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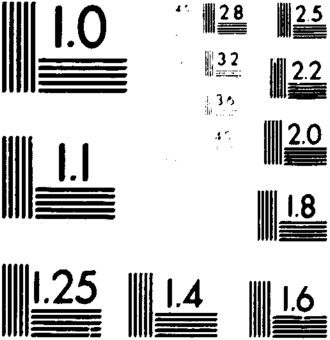

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INSTRUMENTS DESIGN DEVELOPMENT AND FACILITIES CENTRE

PROJECT DP/IND/79/046/11-03

INDIA.

Technical Report : Design of Optical Instrumentation

Prepared for the Government of India by the United Nations Industrial Development Organization, acting as executive agency for the United Nations Development Programme.

Based on the work of Mikhail M.Butusov, design consultant on optical instrumentation.

United Nations Industrial Development Organization

Vienna.

Explanatory Notes

The value of a local currency, Indian rupee

(Rps. 100 = U.S. dollars 12,80m)

Abbreviations used in a report:

Ambala Cantt - Ambala Centonment

IDDC	-	Industrial Design, Development and Facilities Centre (Ambala Cantt)
CSIO	-	Centre of Scientific Instruments Organization (Chandigarh)
LABO	-	Factory for manufacturing optical Scientific instruments mainly microscopes (Ambala Cantt)
IIT	-	Indian Institute of Technology Delhi
CW	-	Continuous-wave
NDT	-	Non.destructive testing
FOI	-	Fiber Optical Instrument
OFT	-	Optical Fourier Transform
A-D	-	Analog to-digital(converter)
LCM	-	Laser Scanning Microcope
OSAW	-	Oriental Science Apparatus Workshops(Ambala)
MD	-	Modular design

ABSTRACT

The mission was performed under the UNIDO Project DP/IND/79/046/ 11-03 "Instruments Design,Development and Facilities Centre", the need of which was identified by the Government of India in order to meet the needs of small scale and cottage industries surrounding Ambala Cantt. Among the basic duties of the Centre it was recognised to produce prototype instrument and related jigs, fixtures and gauges to accelerate the growth of this industry.

The main duties of the expert included:

1. To provide consulting assistance to the National Project Co-ordinator under the direction of the Chief Technical Adviser.
2. To assist the Centre in evolving new designs and better techniques in the field of optical/electro-optical instrumentation.
3. To assist the Centre in developing an adequate training programme.
4. To assist in the preparation of UNDP progress reports in accordance with established practices.
5. To prepare specifications and requisitions for equipment to be ordered for the Centre.
6. To contribute to the development of project work plan.

The duration of the mission (first phase of a split-mission) was one month from 5.02.85 until 5.03.85 including time necessary for briefing-de-briefing sessions in UNIDO (Vienna) in UNDP office in New Delhi and subsequent transportations.

MAIN FINDINGS.

1. Optical scientific instrumentation is one of the main fields of activity of industries situated in Ambala Cantt.

2. The role of IDDC as a leading organization in the improvement of local facilities in this field is recognized.

3. NPP is sufficiently qualified but some additional practical training is necessary to achieve better efficiency.

4. IDDC disposes of a significant capacity in manufacturing of different optical items such as lenses, prisms, flats, coatings, but the lack of corresponding metrics does not give a possibility of qualitative testing of components produced.

5. Several optical instruments such as lasers, CCTV camera, optical fibers and bundles are extremely needed for the further work on the mentioned field.

6. IDDC capacities in optical coating will be significantly improved when the "Balzers" set up will be launched.

RECOMMENDATIONS

1. The capacities of IDDC in the adequate metrological testing of optical components and instruments should be improved in nearest future.

2. Those optical instruments which were designed and tested during the expert's mission (see item 5, Ch. 3) should be manufactured on a solid basis with micropositioners and with more powerfull lasers as sources.

3. The training of NPP and the representatives of local industries at these instruments should be performed in order to get better recognition of efficiency and accuracy of laser-based NDT methods.

4. Those instruments which were designed but not yet realized are to be manufactured and tested in a shortest time for the same reason.

5. Certain pieces of optical devices (see findings, item 4) should be obtained in order to achieve further progress of IDDC activity in the field of optical instrumentation.

6. Optical coating systems purchased from "Balzers" must be launched in a shortest time possible Rigging by additional equipment based on electron gun evaporating sybsystem is desirable.

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I. ANALYTICAL ACCOUNT ON THE ACTIVITY.

A. General Considerations

India is widely recongnized among developing countries for its planned efforts to seriously improve the capacities of national industry and science, thus aiming in development of various branches of technology with considerable cooperation with many developed and developing countries and substantial assistance of United Nations.

In the documents of the Forth General Conference of UNIDO it was emphasized that the lag in industrial progress between developing countries and most of developed ones keeps to grow. Different global and internal constraints were analysed and possible ways to encounter the further delay were suggested.

Among other steps the urge of implementation of modern technologies in developing countries concerning local conditions and requirements was strongly appreciated instead of customary way used now, when technologies are being first developed into products and equipment suitable for developed country conditions and afterwards transferred in developing country in less or more appropriate form. In the course of these recommendations the development and functioning of IDDC is well approved. Haryana State comprises about 50% of Indian production in the field of scientific instrumentation thus giving sufficient basis for implementation of different improvements and innovations.

About 400 small scale instrumentation oriented units are now working in Ambala. In these conditions the UNIDO project leading to establishing of IDDC purposely for design, development services, technical information and coordination, training and maintenance became a serious step in achieving the targets described in the beginning of this section.

B. Current Activity of IDDC.

Design and development activity at IDDC is basically concentrated in two fields which are of the main interest considering the needs of fastly growing local industries. These fields are electronics and optics.

The section of electronics is well equipped with up-to-date instruments for testing, measurements, calibration and data processing The personnel is sufficiently qualified and interested in solving the current problems. Brief introduction made by CTA and subsequent rather detailed aquaintance with the facilities of electronics section gave an impression of substantial progress achieved in two recent years Tight connections are established with the local industry and the needs of industry result in the following activities performed by the section of electronics.

1. Design of prototype electronic instruments which are ordered by the

representatives of local industry, science or medicine, such as digital pH meter, programmed signal generator for accupuncture etc. This design is performed with the aids of modern microcomputers and microprocessors.

2. Periodical testing and calibration of the electronic components and devices under various temperature, acoustical and electrical conditions.

3. Maintenance of instruments and electronic equipment.

4. Design and manufacturing of printed circuit boards for the devices produced by local industries.

The new building for electronic section, electromedical section and mechanical workshop was surveyed. This three storey house provides $1200m^2$ for establishing and further development of these parts of IDDC. The building is to be ready at summer 1985. It is also planned now by city authorities to arrange a computer centre which is supposed to stay at the same building. The total number of personnel to work at the new building will be between 50 and 60.

Optical section which also includes the group responsible for vacuum coating contains nowadays 9 specialists at the /engineering level, most of which are newly recruited in 1985. Basically the expert's duties were connected with the needs and problems of this group, thus the situation there was analysed along numerous meetings, discussions and cooperative practical work. The following results were attained.

C. An Expertise at IDDC in the field of Optics.

Vacuum coating facilities contain two setups: the old one for thermal evaporation of metals and several dielectrics and newly purchased equipment by "Balzers" which unfortunately lacks the electron gun evaporation subsystem.

