NOT FOR PUBLICATION

CLM - M 47

THE CONSTRUCTION, ADJUSTMENT AND OPERATION OF A MULTI-PASS INTERFEROMETER

by

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ABSTRACT

A laser interferometer has been used to measure the radial density distribution of an annular cylindrical plasma. The low plasma density dictated the use of a multi-pass system, and the need for spatial resolution in the radial direction required that all the optical paths traversed the plasma at the same radius. The construction, adjustment, and operation of a 24 or 16 pass interferometer meeting these requirements is described.

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1. INTRODUCTION

The large rotating field experiment(1) produces an annular cylindrical plasma in a discharge tube 100 cm long and 14 cm diameter. Fig. 1 shows a typical radial electron density distribution, deduced from magnetic probe measurements.

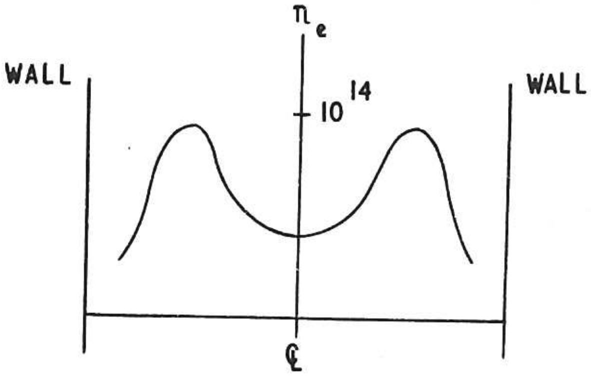

Fig. 1 Typical radial density distribution (CLM-M47)

It was required to make an independent measurement using a laser interferometer(2,3) at a wavelength of 3.4 microns. The number, N, of fringes for one double pass is given by

$$N \simeq 3 \times 10^{-17}\, n_e L ,$$

where L is the optical length of the plasma (cms) and n_e the electron density (cm^{-3}), so N ≃ ⅓ at the radius of peak density in this experiment. Hence a multi-pass system with as many passes as possible was required in order to achieve the sensitivity needed to measure the radial distribution.

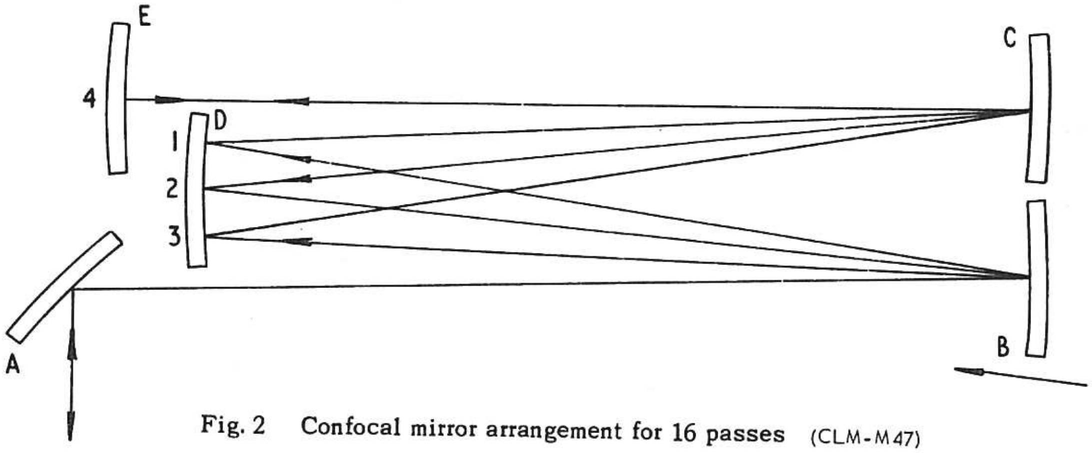

Fig. 2 Confocal mirror arrangement for 16 passes (CLM-M47)

