

**I N S T I T U T F Ü R P L A S M A P H Y S I K**  
**G A R C H I N G B E I M Ü N C H E N**

A Simple Interferometer Based  
on the Ronchi Test

H. Salzmann

IPP IV/6

May 1970

*Die nachstehende Arbeit wurde im Rahmen des Vertrages zwischen dem Institut für Plasmaphysik GmbH und der Europäischen Atomgemeinschaft über die Zusammenarbeit auf dem Gebiete der Plasmaphysik durchgeführt.*

IPP IV/6 H. Salzmann

A Simple Interferometer  
Based on the Ronchi Test

May 1970 (in German)

ABSTRACT

A simple interferometer is obtained by using the setup of the Ronchi test. It requires only low mechanical stability and is easy to adjust.

## 1. Introduction

In a laboratory it is sometimes necessary to check the optical quality of a newly purchased laser crystal. Interferometric tests are normally performed using a Twyman-Green interferometer, but only in a few laboratories is an interferometer of this or the Mach-Zehnder type at hand. In this report a simple interferometer based on the Ronchi /1,2/ test is described.

The principle of the Ronchi test is shown in fig. 1.

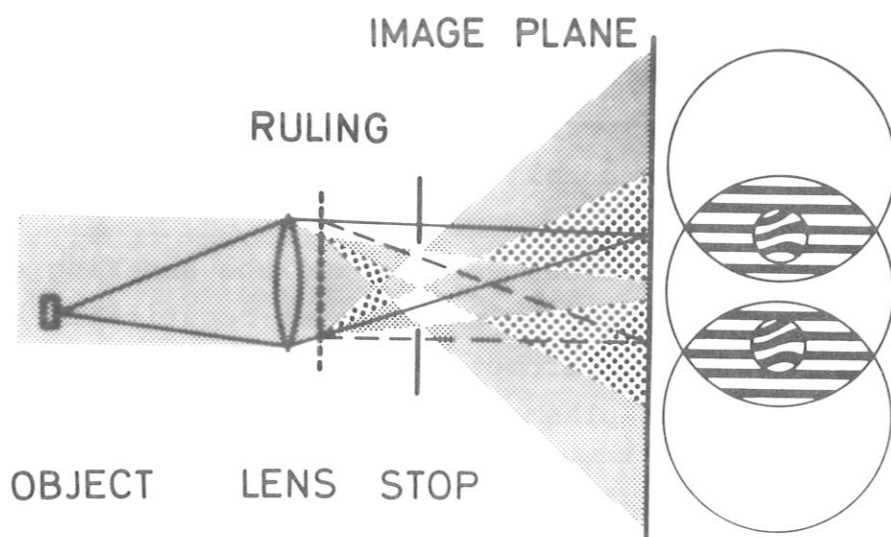


Fig. 1

Principle of the Ronchi test

A well-collimated beam of light passes through the lens system and is then split up into a number of beams by a ruling. After passing the focal plane the light beams diverge. When an appropriate frequency of the ruling has been chosen with respect to the diameter of the

collimated beam and the focal length of the lens, the diverging light cones intersect. If the illuminating light beam is spatially coherent over its cross section visible interference patterns are formed within the intersection volumes. The interference fringes on a screen perpendicular to the optical axis are straight lines for a perfect lens system. From the deviation from the straight one can infer the image forming defects of the lens. This method is known as the Ronchi test. It can be shown quite easily (see Appendix) that the fringes are achromatic for paraxial light rays. This signifies that the fringes may be observed in white light too or in other words, that no conditions need be imposed on the temporal coherence of the light source.

The described setup constitutes a simple interferometer if one puts an object into the light beam as shown in fig. 1. If the object covers less than half of the beam cross section, each image of the object overlaps the undisturbed part of the neighboring beam in the image plane. The additional fringe shifts observed across the image of the object are proportional to the difference in optical length introduced by the object. Thus an object such as a ruby rod can be tested for optical quality. It should be remarked that a perfect lens need not necessarily be used when applying this setups as an interferometer. It is only more convenient to use a perfect lens when the undisturbed reference fringes are straight lines. The conditions imposed on the coherence properties of the light source are more restrictive compared with the simple Ronchi test. The coherence length of the light must be longer than the difference in optical length introduced by the object. Otherwise no fringes will be observed across the image of the object. This requirement can be extenuated by compensating the difference in optical length with a perfect plane parallel glass plate of appropriate thickness in the other half of the test beam.

If the object covers the whole beam cross section and the shearing of the light beams by the ruling is small the arrangement constitutes a differential interferometer. An interferometer of this type was used in /3/ to investigate a theta pinch plasma.