In the old Indian-made set-up the main problem driven to expert was reorganization of the thickness control optical system which was completely disordered. This system contained incandescent light source fed by stabilized power supply, optical single beam system with the white beam transversing the test plate at which the coating is grown, spectroscopic device for splitting the light into three wavelength components, photomultiplier with movable slit to measure the transparency of a film at a chosen wavelength, amplifier, A-D converter and digital counter with corresponding power supply. After therough examination it was assumed to be unreasonale to try to perform a complete repair of this control system. Instead of it the simple laser based optical system was suggested by expert, two different types of it were discussed with NPP, the ways of implementation were drawn.

In order to choose between one beam and two beam (with the reference) schemes we checked the long-term stability of the Ne laser available at NDDC. It was shown that power fluctuations of $\Delta I \sim 10\%$ take place, at periods of several seconds, and even larger instability of $\Delta I \sim 30\%$ is observed with periodicity of ~15 min.

Bearing in mind that coating process and simultaniously performed measurements of thickness take time of several minutes and more we easily concluded that only double beam optical system is applicable here. The following outline of coating thickness measuring instrument was suggested by expert (Fig.1, Annex 2). Because of certain problems connected with the implementation of a modern "Balzers" machine it was emphasized that presently working vacuum coating unit is not to be attributed as a provisional set-up. Thus sufficiently accurate thickness measurements should be performed at this unit by the optical system described in Annex 2.

All details for system accomplishment were manufactured and the alignment was performed in the course of mission.

Optical testing group is intended to perform an adequate testing of the elements currently manufactured at IDDC (lenses, prisms) and also for designing new effective instruments for testing main parameters of more sophisticated components such as microobjectives, ophtalmic instruments etc.

Optical testing group encountered several problems caused by the needs of local industries where various optical components (lenses, prisms, flat plates etc.) are produced in quantities, but the lack of quality causes the following draw backs in the quality of final products, mostly microscopes and ophtalmic instruments (see lower)

For this reason the design, manufacturing and implementation in local industries of simple, accurate and reliable instruments for quality control became the task of extreme necessity for IDDC. laser based instruments were suggested during the mission.

Although lasers are not manufactured in India nowadays, they are widely advertized and sold by several marketing companies. Their price (appr. US$ 400 - and more) is comparable with the corresponding item at other countries. Because the He.Ne lasers available ensure durable performance for many months and laser-based devices give valuable advantages over other optical instruments in many cases, the recommendations of the expert were generally held on laser side.

Prism interferometer (Fig.2, Annex 3) was suggested for attaining fast and accurate check-up of the flatness of glass, semiconductor or metal components with differently processed surfaces (i.e. polished, ground,, milled).

This interferomerer contains minimum number of simple components and provides the information about flatness in the form of interferogram (topogram), which can be treated like lines of equal height at geographic maps.

In addition to simplicity of performance and very clear way of information presentation this instrument has many other advantages.

- the sensitivity (i.e. the distance between two neighboring fringes) can be easily changed in wide range;
- [illegible]

-although the measurement is performed at highly grazing incident angles, the dimensions of the object are not practically distorted because of simmetrical optical scheme of an instrument.
-the estimation of microstructure (roughness degree) can be made by fringe contrast measurements.

The calculations of characteristics of interferometer for prisms with 90° and 60° basement angles were done, critical regimes defined. All components were manufactured, the body of laboratory version of the instrument was made and components were aligned. The demonstration of the instrument lication was performed with convincing results.

Fiber optical roughness sensor(see Annex IV)

The microstructure of the surface can not be easily measured by micro-interferometry unlike to flatness which is macroscopic characterstic. The number of interference fringes surrounding each ledge at the surface which is higher than a wavelength will be hard to count without microscope. Micro-interferometric research although correct is unefficient for randomly processed surfaces such as gournd, milled and roughly polished ones. Thus the fiber optical sensor based on coherent optical fourier transform was suggested. Its principle is clear from Fig.3.

The laser light transmitted through fiber illuminates the rough surface at normal angle. Only the part of this light is returned into fiber, being a result of specular reflection. The scattered light is not returned by fiber to optical power meter, this portion of light being larger for coarse surfaces.

It can be easily shown that for changes is scattering diagram of the surface from δ-function type (highly polished) to Lambertian type (ideal random scatterer); the difference between light powers measured in both cases becomes 10-12 dB. Within this range quite accurate measurements are possible.

The type and length of the fiber to be used in the sensor were discussed, the necessary piece was received from CSIO. Cleaning and other preparatory operations were fulfilled until the end of the mission.

We also elaborated possible ways of using optical fibers and, especially, bundles for design of optomedical instruments based on the endoscopic principle. Justifications for the small scale project proposal were prepared by expert.

Laser scanning microscope

This device was also suggested by expert in his previous investigations. It was confirmed that in IDDC practice this instruments can be effectively applied.

The principle of LCM was discussed with NPP several times in great details. Possible variations were suggested, but the general layout remained unchanged (Fig.4, Annex V).

The instrument is based on the scattering of focused laser beam, scanning across the examined surface, at different inregularities upon this surface-scratches, inclusions, ledges etc. The number, position and shape of surface defects are displayed at the oscilloscope screen in a very short time, typically:
-less than 1 second. The main time-consuming operation is insertion and removal of the sample under test into examination area.

Thus the instrument proposed can be made quite effective in total quality control of surfaces of different optical components.

Different modified versions of such an instrument including polarizing, phase-contrast, calibrating elements were also discussed.

Optical instrument for calibration of microscope objectives

The resolution power, or limit of resolution is the main parameter characterising the magnification which can be achieved by objectives. This parameter may be measured either by resolution limit ΔS ,MKM or by resolved spatial frequency N $(\frac{\text{lines}}{\text{mm}})$ with obvious correlation

$$\Delta S = \frac{10^3}{N}$$

In many cases it's more efficent to measure N by means of test plates but this method is hardly ideal due to necessity to have large set of test plates for accurate measurements and huge time consumption needed for setting and resetting each test plate. It is thus recommended to use an interference fringe pattern produced by two coherent point sources (say-two virtual images of laser beam focus, situated at a distance S) and observed at distance Z from the source plane (Fig.5, AnnexVI).

The formulas were derived for the range and ways of changes of N in the interference fringe patterns produced by point sources, situated at different distances. The calculations and curves, plotted by their results, (Fig.6) confirmed that this instrument may be applied for testing of objectives with poor and high resolutions.

II TRAINING, CONSULTATIONS, EXPERTISE PROVIDED FOR LOCAL INDUSTRY.

During my staying at IDDC I was invited to visit several industries situated in Ambala.

The first visit was paid to the factory which produces optical scientific instruments, mostly microscopes. The capacitieis of this factory, named "LABO" allow it to manufacture more than 500 items per month. Normally there are 3 to 4 different models produced simultaneously and spread overall India and to several foreign countries mostly for the educational needs (for schools, colleges, univeristies).

Bearing in mind the international trend of improving main parameters of scientific instruments and trying to keep the prices of items produced at comparatively low level, the authorities of LABO declared their interest to implement at the factory modern and accurate metods of nondestructive control of most improtant components.

Our discussions resulted in several possible solutions to be realized at LABO, among which the most interesting seen to be the following:

1. Finding and evaluation of different surface inhomogeneities at spherical and other lenses for microobjectives. Such defects (i.e. Scratches, bubles) exist on both surface of the lens. The method close to Shadow-graphy on schlieren-technique was discussed, but the power of the laser source available at LABO at present time does not allow to implement this technique.

