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A TEN-CHANNEL FIBRE OPTIC FABRY-PEROT FRINGE SPLITTER

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A TEN-CHANNEL FIBRE OPTIC FABRY-PEROT FRINGE SPLITTER

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A B S T R A C T

The spectral analysis of extremely faint transient line profiles is most efficiently carried out if a Fabry-Perot interferometer is used in conjunction with a photoelectric multi-channel spectrometer. In the instrument described the Fabry-Perot fringe is focussed on to an array of concentric annular light guides of equal area, each representing the same increment of wavelength $d\lambda$. These light guides are fabricated from optic bundles each annulus being led to a separate photomultiplier. Construction of the array is described and the completed instrument is evaluated. A spectral profile obtained with the device is compared with that produced by the conventional photographic technique.

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C O N T E N T S

1. INTRODUCTION

Experiments requiring the spectral analysis of scattered laser light from plasmas have stimulated the development of multi-channel Fabry-Perot interferometers.

Jacquinot (1954, 1960) has shown that the luminosity-resolution product of the Fabry-Perot is superior to that of prism and grating spectrometers. Thus the combination of a Fabry-Perot with high gain photomultipliers provides the optimum system for the spectral analysis of extremely faint transient profiles.

One of the most direct methods of utilising this arrangement as a photoelectric multi-channel spectrometer is as follows. The Fabry-Perot fringe is imaged centrally on to a set of concentric annular light guides each leading to a separate photomultiplier. When these annuli are of equal area then each corresponds to the same increment of wavelength $\Delta\lambda$.

The topological problem of matching concentric annular light guides to their respective photomultipliers is overcome by the use of fibre optics. Even so, the difficulties of constructing such a device are manifold and to overcome them requires techniques which represent the limit of the art.

2. ALTERNATIVE SYSTEMS

Two other devices have been developed but these are elaborate and are dependent on critical alignment procedures.

Hirschberg and Platz (1965) have used an instrument referred to as FAFNIR. It uses an array of precision ground annular mirrors to reflect successive increments of a fringe on to a sequence of photomultipliers.

The other approach described by Katzenstein (1965) uses an axicon to project the resolution intervals from the Fabry-Perot on to light guides located along the axis of the instrument.

3. THE TEN CHANNEL FIBRE OPTIC ARRAY

With any multi-channel device it is desirable to obtain as many channels as possible for this determines the ultimate resolution of the system. The width of equal area annuli decreases rapidly with the number of channels. For an n-channel system with centre light guide radius r_0 the outer annulus will have a thickness $r_0(\sqrt{n+1} - \sqrt{n})$.

Thus the resolution of the instrument depends on how thin an annulus can be made. It was decided that ten channels was the practical limit for the initial attempt. For a centre channel of radius 4 mm this means an outer channel of thickness 0.62 mm. A larger centre radius would involve the use of a prohibitive number of optical fibres.

The concentricity of the annuli was specified to be better than 10% of the channel thickness; cross talk by light transfer between adjacent channels was not to exceed 3%.

Barr and Stroud Ltd., Glasgow undertook the fabrication of the device and the technique devised by their research department is summarised in the next section.

4. FABRICATION OF THE FIBRE OPTIC BUNDLES

Assembly of this device was carried out in a specially designed jig (see Fig.1). Part A consisted of two mild steel blocks bored to accommodate the central channel- a rigid, sheathed glass fibre rod 0.316" diameter. These blocks were located in position by supporting them between two stub steel rods which were accurately located on the base plate. In position these blocks determined the concentricity of annuli relative to the centre fibre rod.

Part B consisted of a metal block machined to accept nine PTFE formers. The inner diameter of each former was machined to the outer diameter of the annulus which was built up within it.

The first PTFE former was fitted over the central rod and when correct alignment was assured flexible fibres were tightly packed into the annular space between it and the central rod through the slot at the top of the former. This slot was then plugged with PTFE and the annulus potted in an epoxy resin.