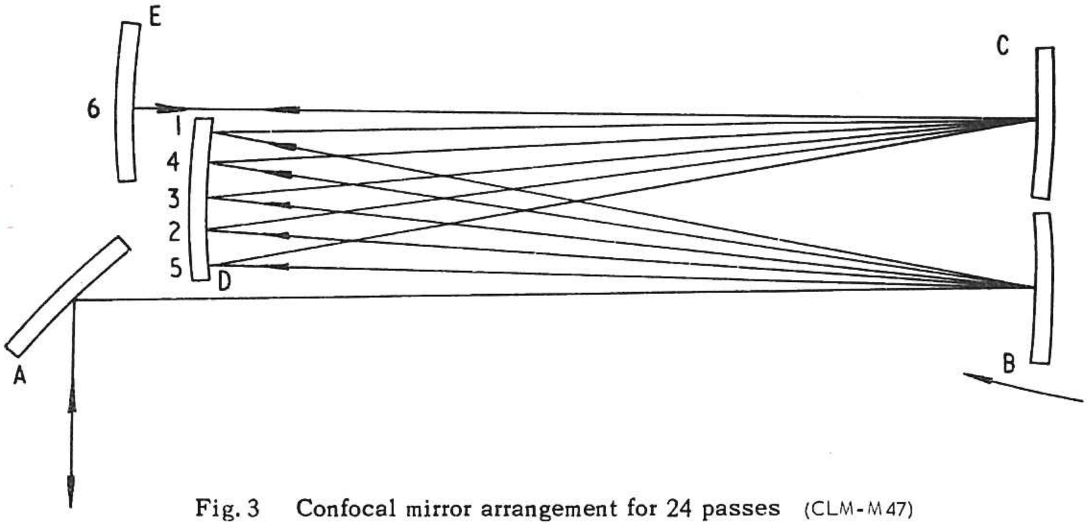

Fig. 3 Confocal mirror arrangement for 24 passes (CLM-M47)

A system using confocal concave mirrors(4) (Figs.2 and 3) was found to be satisfactory

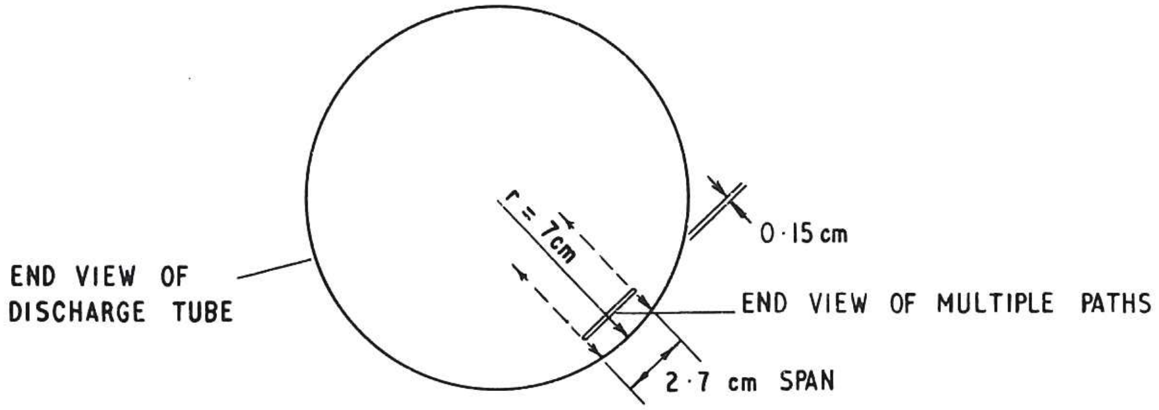

Fig. 4 Dimensions of cross-section of discharge tube and laser beams (CLM-M47)