## II. Dimensioning of the interferometer

As shown in the Appendix, the following two relations are valid in good approximation:

$$S_m x = f v \quad (1)$$

$$f m \lambda \approx d \quad (2)$$

- S = fringe distance in the image plane
- m = ruling frequency
- x = distance of ruling
- f = focal length of imaging lens
- v = enlargement ratio
- $\lambda$  = optical wave length
- d = radius of collimated light beam
- = maximum lateral object dimension

Relation (2) is quite useful for it combines the characteristic data of the optical parts of the interferometer, ruling frequency, and focal length of the imaging lens with the lateral object dimension. In fig. 2 the focal length is plotted versus the ruling frequency for some values of the object dimension. The wavelength chosen is that of ruby laser light.

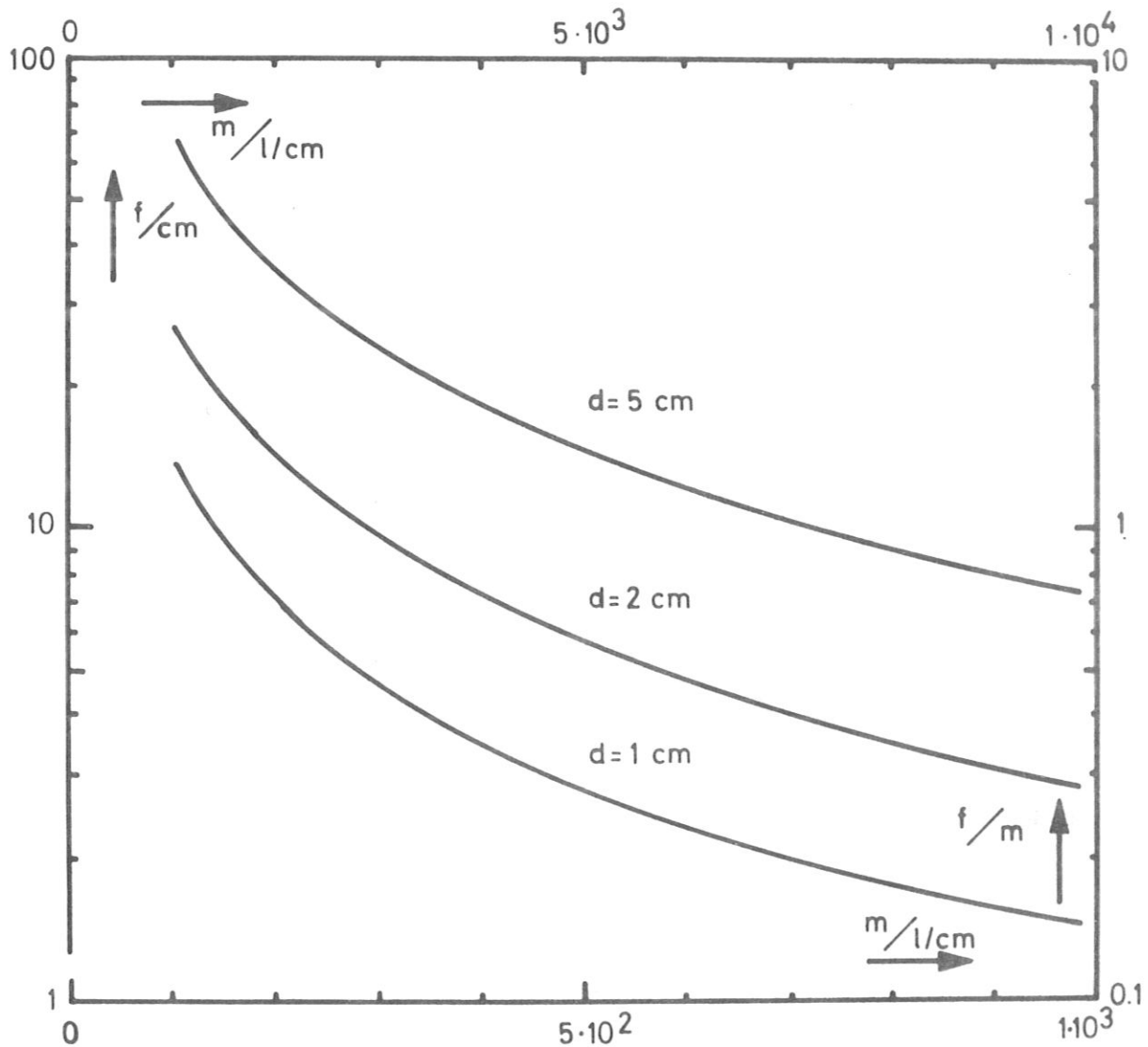


Fig. 2

Relation between maximum object diameter, focal length and ruling frequency

It is very favorable that according to eqs. (1) and (2) the choice of the optical components is independent of the required separation of the interference fringes in the image plane. The appropriate fringe distance is adjusted merely by shifting the ruling along the optical axis in the vicinity of the focal plane.