When the epoxy was cured the central block was removed followed by the PTFE former. PTFE was used because it acts as a release agent for epoxy resins and does not adhere to potted components.

This process was repeated eight times using a larger former each time. The entire rigid portion of the assembly was finally potted into a dural canister and all the exposed fibre ends ground and polished.

5. INSTRUMENT CHARACTERISTICS

The completed instrument is shown in Fig.2 with the photomultipliers removed. The effectiveness of the device depends on the accuracy of the annular channels: this was measured by the following procedure. All the 'tails' were illuminated evenly and the front face photographed to produce a distortion-free enlargement of the channels. This was then projected on to a drawing of the ideal configuration with a matching magnification. The outline of the channels was then drawn, as shown in Fig.3. The dotted circles represent the true annuli and the continuous lines the shape faces of the fibre bundles. Channel overlap is indicated by the hatched-in areas. It is obvious that one half of the face is severely distorted and of no practical use. It appears that this cumulative error is due to fibres not packing properly in the vicinity of the loading slot.

The 'good' half is indicated in Fig.3 and the other half was masked off for evaluation purposes.

A planimeter was used to measure the effective areas of the annuli and to determine the overlap between adjacent channels. The results of these measurements are listed below for the usable half and are accurate to ± 5%.

Relative Size of Channels

Channel Number	Deviation from Correct Area
1	0%
2	+ 3%
3	+ 3%
4	+ 23%
5	- 5%
6	+ 9%
7	- 8%
8	+ 15%
9	- 32%
10	- 10%

Area Overlap Between Adjacent Channels

1 into 2	3%	2 into 1	3%
2 into 3	4%	3 into 2	1%
3 into 4	3%	4 into 3	2%
4 into 5	20%	5 into 4	0%
5 into 6	14%	6 into 5	0%
6 into 7	20%	7 into 6	0%
7 into 8	15%	8 into 7	0%
8 into 9	35%	9 into 8	0%
9 into 10	8%	10 into 9	0%
10 into outside	3%		

6. THE ARRAY USED FOR SPECTRAL PROFILE DETERMINATION

The most important test was to compare the spectral profile obtained with the multi-channel array with that determined by a standard method.

A mercury source was used to illuminate a Fabry-Perot interferometer and the fringes were then projected on to the focal plane of a DeVere plate camera. The image of the two centre fringes was magnified by means of the camera lens and a relay lens to cover an area equal to that of the ten annular channels. The fringe pattern was photographed on HP3 sheet film and then the back of the camera removed. In its place the polished face of the fibre optic device was positioned in the focal plane, its annuli centred concentrically on the fringe image. Signals from each of the photomultipliers were then recorded, all the channels having been previously normalised so as to have equal responses. Next the fringe was rephotographed to ensure there had been no change in the excess fraction.

Fig.4 shows a densitometer trace of the mercury fringes corrected for the emulsion characteristic. On it are superimposed numbered points representing signal strengths in each channel of the 10-channel fibre optic array.

It can be seen that there is reasonable agreement between the two versions of the fringe pattern.

7. TRANSMISSION OF THE INSTRUMENT

As the instrument is required for the measurement of very faint line profiles it should have as high a transmission as possible. At 6943 Å, which is the wavelength at which the device is intended to be used, all the channels had transmissions of between 50% and 60%.

8. LIGHT TRANSFER BETWEEN CHANNELS

This was rigorously tested by shining a microscope lamp from the photomultiplier end of a channel and looking at the photomultiplier outputs on adjacent channels. No transfer could be detected with 14 stage RCA 7265 photomultipliers.

9. SUMMARY

Despite the fact that only one half of the device proved usable it still provided a spectral profile comparable with that obtained with the conventional photographic method. It is easy to use and needs no alignment except for centering the fringe pattern correctly. This and the reasonable transmission characteristics and the excellent channel isolation makes further development of this device worthwhile.

ACKNOWLEDGEMENTS

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REFERENCES

HIRSCHBERG, J.G. and PLATZ, P., 1965, Appl. Opt., 4, 1375.