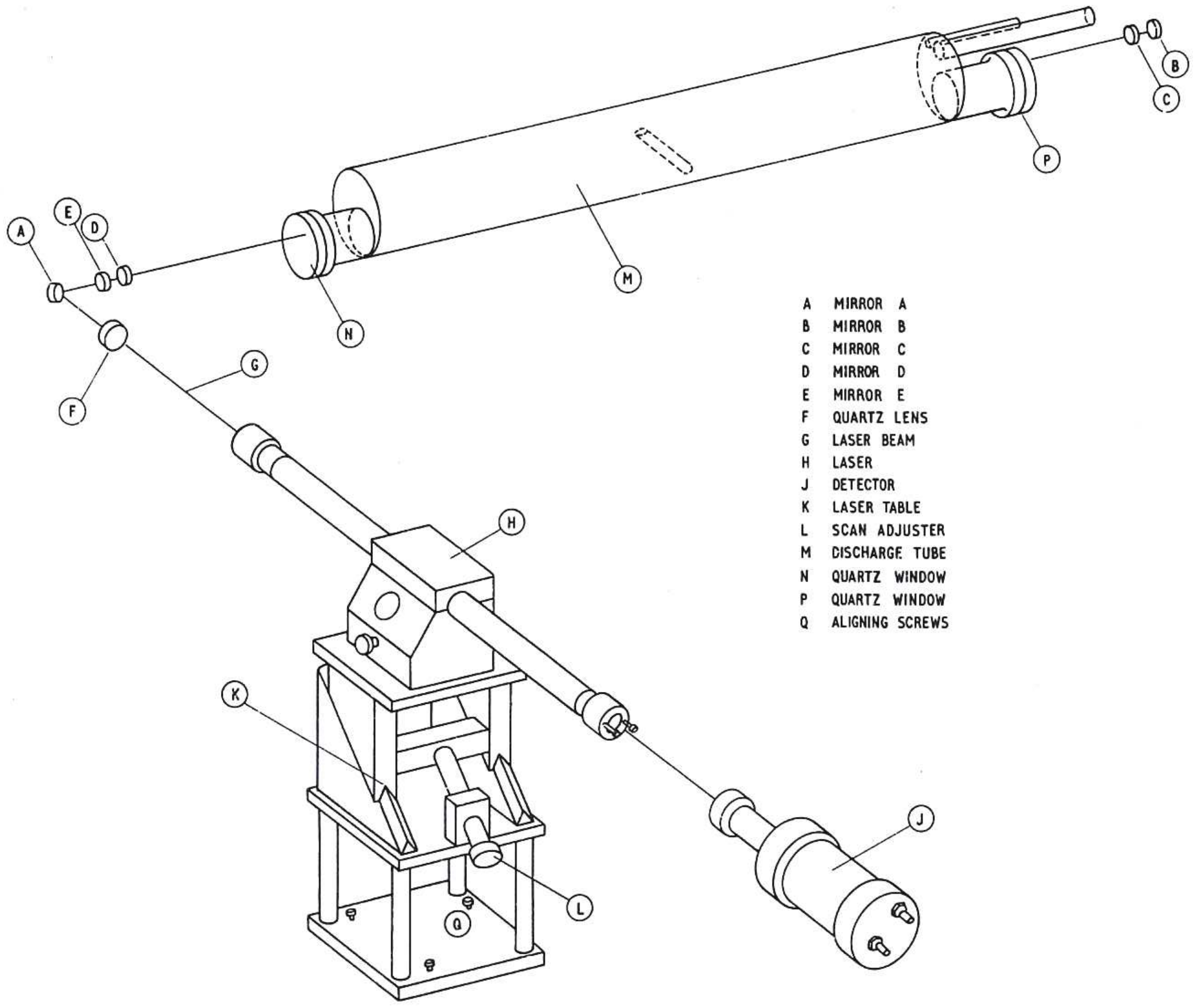

Fig. 5 General arrangement of apparatus (CLM-M47)

for eight or twelve double passes. Beyond this number of passes the increasing number of spurious reflections due to the quartz end windows of the discharge tube made adjustment tedious.

Assuming a cylindrical geometry for the plasma, greater spatial resolution will be obtained for larger radii of discharge (when the beam is at a greater distance from the centre of the tube) than for smaller ones due to the size of the path swept out by the traverses of the laser beam. Fig.4 shows the dimensions. The span of the multiple passes is dictated only by the size of the mirror D (Fig.5) and is independent of the number of passes.

Fig.5 shows the general layout of the interferometer. The laser unit and detector are outside the screened room containing the experiment and the confocal mirror arrangement. The whole system can be moved at 45° to the horizontal to scan an accessible segment of the discharge tube. The beam emerging from the laser is about 0.1 cm diameter and is diverging. The concave mirrors focus the beam at every pass through the plasma and the return beam is focussed by the quartz lens F.

2. CONSTRUCTION

The five mirrors A, B, C, D and E and the quartz lens F (200 cm focal length), were mounted in the immediate vicinity of the quartz end windows of the discharge tube and were accessible for adjustment (Fig.5). The distance between the two sets of mirrors was about 200 cm. The mirrors were individually adjusted as in Fig.6, and mounted on sliding platforms, one at each end of the discharge tube.

