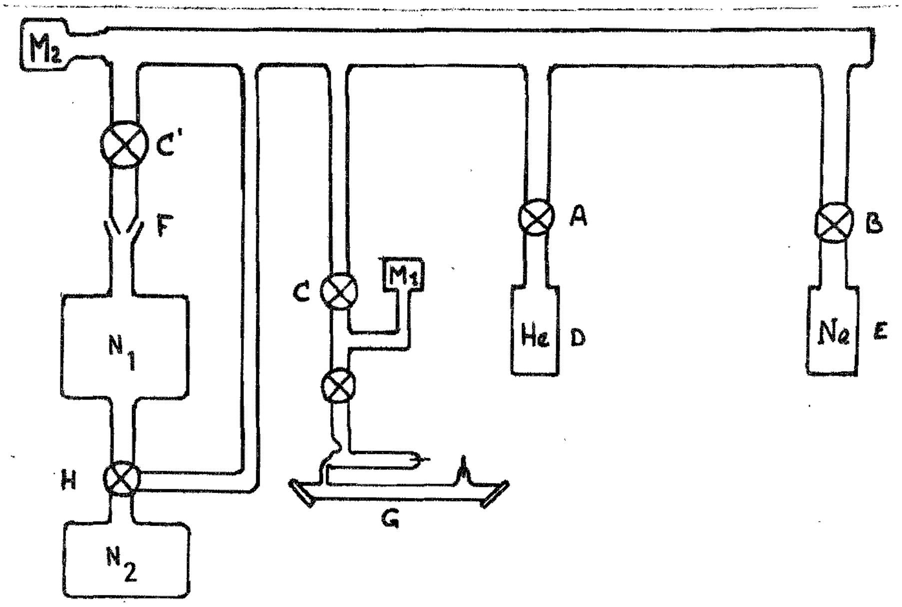

Fig. 3.

A,B : Filling taps
C,C',H: Headtaps
D,E : Supply He, Ne
F : Liquid nitrogen trap
G : Plasmatube
O : Teflon taps
M_1, M_2 : Manometers
N_1, N_2 : Vacuum-pumps

Fig. 3. gives a schematic diagram of the setup. After the tube is pumped to 10^{-5} Pa, ^{20}Ne is filled in to the required partial pressure and then this is repeated with ^{3}He. Then a discharge is started and run for one hour. If there are leaks the discharge will turn to a blue colour. Next the tube is pumped vacuum again and refilled to a total overpressure of 100 Pa and the discharge is run for 48 hours so that diffusion processes can come to an equilibrium (burning-in process). The last step consists of vacuum pumping, evaporation of getter material and refilling with ^{3}He : ^{20}Ne = 7 : 1 to the total pressure calculated from pD = 400 Pa.mm. The pressures are measured by a pirani gauge, using calibration curves for the gasses used. If, after starting the discharge, the colour is rose-red the plasmatube is sealed off.

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*) APCO R 313 delivered by: Applied Plastics Co. Inc.
612 E. Franklin Avenue, El Secundo, California 90245.

C. DETERMINATION OF OPTIMUM FILLING PRESSURE AND DISCHARGE CURRENT IN A He-Ne PLASMATUBE

To carry out this experiment we have mounted a cavity around the plasmatube while it was connected to the filling station. Within this cavity a rotatable glassplate was mounted so we could introduce variable losses. If oscillation just stops gain equals total losses

or: $$G_m = a_t + l\,(\phi_m) \qquad \text{(a)}$$

where G_m = roundtrip gain

a_t = roundtrip losses (scattering + transmission)

$l(\phi_m)$ = loss introduced by rotatable glassplate

$l(\phi_m)$ can be calculated from: [4]

$$l(\phi) = 1 - \left[\frac{(1-R)^2}{1-R^2}\right]^2 \qquad \text{(b)}$$

where (from Fresnell's equations):

$$R = \frac{\tan^2\left(\phi - \arcsin\left(\frac{\sin\phi}{n}\right)\right)}{\tan^2\left(\phi + \arcsin\left(\frac{\sin\phi}{n}\right)\right)} \qquad \text{(c)}$$

with: n = index of refraction of glassplate.

ϕ = the smallest angle between the normal on the glassplate and the laserbeam direction.

Fig. 4 gives a schematic diagram of the experiment.
By filling the plasmatube to various partial and total pressures and measuring ϕ_m at different discharge currents the gain can be determined as a function of pressure and discharge current and optimum filling pressure can be read from a graph. From power measurements with $\phi \neq \phi_m$ we have calculated the saturation parameter W_0 [5].