JACQUINOT, P., 1954, J. Opt. Soc. Am., 44, 761.

JACQUINOT, P., 1960, Rep. Prog. Phys., 23, 277.

KATZENSTEIN, J., 1965, Appl. Opt., 4, 263.

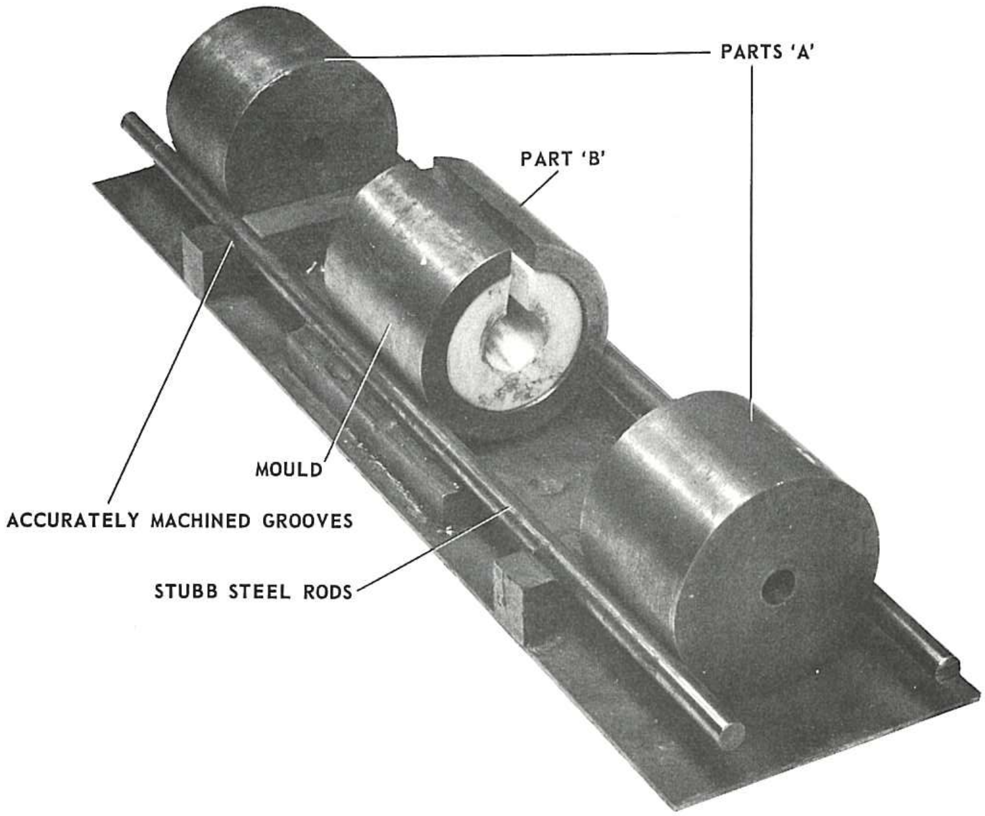

Fig. 1 (CLM-P 116)
Jig used in assembly of the fibre optic bundles

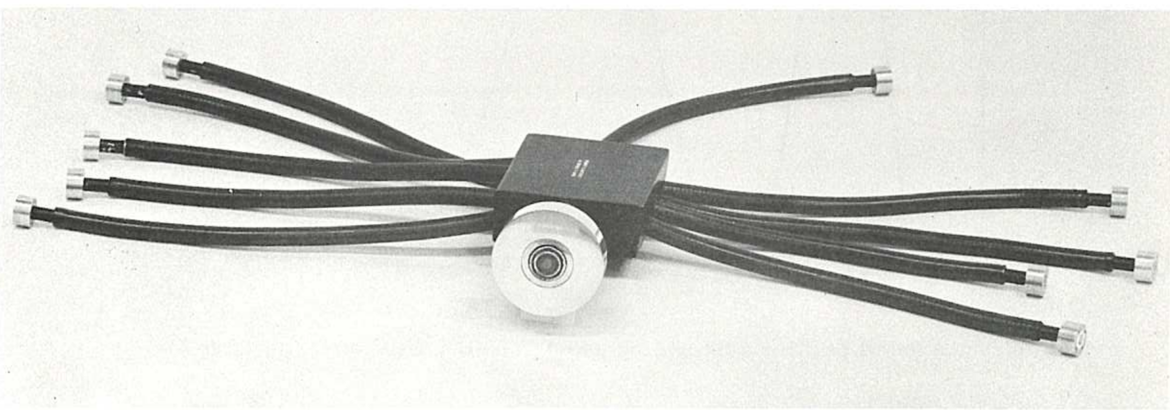