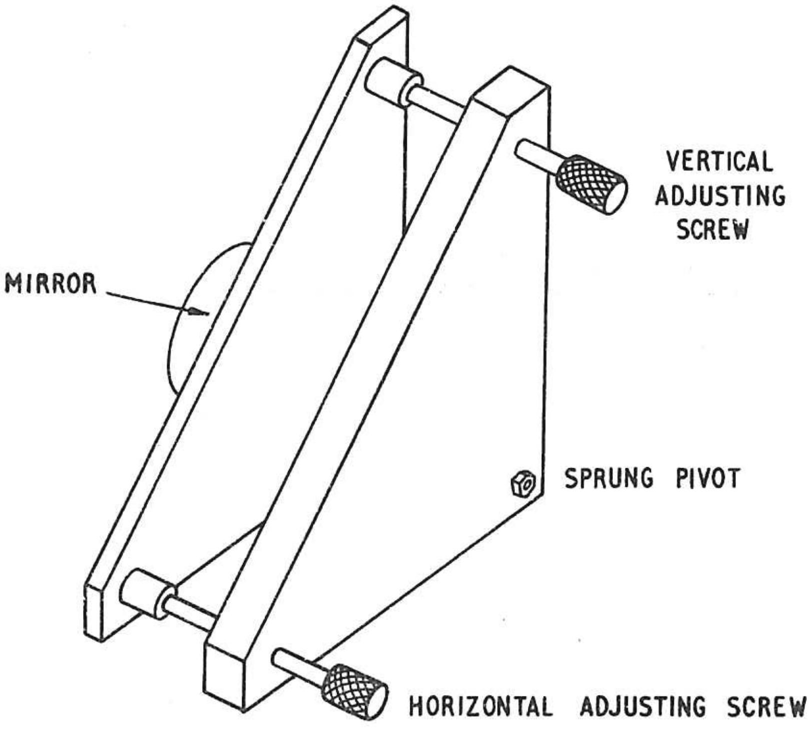

Fig. 6 Adjustable mounting for mirror D (CLM-M47)