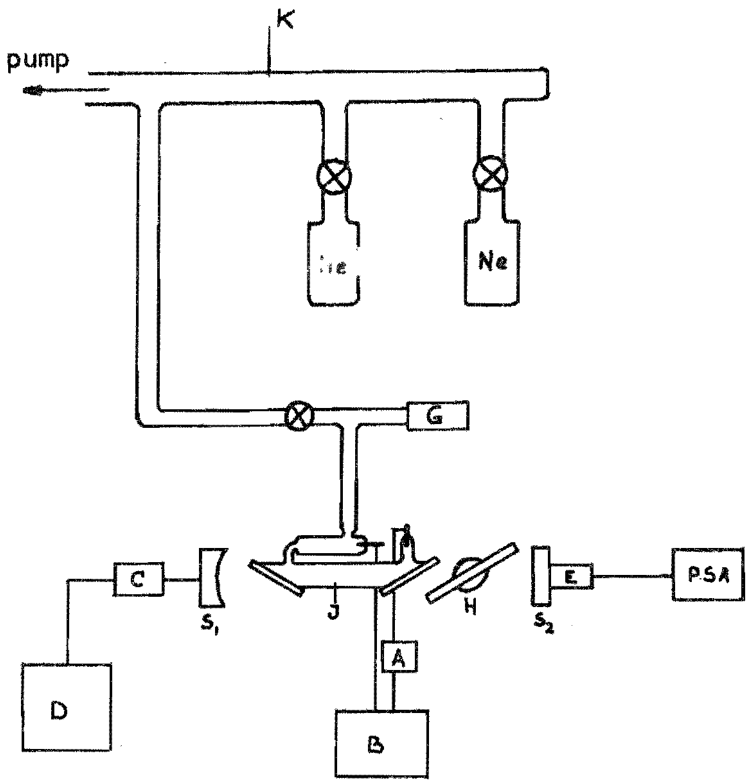

Fig. 4.

A : Ammeter
B : Power supply
C : Detector
D : Power meter
E : Piezo-cylinder
S_1, S_2: Laser-mirrors
G : Manometer
H : Rotatable glassplate
J : Plasmatube
PSA : DC supply

Smith [6] gives a roundtrip gain for λ = 0,6 µm:

$$G_m = \frac{g_0' \times L}{D}$$

with:
L : roundtrip gainlength
D : internal plasmatubediameter
g_0': $3,0 \times 10^{-2}$ (%)

Fig. 5 shows some of our measurements with a 7 : 1 mixture of ^{3}He and ^{20}Ne, a plasmatubediameter of 1,20 mm and a gainlength of 135 mm. Maximum gain is reached around 400 Pa mm.

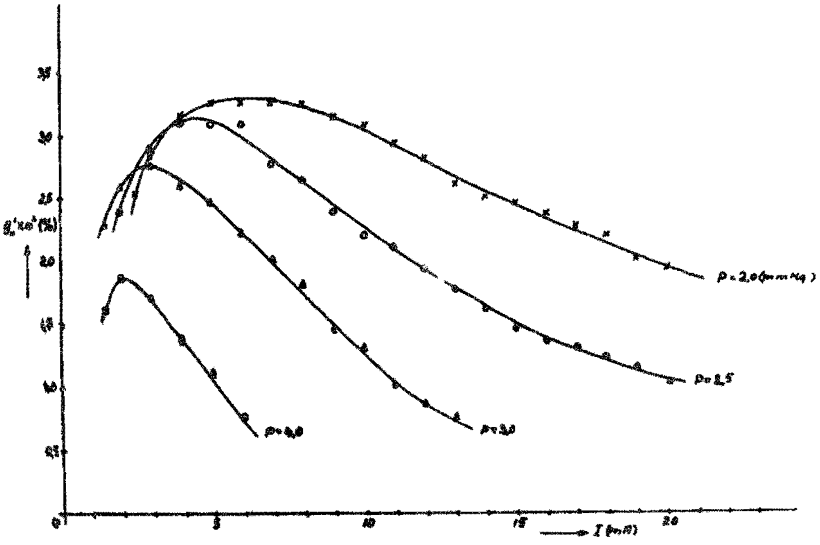

Fig. 5.

We have calculated a value of W_0 of

$$W_0 = (28 \pm 3)\ \mathrm{W\ cm^{-2}}$$

which is in good agreement with the value given in [5].

D. FINAL REMARKS

The results of our experiments with homemade plasmatubes shows good agreement with other experiments published and the power measurements give results comparable with commercial lasers [2]. We think we can conclude that the methods described in part B results in a plasmatube suitable for iodine and methane stabilized lasers. The experiments were carried out by only a few people and the neccessary instrumentation and apparatus was neither very expensive nor complicated.

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