Fig. 2 (CLM-P 116)
The completed 10 channel fibre optic array

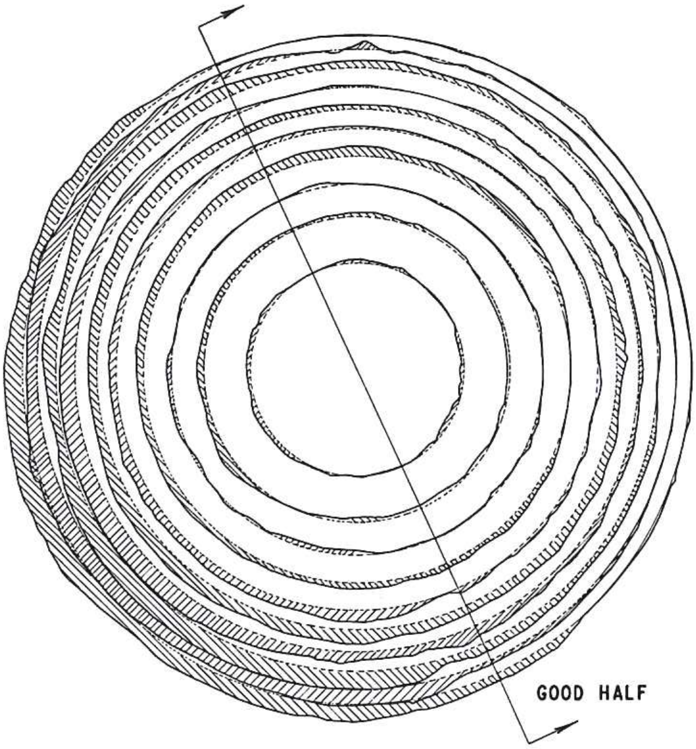

Fig. 3 Detail of channel shapes (CLM-P 116)

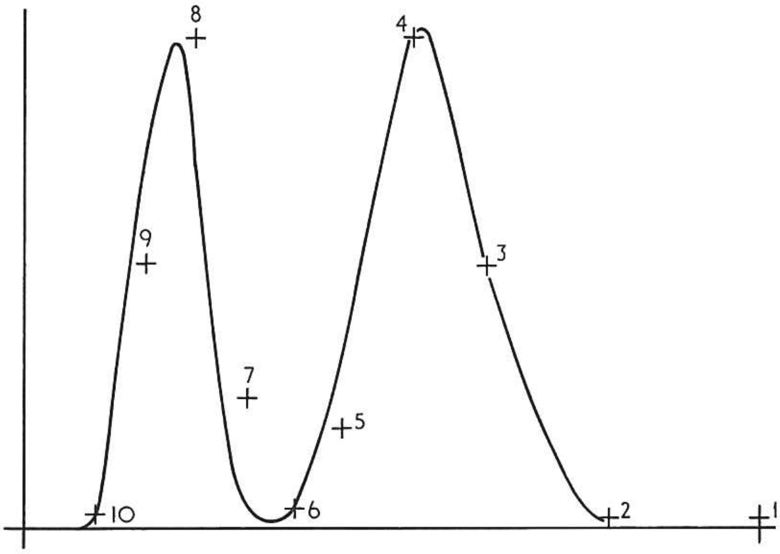

Fig. 4 (CLM-P 116)
Comparison of profiles obtained by photographic method and with array