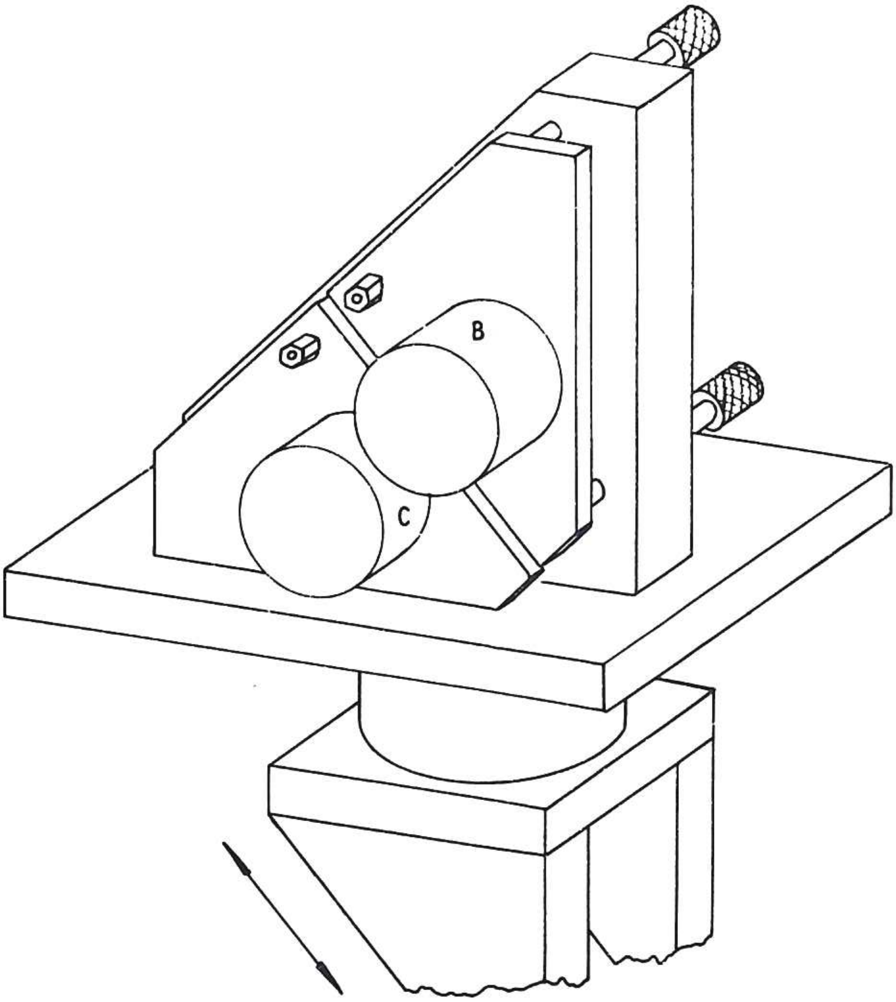

Fig. 7 Platform for mirrors B and C (CLM-M47)

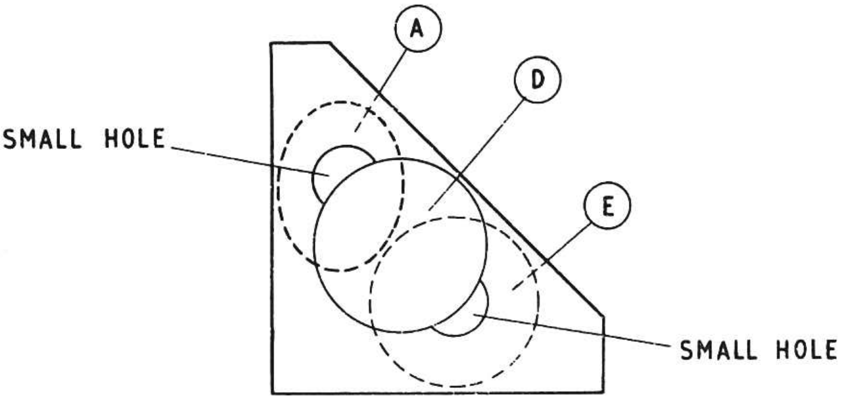

Fig. 8 Arrangement of mirrors A, D and E viewed from B and C (CLM-M47)

The platform carrying mirrors B and C is shown in Fig.7, the distance between the centre of the two mirrors being 2.6 cm.

The adjustable mounting for mirror D was provided with two small holes one each side of the mirror as in Fig.8, to allow the laser beam from A to pass close to the edge of D, and to allow the beam from C to pass close to the other side of D and reach E.

The two mirror platforms could be individually adjusted at 45° to the horizontal and were normally adjusted at the same time and in sympathy with the laser platform.

All the external mirrors were made by aluminising glass concave substrates, 2.5 cm diameter by 1 cm thick, and had a reflectivity of about 98% at 6328 Å. Mirrors B, C, D and E had a focal length of 100 cm, and the focal length of A was 200 cm.

The laser assembly was mounted on a sturdy adjustable platform (Fig.5) which was provided with three levelling screws, Q, that stood in three cups which were fixed to the floor.

An E.M.I. type 9637 T.A. photomultiplier tube was used as the detector, item J, in Fig.5. The circuit diagram is shown in Fig.9. The tube and circuitry were housed in a metal container and fitted with an adjustable iris and a Wratten 25 daylight filter.