### III. Applications

In Fig. 3 the setup chosen for testing the performance of the interferometer is shown. A He-Ne laser beam is expanded using a Cassar 1 : 3.5  $f = 50$  mm and an Apo-Skopar 1 : 9  $f = 60$  cm lens. In most of the experiments a 20 micron pinhole was introduced as spatial filter in the beam expander. A Halle  $f = 3$  m spherical mirror images the test object on the film plane. A 200 lines per inch Ronchi ruling serves as a beam splitter. When the ruling is placed in the vicinity of the focal plane, the fringes become visible at once.

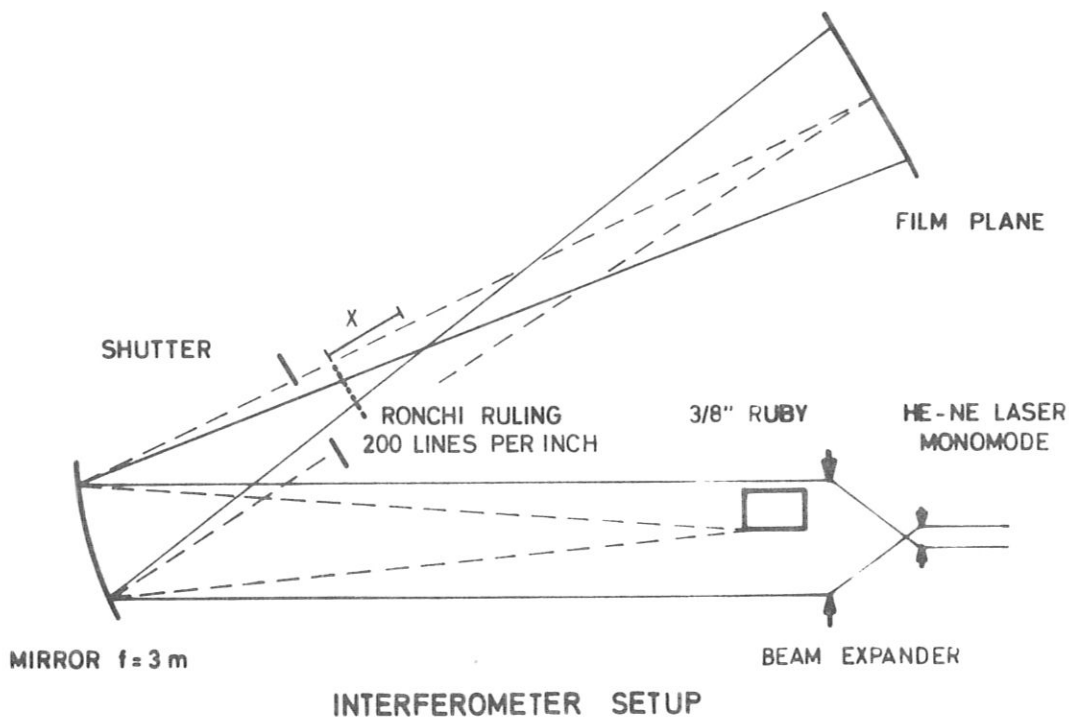
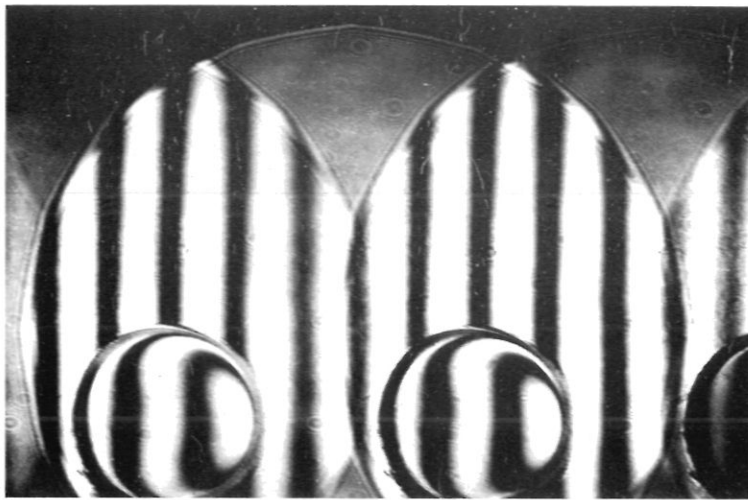
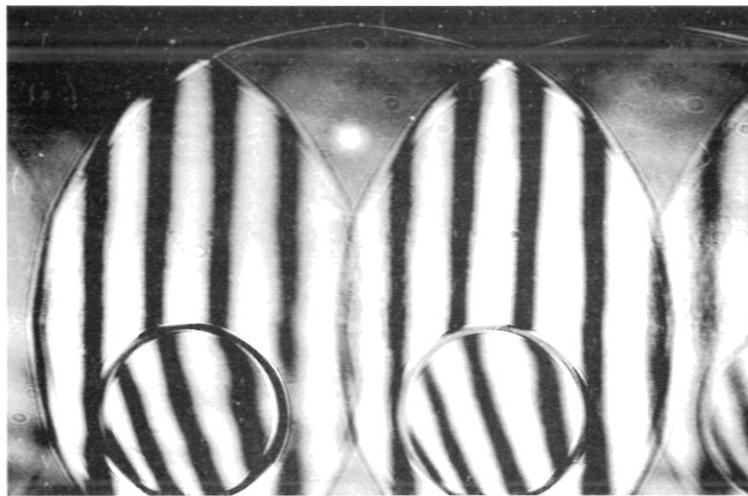