2. More sophisticated instrumentation seems to be needed for localization of the same defects but only on the front surface of the lens. Coherent Schlieren technique may also be of substantial help. But taking into consideration that only 4% of the light is used (the Fresnel reflection wave from the front surface is investigated, the basic surface being covered with highly absorbing material, say wet velvet)-then even higher laser powers are needed.

It was agreed that 10-20 mw CW laser will be purchased in nearest future.

3. Control technique of the spherisity and curvature radious of small lanses was suggested using the double beam (Mach-Zender) interferometer with the reference sample lense in one of the beams (Fig. 7)

This set-up was manufactured at LABO at surprizingly short time and together with the representatives of LABO it was aligned and test experiments were performed.

I regard this rather successfull experience high enough because it was first practical confirmation of vast capacities of coherent optical methods for fast and accurate NDT in optical industry given to Ambala manufacturers.

Alltogether it was four visits to LABO which were dedicated for improvement of NDT methods aiming substantial rise of quality of optical components.

Other interesting company visited was "Indian Optics". This industry also produces microscopes, including interference and polarization ones, but also wide bunch of ophtalmic instruments for medical purposes. The main impression were:

1 Very high speed of design of new instruments. The whole period between decision made on new item to be produced and the pilot sample produces taxes not more than several months.

2. Rather high quality and good design of several microscopes.

3. Advanced design concepts used by the "Indian Optics".

For example, modular design concept worked out by the expert in 1983 during his mission in Bulgaira was independently elaborated(concerning microscopes) in this industry.

Next visit was to OSAW Company which is the oldest in scientific instrumentation in India. It has high grade reputation in India and now is involved with plenty of its subcontractors into production of vast variety of instruments including optical and electronic devices for teaching, metrology, industry.

Here also the modular principle was suggested for construction of three different interferometers by rearranging of components taken from the kit(See Annex VII).

This example confirmed the viability and necessity of modular design concept for scientific instrumentation in developing countries.

Among lectures prepared and given during expert's staying in India, the following topics are to be mentioned (each lecture have taken about 1,5 hours).

1 "Fiber Optics in Instrumentation"
(CHIO, Chandigarh, 22.02.85)

2. "Non-destructive testing by lasers"
(IDDC, Ambala, 26.02.85, for local industry).

3. "Fiber Optics in Instrumentation, basic principles and applications"
(IDDC, Ambala, 27.02.85 for local industry.)

4. "Active Fiber Optics"
(IIT, New Delhi, 28.02.85 for the staff of IIT)

III. ACHIEVEMENT OF THE MISSION OBJECTIVES

1. Consulting assistancy was provided to NPC and CTA in the field of optical instrumentation. Further development of contancts between IDDC and local industries was achieved .

2. Five different optical instruments with simple construction and effective performance were worked out, discussed with NPP in details and are now on their way to practical realization (see Annexes II-VI). These instruments are dedicated to;

-thickness measurements of vacuum coatings;

-flatness measurement of plane elements made of different mateirals and having different roughnesses of their surface;

-surface roughness measurements;

-fast finding and evaluation of surface defects on flat surfaces;

-calibration of microscope objectives;

3. In the course of training of NPP and the representatives of local industry two lectures were prepared and given at IDDC. Numerous consultations and discussions also raised the level of NPP in the field of modern optics, although they already had rather wide preparedness for the current work.

All materials which seem to be useful for NPP and for progress reports were put into the manual form to simplify their uses.

4. Specifications and requisitions were prepared for lasers (CW and pulsed), CCTV camera and other equipment. The purchase of Fizeau Optical Test Interferometer FOTI-100 was not approved because of high prize and narrow range of possible applications.

5. Fruitfull contancts with local industries resulted in eleaboration of several optical instruments to be designed and manufactured to achieve efficient NDT in these industries.

GENERAL CONCLUSIONS

1. UNIDO assistance is considered as externaly valuable for IDDC activity in important field of scientific instrumentation.

2. Project objectives are carried out by NPP under the supervision of NPC and CTA with substantial help of Indian authorities.

3. IDDC and local industry are working in close and growing co-operation.

4. Metrological capacities of IDDC in the field of optical instrumentation must be enhanced in order to achieve accurate and fast testing of the quality of all items under production.

5. Several effective laser based instruments were proposed by the expert for NDT of optical components.

6. Among these instruments the set ups for measuring the flatness of plane objects, for calibration of microscopes and for testing spherical lenses were constructed and demonstrated.

7. Further efforts in elaboration of laser based instruments for needs of IDDC and local industry should be undertaken.

8. Modular Design concept in optical Scientific Instrumentation finds recognition within local small scale industries.

ANNEX I

Programme of the expert's mission

	FEBRUARY, 1985																				MARCH		
	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	1	2	3
1. Arrival to New Delhi	x																							
2. Briefing and debriefing in the UNDP Office.	x																				x	x		
3. Arrival to Chandigarh		x																						
4. Studying project documents			x																					
5. Meetings with NPC				x		x				x	x							x						
6. Meetingswith CIA			x	x	x	x	x	x	x		x	x				x			x	x				
7. Meetings with NPP		x	x	x	x	x		x	x		x	x				x			x	x				
8. Visit to "LABO" Factory						x	x											x						
9. Visit to "Indian Optics"Factory								x																
10. Discussions on the contracts with foreing companies						x	x	x																
11. Attending the Programme "Workshop of Microprocessors"											x	x	x											
12. Preparation of terminal report								x	x		x		x				x	x	x	x				
13. Preparation of lectures for training course										x			x			x	x							
14. Visit to CSIO.Seminar FOI														x			x							
15. Training course on NDT and FOI for the representatives of local industry																			x	x				
16. Visit to IIT Seminar on FOI																					x		x	
17. Visit to Telecommunication Research Centre (Delhi)																						x		
18. Departure from Delhi																								x

ANNEX – II

Optical instrument for thickness measurements of Vacuum Coatings

(Basic principles and structure)

The system includes He–Ne laser 1, based on massive mounting 2, where the beamsplitter 3 with reflectivity of 10% is also adjusted.

The periscope system containing two prisms 4 and 7 and transparent vacuum seal 5 serves to put the testing light beam into vacuum chamber 6 and to direct it to the sample where the optical coating is grwon from the evaporizer 10. Analogous periscope is used to outlet the beam and to send it into the photodetector 15.

The intensity of the output light will change with the growth of thickness d of a coating accordigly to

$$I(d) = I_0 \cdot \exp(-\alpha d) \qquad (1)$$

for metal coatings with extinction coefficient α, specified for a given metal; and to

$$I(d) = I_0 \left[1 - R\cos\left(\frac{4\pi n_f d}{\lambda}\right)\right] \qquad (2)$$

for transparent coatings, where n_f–refractive index of a film and R–averages Fresnel reflection coefficient lying in between R_{sf} and R_{fv} these coefficients being specified for substrate–film and film–vacuum boundaries. Because of laser power instability each time after getting the test signal the measurement of reference signal must be achieved in order to fulfill proper signal calibration.