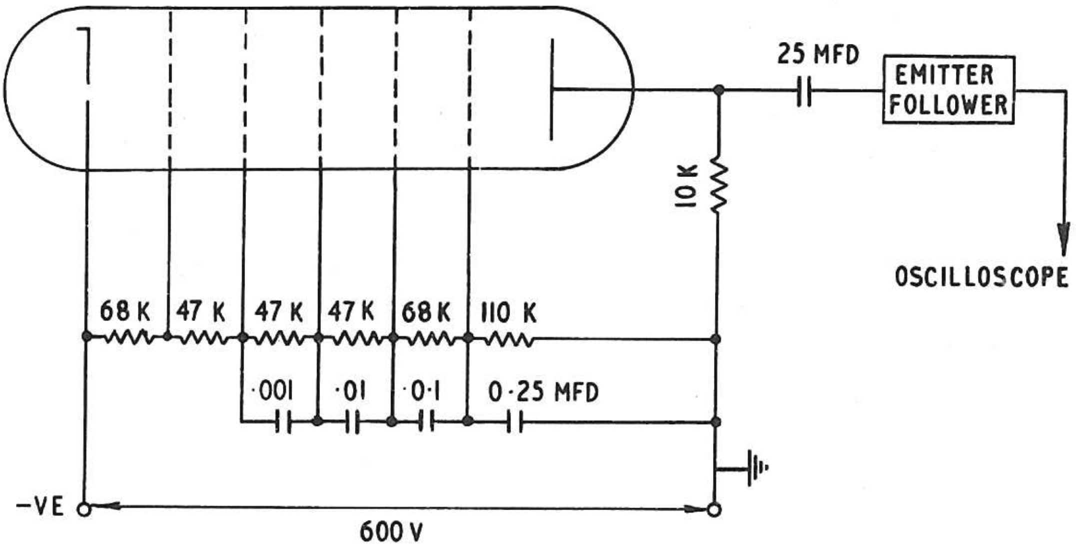

Fig. 9 Circuit diagram of detector (CLM-M47)

3. ADJUSTMENT

Beam Alignment

The laser beam can be aligned horizontally by the three screws (Q) fitted to the base of the laser platform (Fig.5), and parallel to the axis of the discharge tube by adjustment of mirror A.

Multi-Pass

The 24 pass arrangement can be set up by one person, adopting the following procedure and referring to Fig.3.

(a) Cover mirror E with a card.

(b) Set the laser beam at a chosen radius by adjusting the laser platform.

(c) set the height of the platform carrying mirrors A, D and E so that the laser beam just misses the edge of D, repeating (b) and (c) as necessary.

(d) Set the platform carrying mirrors B and C, so that the laser beam falls on the centre of B.

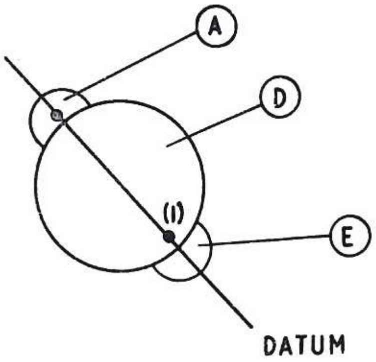

Fig. 10 (CLM-M47)
Aid to alignment procedure (step e)

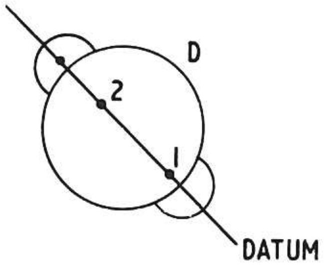

Fig. 11 (CLM-M47)
Aid to alignment procedure (step g)

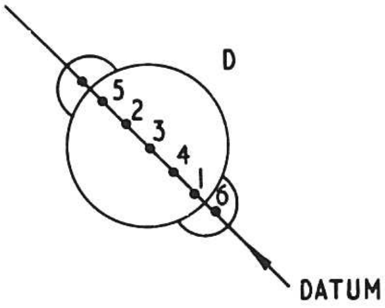

Fig. 12 (CLM-M47)
Aid to alignment procedure (step g)

(e) Look from behind B obliquely towards D in the direction shown by arrow in Fig. 3 and adjust B to produce a scattered image at (1) on D, as shown in Fig.10. (DO NOT look directly down the laser beam.) The datum line, shown, is a line that would appear to pass through the centres of A, D and E when viewed from B.

(f) Look from behind D obliquely at C and adjust D to produce an image at the centre of C.

(g) Look from behind C obliquely at D and adjust C to produce an image at (2) on D as shown in Fig.11. If the image is brought to position (2) in the direction of the arrow and along the datum line (Fig.12), images 3, 4, 5 and 6 will then appear.

(h) Uncover E and look from behind E obliquely at C and adjust E to reflect the beam on to the centre of C.