Fig. 3

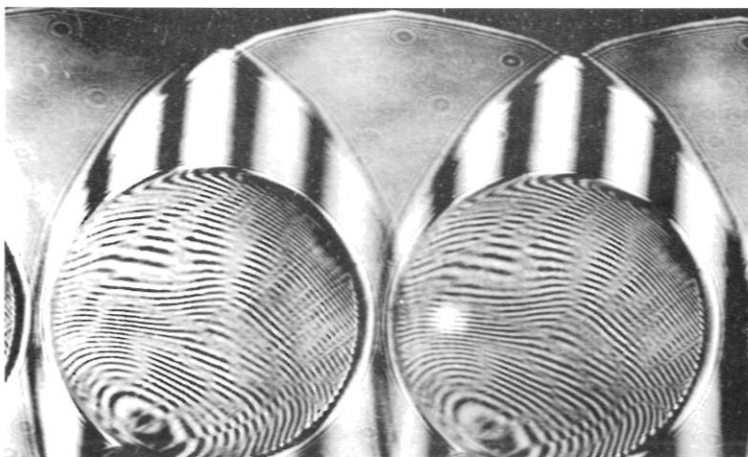
Fig. 4 a - c shows the interferograms of a Nd rod, a selected high quality Czochralski grown ruby, and a medium quality Verneuil grown ruby. A spatial filter was used to take these pictures.



a)



b)



c)

Fig. 4 a - c Ronchi-Interferograms  
a) 3/8" Nd rod  
b) 3/8" Czochralski ruby  
c) 5/8" Verneuil ruby

It will be noticed that the visibility of the interference fringes is not constant across the overlapping regions. This is explained by taking into account the fact that the light beams split up by the ruling are not of equal intensity. The intensities of beams of higher order are lower than those of lower order ones. Therefore the light intensity in the region where two beams of order  $m$  and  $m + 1$  overlap is not modulated down to zero intensity. If one also takes into account the fact that the intensity of the collimated test beam is not constant over its cross section, one can explain the varying visibility of the interference fringes. The interferometer setup requires only very low mechanical stability. This important inherent advantage of the interferometer is due to the fact that the reference and object beams are separated only by a small distance and pass the same optical components.