The details of system implementation and the order of measurements were discussed with NPP. –

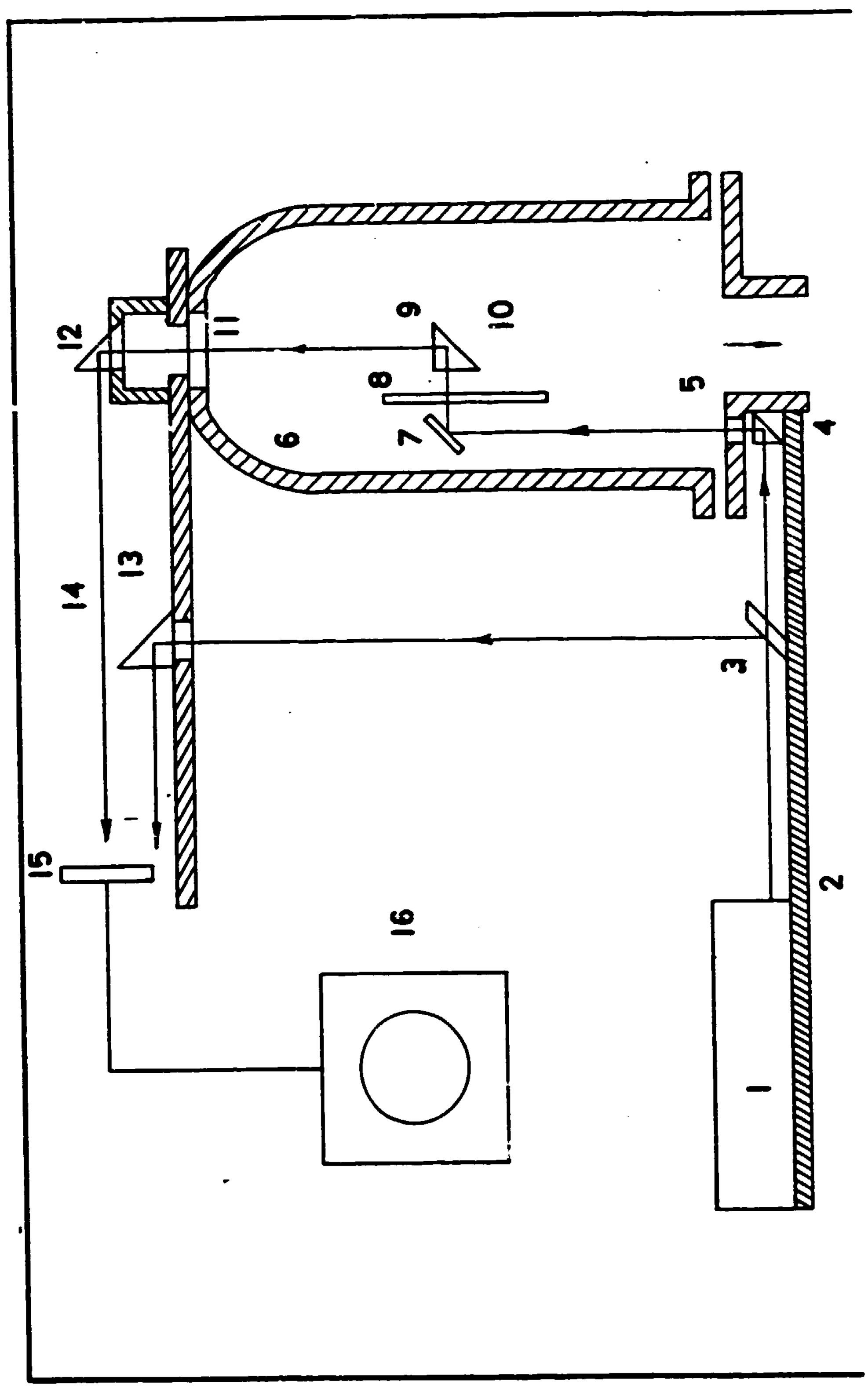


FIG. 1

ANNEX - III

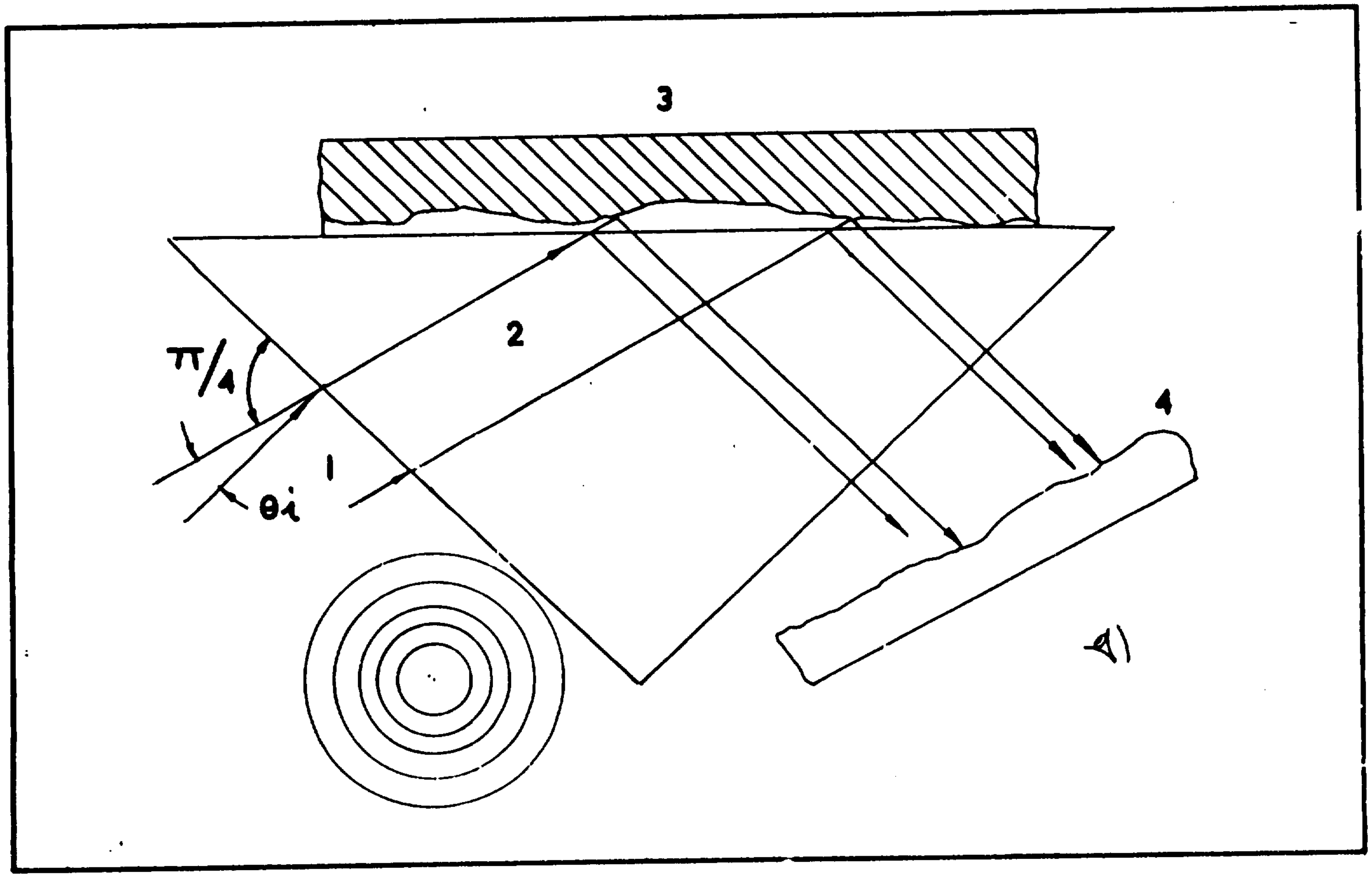
Prizm interferometer

The basic principles of prism interferometer elaborated by the expert earlier were adapted for the local needs. This instrument enables to get a fast evaluation of the flatness (or surface relief) of different plane elements made of glass, metal etc. and having not only optically polished surface, but also substantially rough (i.e. ground one). The principle of its functioning is clean from Fig.2. Collimated laser beam 1 is splitted at an upper flat plane of a prism 2 into two parts. One of them is reflected from this interface and keeping to be plane wave is used as a reference. Other part emerges at an upper space at highly grazing angle, thus striking the lower surface of observed object 3 at about the same angle. Under that condition even rough surfaces give rise to specular reflection, thus reflected wave contains all information about how flat is the lower surface of 3, After that the object wave returns into prism and both waves interfere and produce a fringe pattern, describing the topography of a surface. The accuracy of the instrument can be varied due to the following experession:

$$h = \frac{\lambda \cdot \cos\theta}{2m} \qquad (3)$$

Where h is a local "height" of an object over the prism surface, λ-laser wavelength, θ -angle of incidence of the light, measured or calculated by initial angle θ_o and prism paramaters, m-number of fringes between point of interest and reference point on the same surface which is touching the prism. Such reference points always exist because the object simply lies on the upper surface of prism. Thus the prism interferometer is strongly recommended as a simple instrument for fast evaluation of flatness of different details with various degrees of surface evenness.