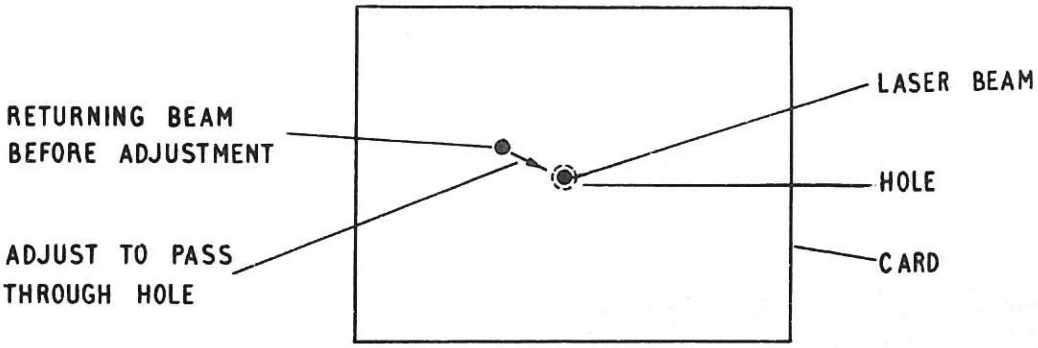

Fig. 13 Aid to alignment procedure (step i) (CLM-M47)

(i) Punch a hole, approx. 0.15 cm diameter, in a white card and support the card about a foot in front of the laser so that the beam passes through the hole as shown in Fig.13, and adjust E so that the return beam also passes through the hole and back into the laser.

(j) Finally remove the white card, when waveforms corresponding to interference fringes due to mechanical vibrations should now be observed on the oscilloscope. It may be necessary to open the iris on the laser slightly to produce more than one mode.

16 Pass

The 16 pass arrangement can be set up in the same way as described above except that (g) will read:

> 'look from behind C obliquely at D and adjust C to produce an image at the centre of D, when images 3 and 4 (Fig.2) will appear'.

General

It is helpful to the operator if all adjustments are carried out in subdued room lighting. It is useful to check that the final images observed on D are true images and not spurious reflections. To do this cut a tapering piece of card and hold it just in front of D so as to cover one of the images at a time, as in Fig.14. By interrupting each traverse of the beam in turn, check that the succeeding images disappear.

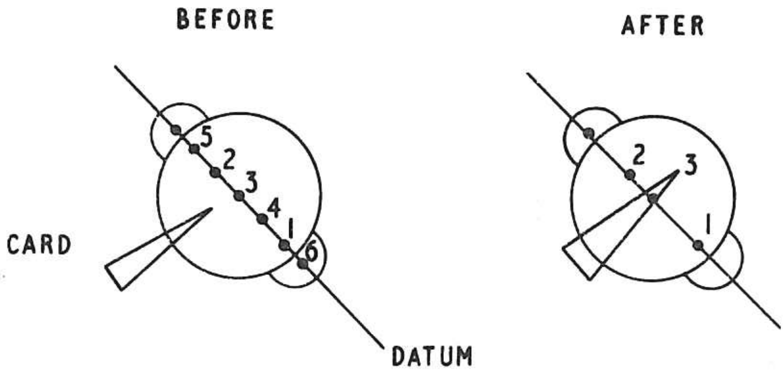

Fig. 14 Method for checking correct alignment (CLM-M47)

4. OPERATION

The character of the infra-red fringe waveforms is distinctive and their spiky appearance distinguishes them from the red fringe waveforms which may be produced. A typical oscillogram of the infra-red fringe waveforms is shown in Fig.15. The waveform amplitude will usually decrease as the number of passes is increased. A typical signal input to the oscilloscope is 100 millivolts, for a 24 pass system and a 100 cm long plasma. The number of fringes due to mechanical vibration will depend on the locality in which the interferometer is set up. With reasonable care the period can be made to exceed 0.01 sec which is large compared to the discharge time. The iris of the detector should be adjusted to the diameter of the laser beam entering the detector.

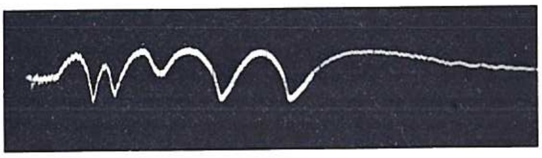

Fig.15 (CLM-M47)
Typical infra-red fringe waveform

It is essential to keep the entire optical system clean, using a lens tissue. It is not recommended that the surfaces of the aluminised mirrors be cleaned; it is better to have these re-aluminised if they become too dirty. The internal mirrors of the laser should on no account be cleaned.

5. REFERENCES

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