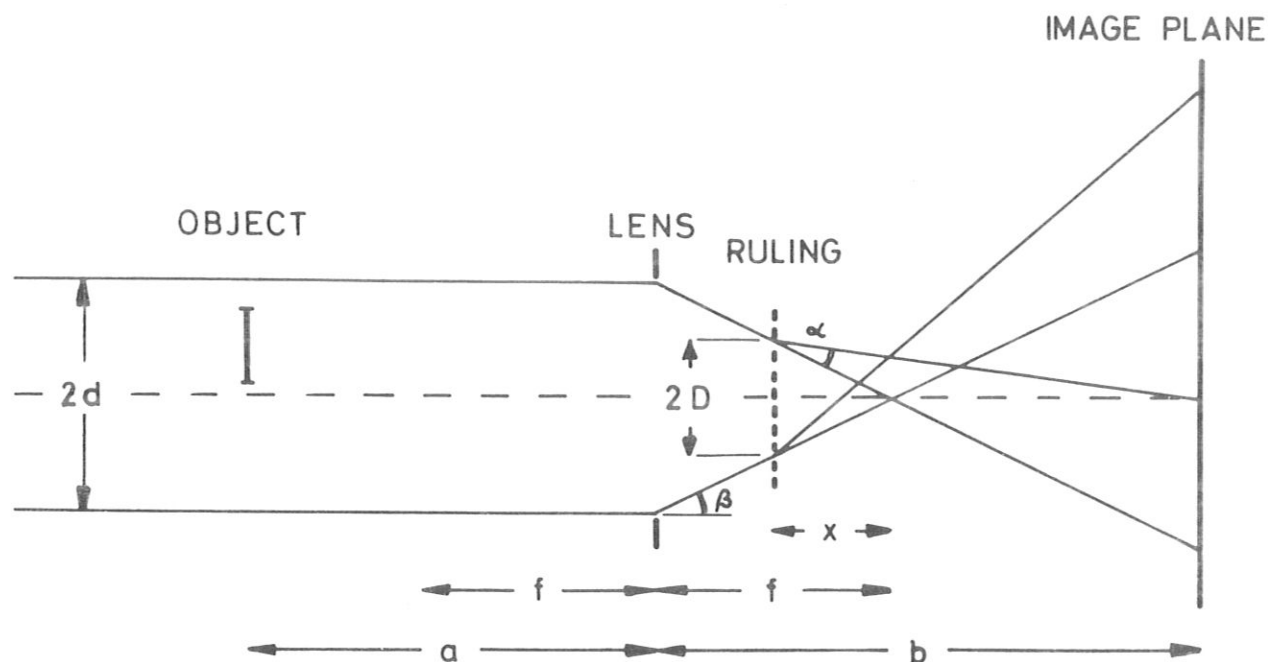
#### IV. Conclusions

It has been shown that the optical arrangement of the Ronchi test may be used as a simple interferometer. The setup requires only low mechanical stability and is easy to adjust because the fringes are visible at once.



## V. Appendix

The optical setup is shown in fig. 5. In the following a simplified description of the interferometer is given assuming paraxial light rays.



## SETUP OF THE RONCHI INTERFEROMETER

Fig. 5

After passing through the lens the light beam converges and is split up by the ruling into a series of light cones which are inclined at an angle  $\alpha = m\lambda$  with respect to each other.  $m$  is the spatial frequency of the ruling,  $\lambda$  the wavelength of the incident light.

Thus in the focal plane of the lens a one-dimensional array of equidistant light sources is formed with a spatial frequency  $M = 1/\alpha x$ ,  $x$  being the distance of the ruling from the focal plane. Beyond the focal plane the light beams diverge and partially overlap. In the regions of overlapping interference fringes are visible if the collimated test beam is spatially coherent over its cross section. The directions in which interference maxima are observed behind the array of light sources in the focal plane are given by  $\gamma_n = nM\lambda$ . The fringe separation  $S$  on a screen at a distance  $b$  from the imaging

lens is equal to

$$S = (b-f) M\lambda \quad (3)$$

From the condition of optimum overlapping, viz. the distance of two cone axes in the image plane is equal to the cone radius, it follows that

$$(\beta - \alpha) (b - f + x) = D \quad (4)$$

where

$$\beta = d/f, \quad D = \beta x,$$

and  $2d$  being the diameter of the collimated light beam. Using the relation  $b = f(1+v)$  one gets the two equations

$$Smx = fv \quad (5)$$

$$\text{and} \quad m\lambda (fv+x) = dv \quad (6)$$

which can be combined to yield the relation

$$f\lambda (m+1/s) = d \quad (7)$$

which is independent of the enlargement ratio  $v$ . Assuming  $1/s \ll m$ , which is quite justified since  $m$  is of the order of a few hundred and  $1/s$  varies between zero and about 10, one gets the relation

$$fm\lambda \approx d \quad (8)$$

This relation is quite useful for it combines the characteristic data of the interferometer: ruling frequency, object dimension, and focal length of the imaging lens.

Since the relation  $1/s \ll m$  is quite justified, the choice of the optical components of the setup is independent of the required fringe distance  $S$  and is only a function of the lateral object dimension. Figures 6 a - 9 a show the exact relation (7) for several values of

the ruling frequency  $m$ , while in figs. 6 b - 9 b the distance  $x$  of the ruling from the focal plane is plotted in order to achieve a certain fringe separation.