FIG. 2



ANNEX IV

Fiber optical roughness sensor

(Basic principles and structure)

The light from CW laser (say, He-Ne)1 Fig.3 through beam splitter 2 and micro-objective 3 is coupled into optical fiber 4, which has the length L. After passing through this fiber the light emerges at an angles $\varphi \leq \varphi_0$ from the output end of the fiber, fastened in the sensor head 5. The angle φ_0 is defined by so called numerical aperture (NA) by the refractive indexes of fiber core and cladding, n_1 and n_2 respectively.

$$N.A. = \sin\varphi = \sqrt{n_1^2 - n_2^2} \qquad (4)$$

This light is collimated by lens 6, having a focal distance f, and strikes the surface 7 of the tested object at normal incidence angle.

The amplitude of illuminating light over the whole cross-section of sensor head is approximately constant:

$$A_i(x_1) = const(x_1)$$

at the surface the incident light encounters the scattering which may be described in terms of Kirchhoff theory for random surfaces with average size of inhomogenuety $\delta \geq \lambda$

If the absorption at the surface is negligibly small (or permanent), the specularly reflected part R of the total light intensity I is given by

$$R/I_i = \exp\left[-\left(\frac{4\pi\delta}{\lambda}\right)^2\right] \qquad (5)$$

Because the distance between the surface 7 and lens 6 is also chosen to be equal to f, the lens 6 performs OFT over the scattered light. Thus only the part defined by (5) will be focused on-to the core region of the fiber and tranmitted through fiber to photodetector 9, amplified and displayed by meter 8. Exponential inter-dependence between roughness 8 and light intensity measured by means of 8 and 9, permits to attain the functional connection 2 between signal and roughness for a given material. This function may be obtained experimentally by independent calibration i.e. roughness measurement by conventional tools. Then it must by stored in a form of calibration tables.

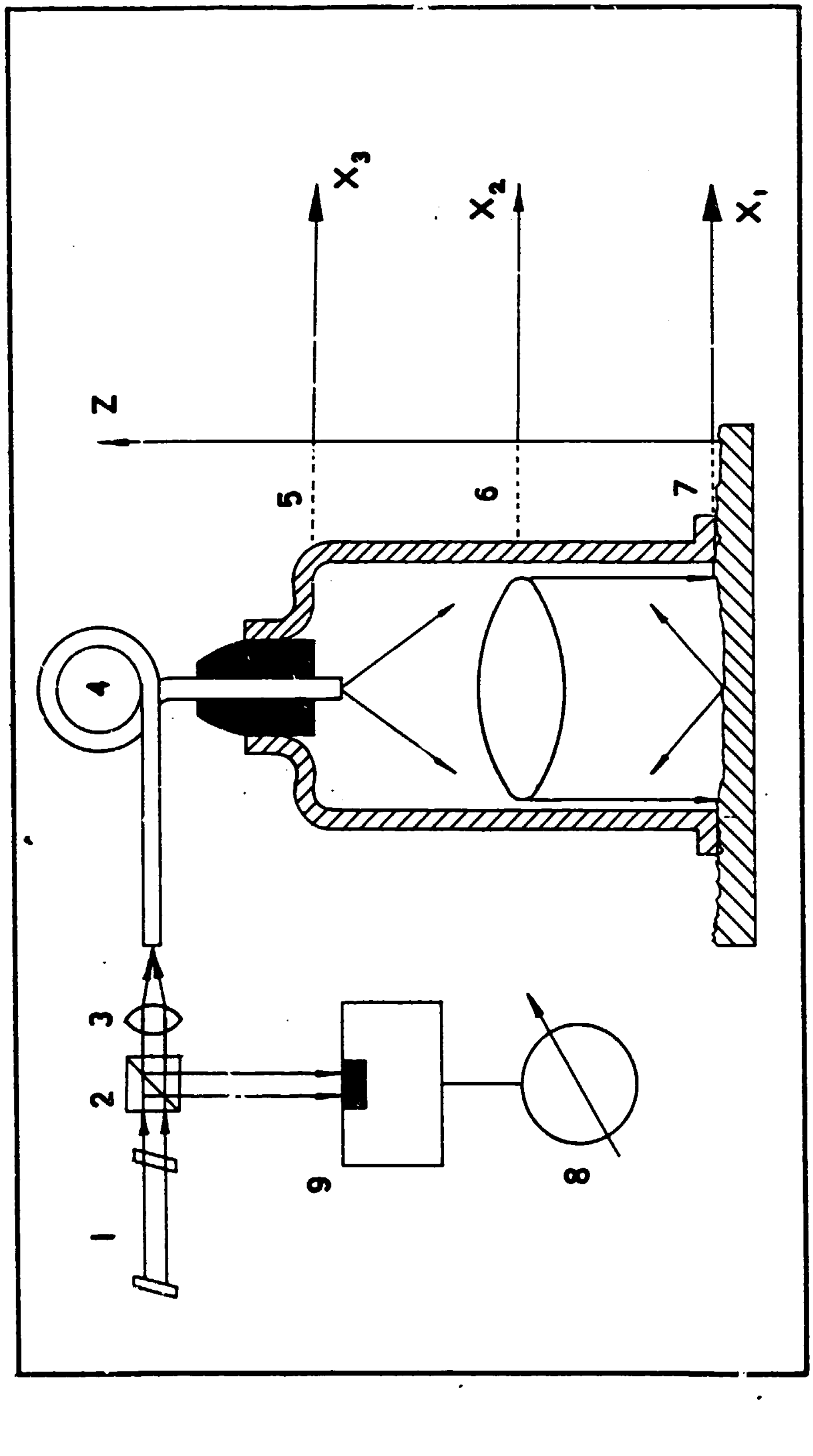


FIG. 3

ANNEX - V

Laser scanning microscope

(Basic principle and structure Fig 4)

The CW laser 1 illuminates two rotating pentaprisms or swinging mirrors successivel (14 and 13) mirrors move around orthogonal axes and their speeds or periods are selected in such a/way that the resulting beam scans the surface under test 11. The lens 12 is positioned in order to tranform the angular scanning into parallel beam scanning. The specularly reflected light is collected by lens 2 and focussed on to the stop. diafragm 3 . The scattered light passes by this diaphragm and is focused by lens 4 onto photodetector 5. Photo current is amplified by 6 and sent to the oscilloscope 7, where it drives the circuit which modulates the intensity of electron beam. By means of feeding the deflecting coils (or electrodes) of the oscilloscope from the same signal generators 9,8 which are used for driving the mirrors, we obtain the synchronous scanning of the laser and electron beams. Thus, when scattering occurs at the surface 11, it is immediately displayed by the spark at the dark screen of 7.

The larger is the cros-section of the deffect on the surface the higher is the scattered signal on the screen. Thus the brightness, number, and position of bright sparks at the luminescent screen corresponds to ther size, number and position of defects on the illuminated surface. The instrument provides fast and accurate finding and ranging of different surface defects on reflecting surfaces of silicon wafers, optical glasses etc.

If sensitive CC TV camera with the monitor is available with senstive vidicon, and the laser power is sufficient for parallel measurements, the optical scheme without moving mirrors but with uniform light intensity over all surface is applicable.

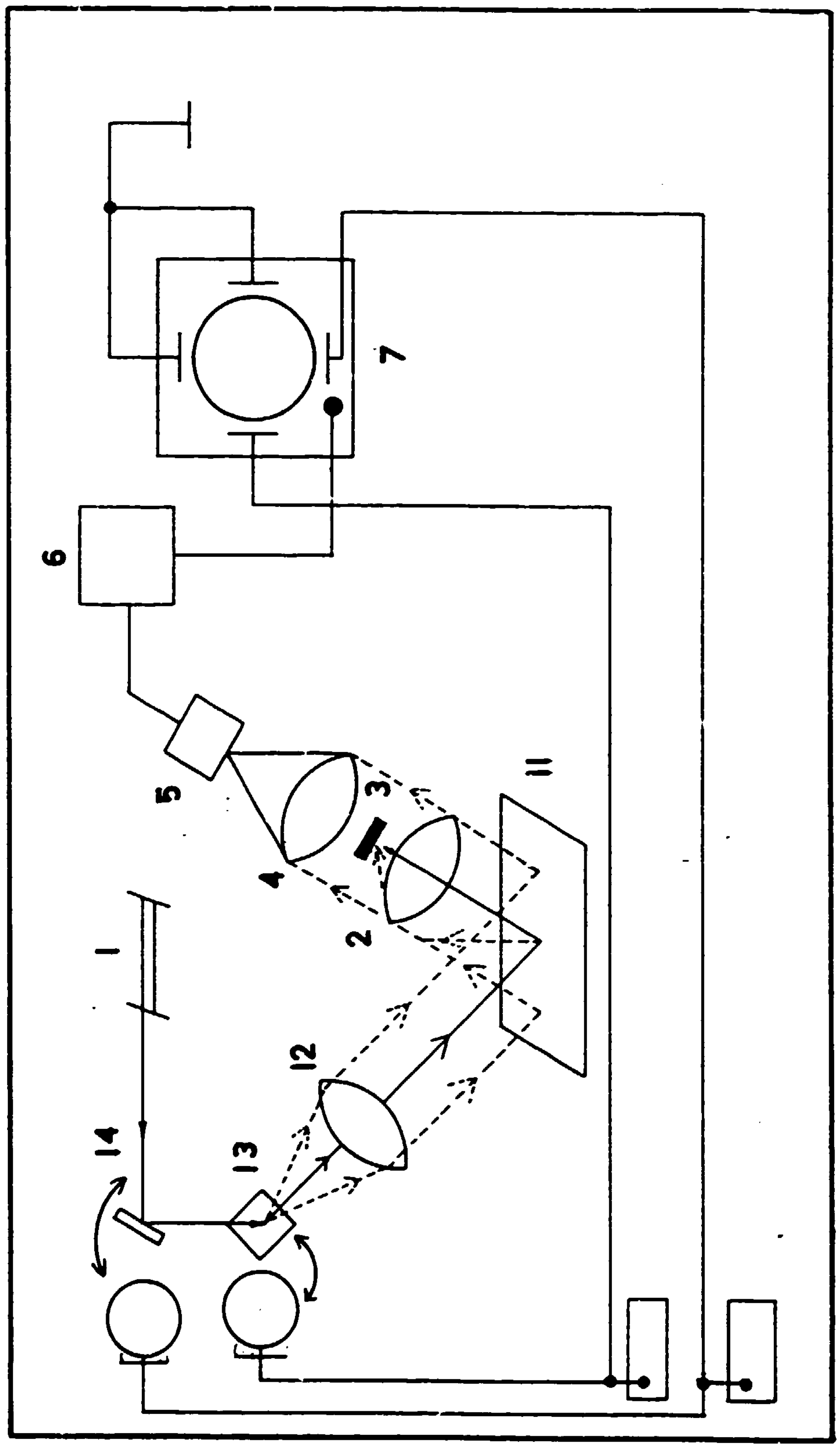


FIG. 4

ANNEX VI

The interference optical instrument for calibration of microscope objectives

The instrument is suggested for accurate measurements of resolution power of different objectives by the resolution of interference fringe pattern with variable spatial frequency N (lines/mm).

The frequency N is connected with resolution limit ΔS by simple relation

$$\Delta S = 10^3/N \qquad (6)$$

Th interference pattern is produced by two coherent point sources, situated at a distance S in the plane normal to the axis of microscope movement (Fig 5)

If z- distance between objective pupil and source plane, then

$$\Delta S = \frac{\lambda}{2 \cdot \sin\left\{\arctan\left[\left(\frac{S/2}{z}\right)\right]\right\}} \qquad (7)$$

For the cases (λ=0.63 MKM):
S=10, 50 and 100mm
and z ranged within 0-200mm we get results, which are plotted at Fig.6 and which we easily sum up the following:

1. Different separations S are to be used for testing objectives with different resolutions,
2. For poor objectives having, resolving frequencies 100-200mm^{-1}, very accurate limit measurements can be performed at S=10mm. Accuracy N=5-10 lines per mm. can be easily achieved.
3. For high resolution objectives there is a wide range from 750 up to 1750 lines/mm where resolution power can be defined with the accuracy 10-20 lines per mm.
4. Provided that optical set-up is made Viberation-proof, the laser, the set-up and microscope are to be mounted at an optical bench. For a given S,λ the measurement is done by slight movement of microscope forward to Z=0 plane, until the resolved fringes disapperar; then -by Fig.6 the resolution is accurately defined.