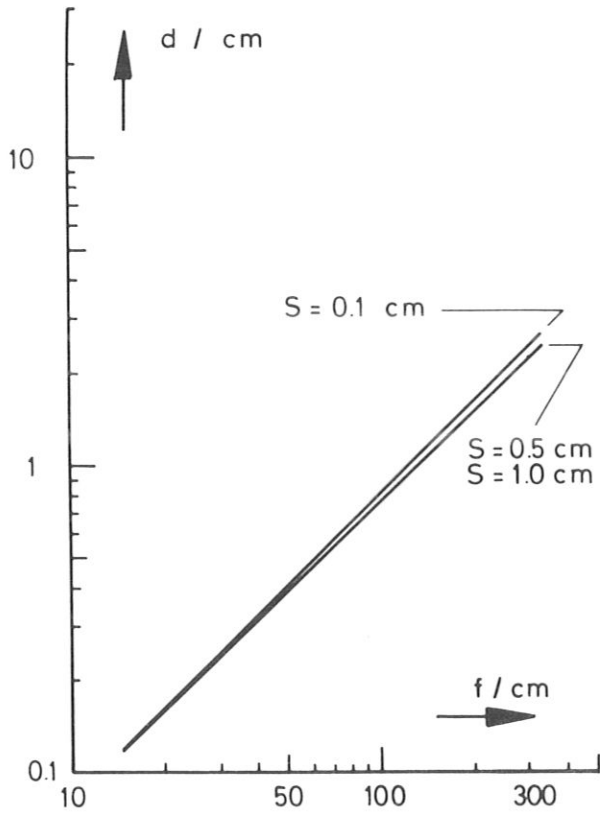


Fig. 6 a

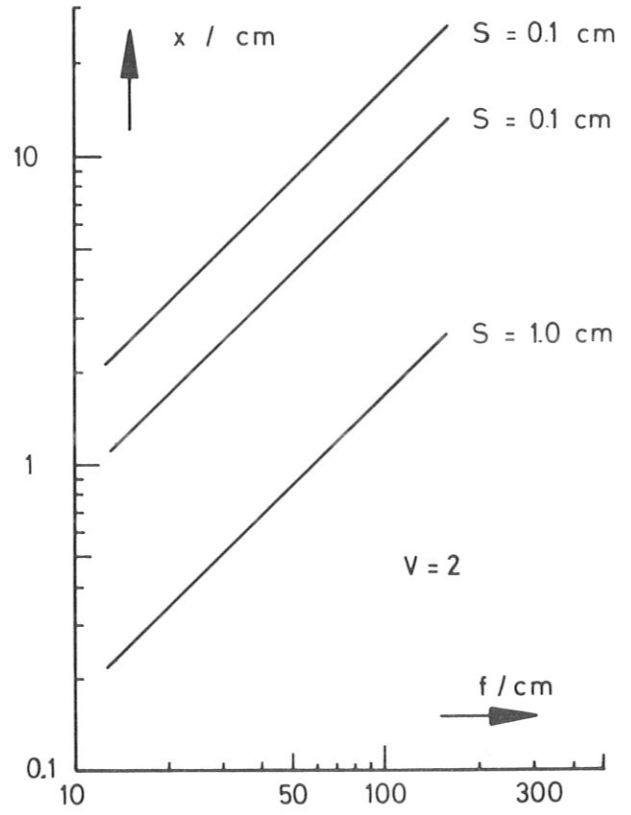