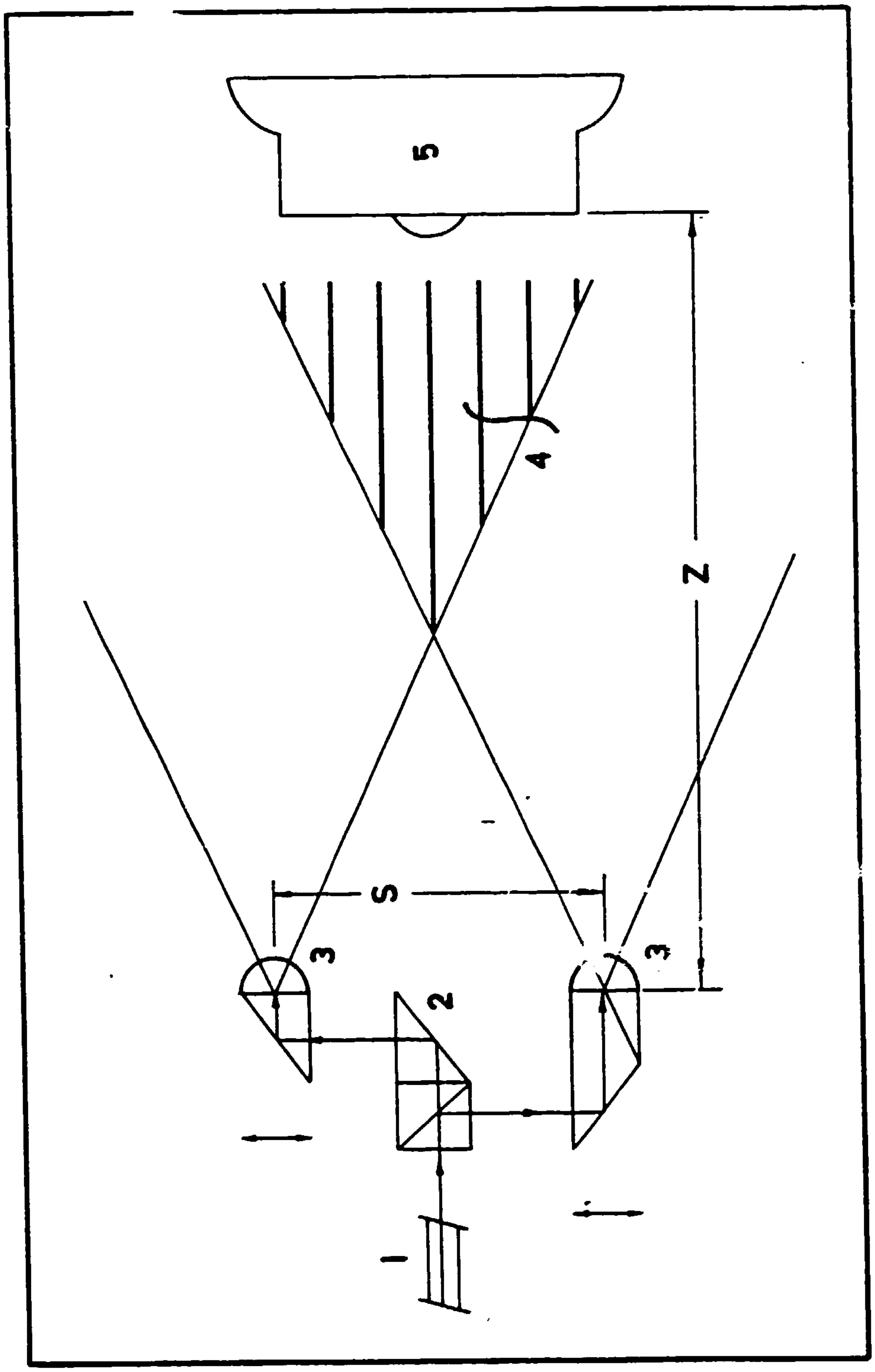


FIG. 5

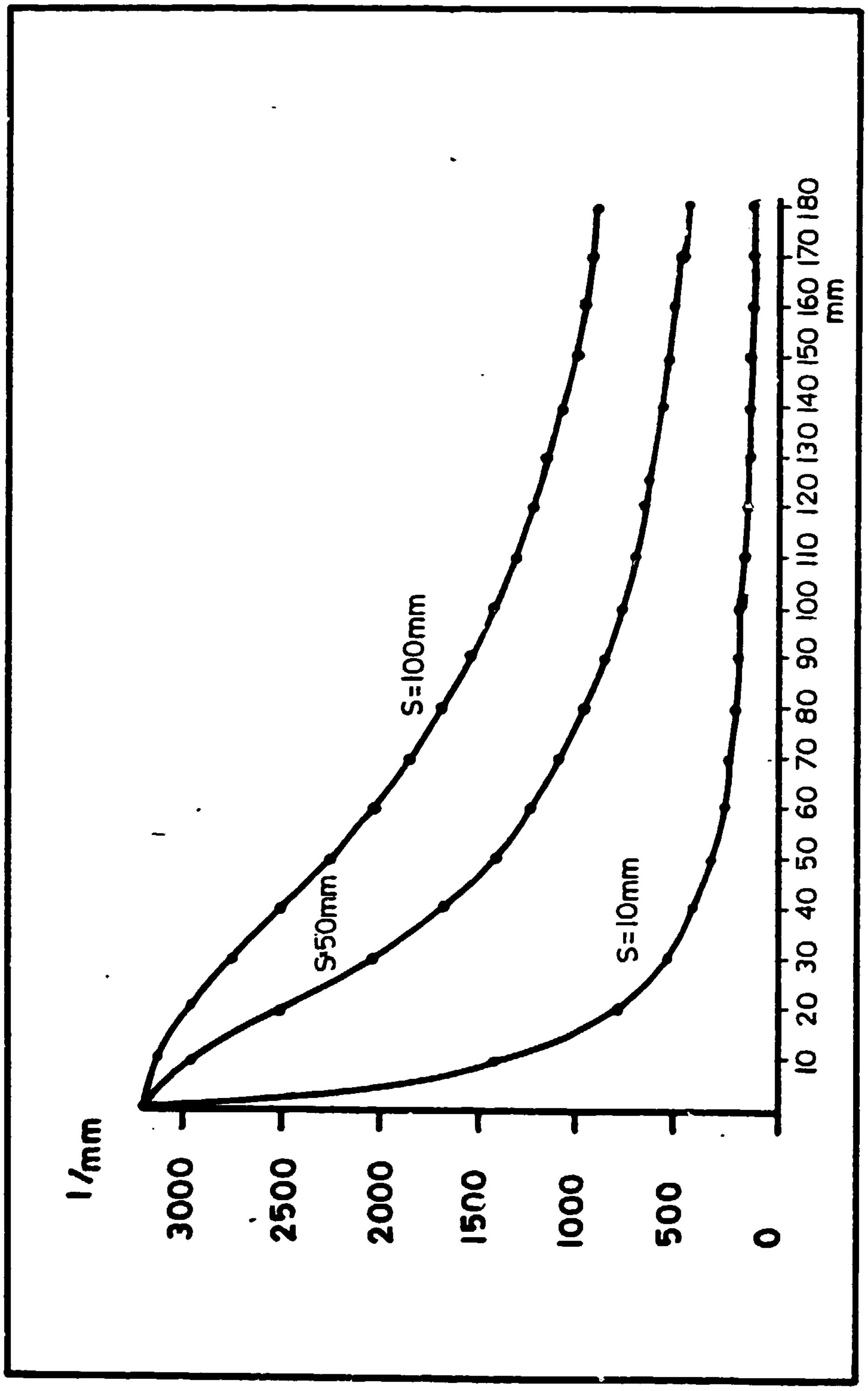
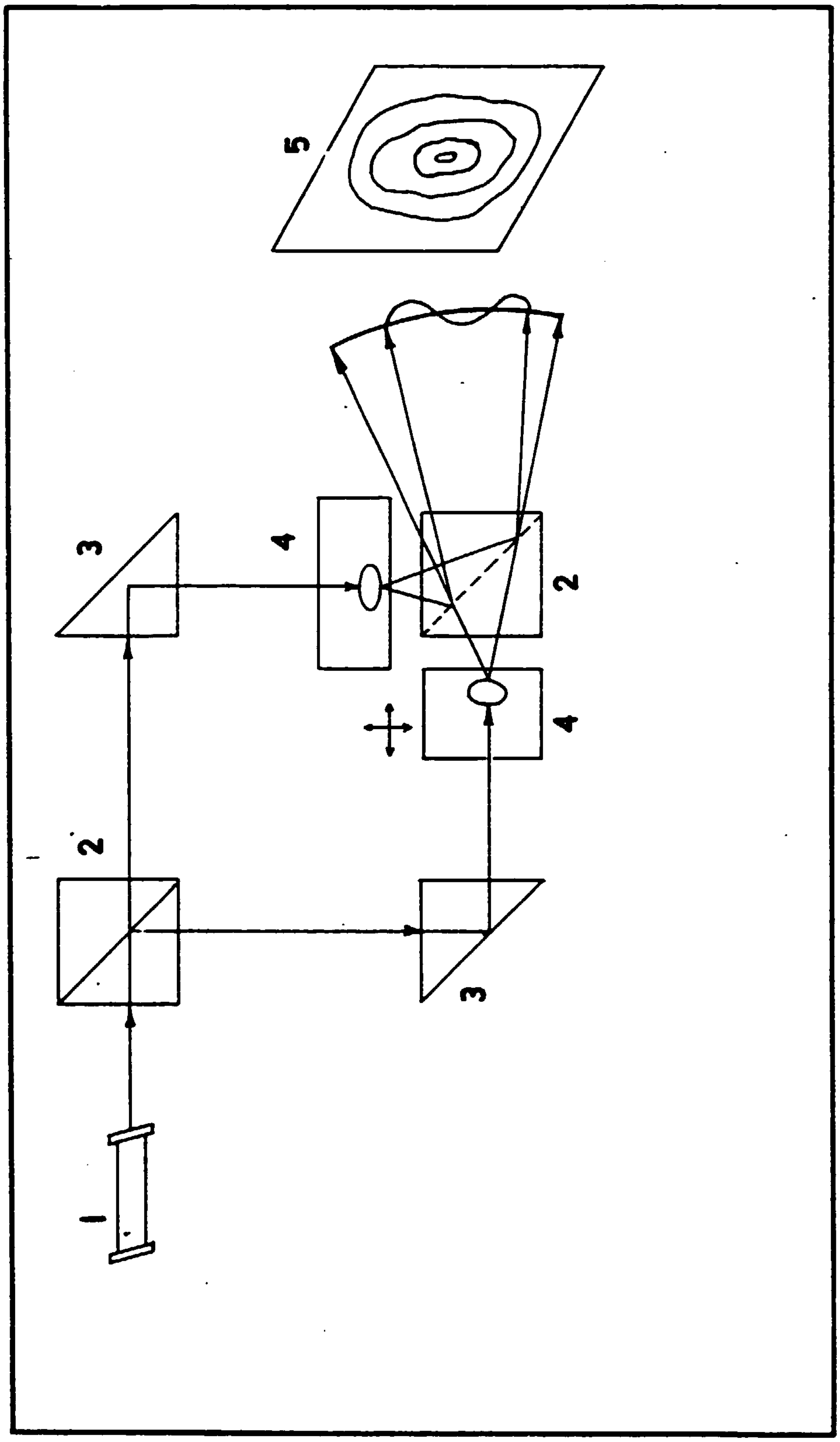