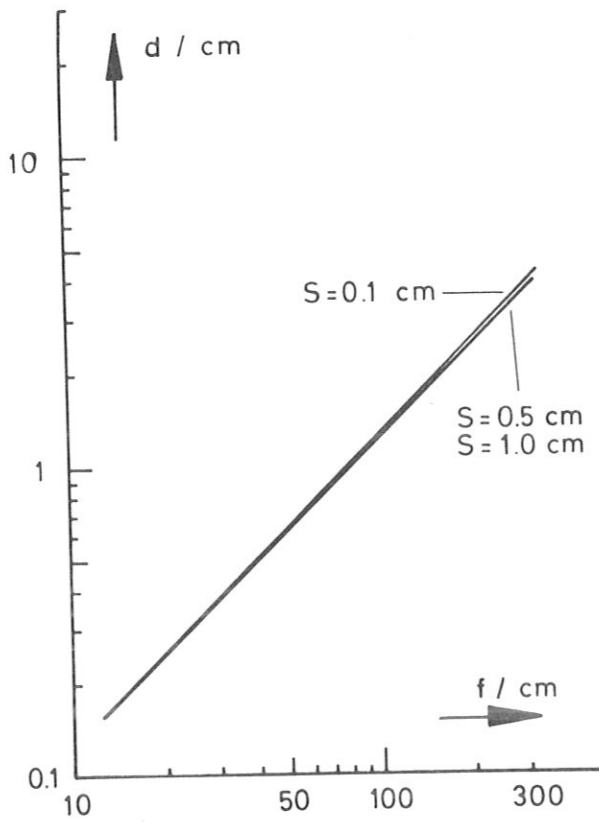
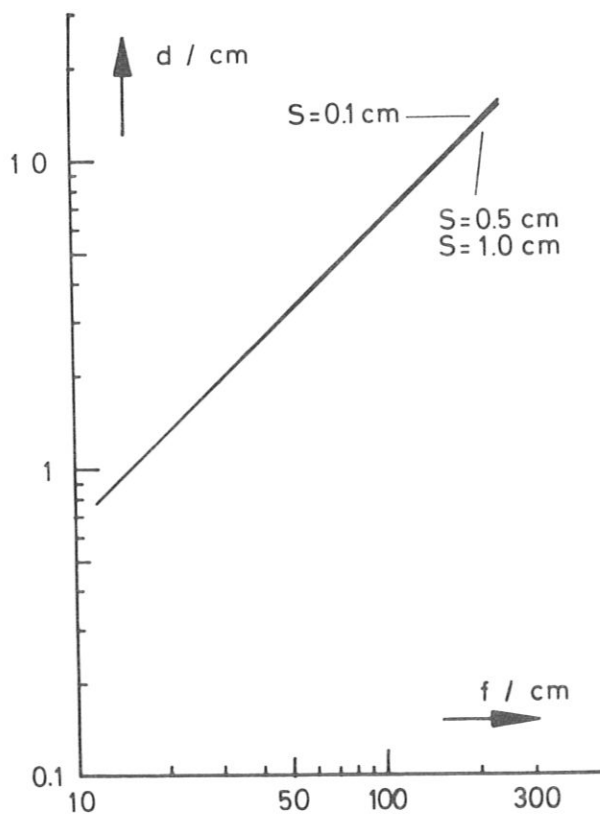
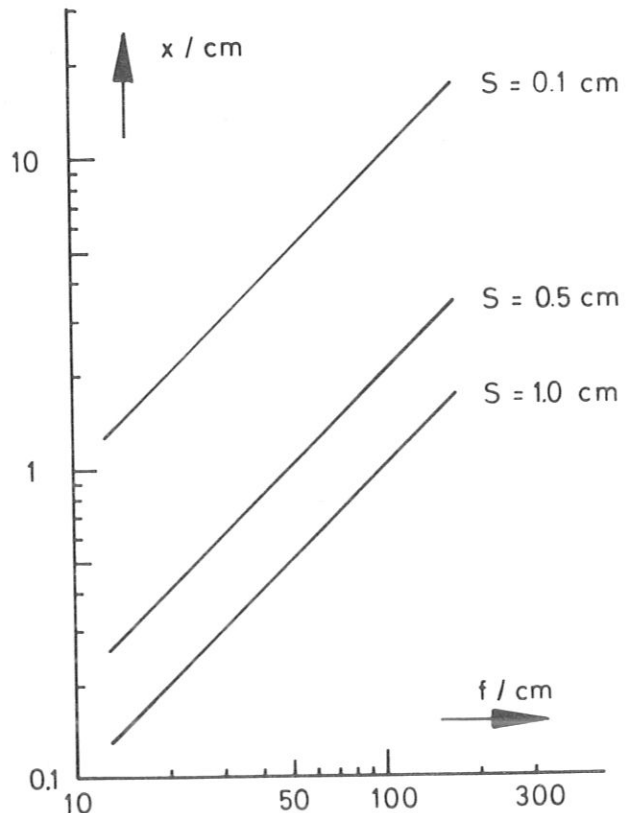


Fig. 6 b

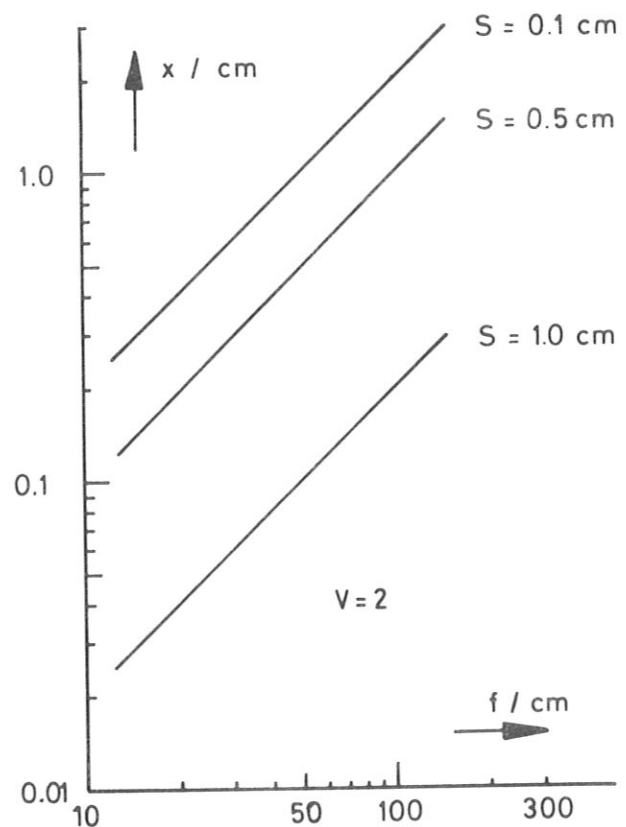
$m = 300$  lines / inch



$m = 500 \text{ lines / inch}$



$m = 1000 \text{ lines / cm}$



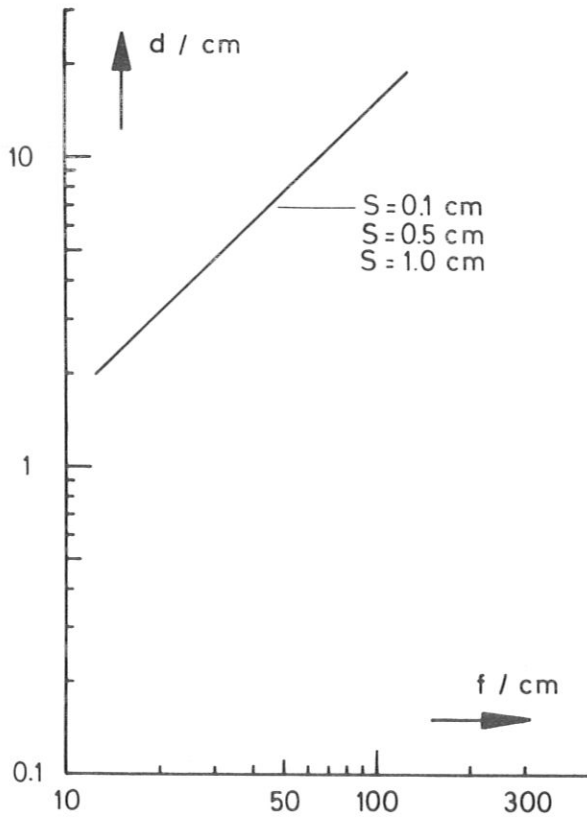


Fig. 9 a

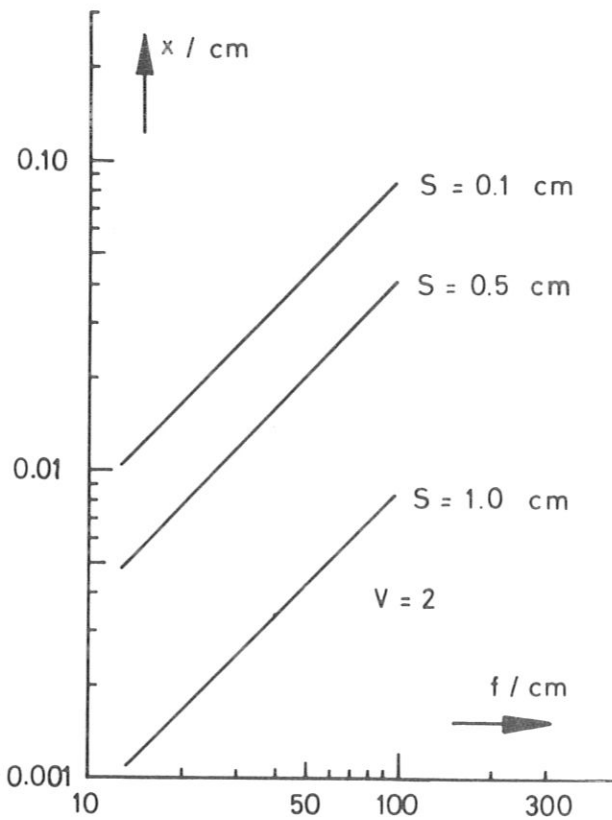


Fig. 9 b

The author wishes to thank H. Kolenda for his assistance in setting up the interferometer.

References

- /1/ V. Ronchi, Atti della Fondazione Giorgio Ronchi, 13 (1958)
- /2/ G. Toraldo di Francia, "Optical Image Evaluation",  
National Bureau of Standards (Washington, 1954), p. 161
- /3/ U. Ascoli-Bartoli, S. Martellucci, Comitato Nazionale Energia  
Nucleare, Rapporto Tecnico RT/Fi (62) 62, (1962)