I/mm
3000
2500
2000
1500
1000
500
0
S=100mm
S=50mm
S=10mm
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
mm

FIG. 6

FIG. 7

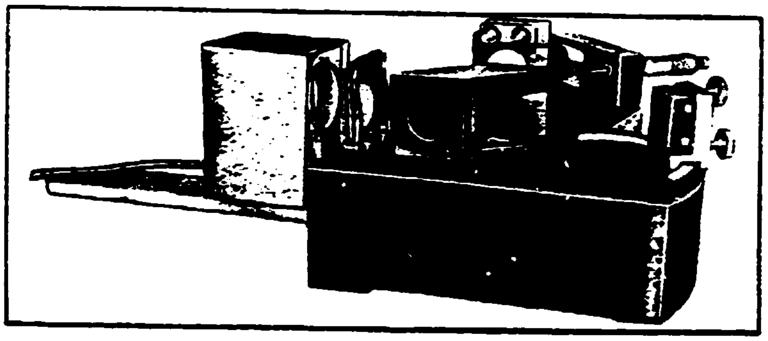


ANNEX VII   Excerpt from the leaflet of OSAW Company MD concept.

"OSAW UNIVERSAL INTERFEROMETER"

Michelson, Fabry Perot, and Twyman-Green interferometers are the three most standard and common techniques which are employed in laboratories for various accurate measurements. These also provides an accurate and readily operated measuring tool for industrial purposes. All the three can be assembled on the same Universal base by fitting standard outfits. Any of the three interfer-ferometers may be ordered separately or combined.

The Michelson Interferometer

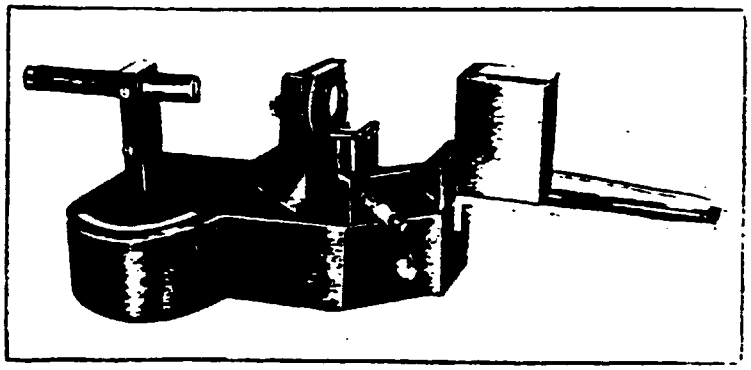


This technique employes a beam-splitter mirror to divide a beam of light into two part to be recombined at the same surface to produce interference effects. The following demonstrations are possible :—

1. **Formation of circular and localized monochromatic and white light fringes.**
2. **Accurate comparision of wave length.**
3. **Establishment of zero path difference.**
4. **Measurement of refractive indices of gases and transparent solids.**
5. **Accurate measurement of small changes in length.**

Michelson Interferometer can be assembled by fitting to the universal base. (Unit A), Unit B, Unit C, Unit E, and Unit F, Unit N, is used for specific experiments.

Fabry Perot Interferometer

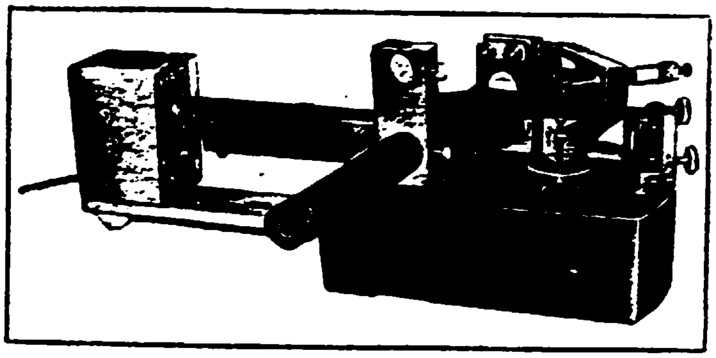


This technique is employed for resolving spectral lines only a few angstrom apart. Multiple reflection between two parallel mirrors produce bright circular fringes of high resolution on a dark field. The following applications are possible :—

1. Wave length changes when a gas discharge is subjected to a magnetic field.
2. Zeeman splitting in magnetic field.

It can be assembled by fitting the standard units D, Unit F, Unit G, Unit J on the universal base with moving mirror (Unit A).

The Twyman-green Interferometer



It is a development of the michelson in which a collimator in the beam produces a plane wave-front. It is primarily used for :

1. Accurate determination of dispersion of prisms.
2. Quantitative assessment of inhomogeneties and surface variations in windows and prisms. It can be assembled by fitting Unit B, Unit C, Unit F, Unit G, Unit H, Unit J, Unit L and Unit M, to universal base moving mirror (Unit A).