A COMPUTER PROGRAM TO EVALUATE OPTICAL SYSTEMS

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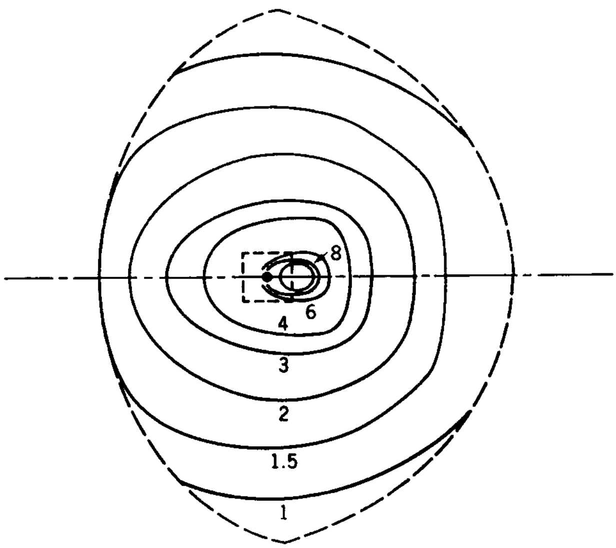
It is customary to use geometrical optics in the design of optical instrumentation. Usually these methods predict performance which is in reasonably good agreement with that achieved when the instrument is finally manufactured. However, in the case of the glancing incidence systems for use in the X-ray and extreme ultraviolet (EUV) region of the spectrum, this did not prove to be the case. Figure 1 shows the results of the geometrical analysis for a 25.4 cm X-ray telescope at a field angle of 20 minutes of arc. The large area represents the size of the spot based upon geometrical optics.

The black spot in the center represents the size of the Airy disc at 5000 Å for a diffraction limited system. Hence, even in the visible region, a performance many times poorer than the theoretical limit is predicted. However, when the telescope was constructed and tested in the visible region, it was found that the entire observable image fitted inside the dotted box. In an attempt to account for this discrepancy, we turned to a wave optical analysis.

Since very large computers were at our disposal, we decided to write a computer program based upon very exact general principles. In short, we decided to solve Maxwell's equations numerically. The object is regarded as a point source of electromagnetic radiation, and the optical surfaces are treated as the boundary conditions in the solution of the electromagnetic wave propagation equations. The electric field distribution is then evaluated in the region of the image, and from this, the intensity distribution is inferred.

Figure 2 shows the results of the wave analysis and a photograph taken through the actual telescope. Note the excellent agreement of results. Since the program was formulated in such general fashion, it was found to be readily adaptable to the analysis of a large class of optical systems. Figure 3 shows the results applied to a 1-meter diameter, f4 parabola at 0.1 deg off-axis. In addition, the program is being used in the evaluation of the large space telescopes and the design of an EUV interferometer.

In conclusion, we may state that although we will still use geometrical optics in the design of optical systems in the future, we now have, in addition, a tool for the accurate evaluation of the performance of optical systems prior to their construction.



COMPARED WITH ACTUAL IMAGE (SMALL SQ.)
FOR 20 MIN. OFF-AXIS SOURCE.

GEOMETRIC IMAGE DIA.-200 MICRON,
DIFFRACTION LIMITED AIRY DISK-5 MICRONS.

Figure 1—X-ray telescope geometric optical image.

WAVE OPTICAL IMAGE

ACTUAL IMAGE

FOR 20 MINUTES OFF-AXIS SOURCE

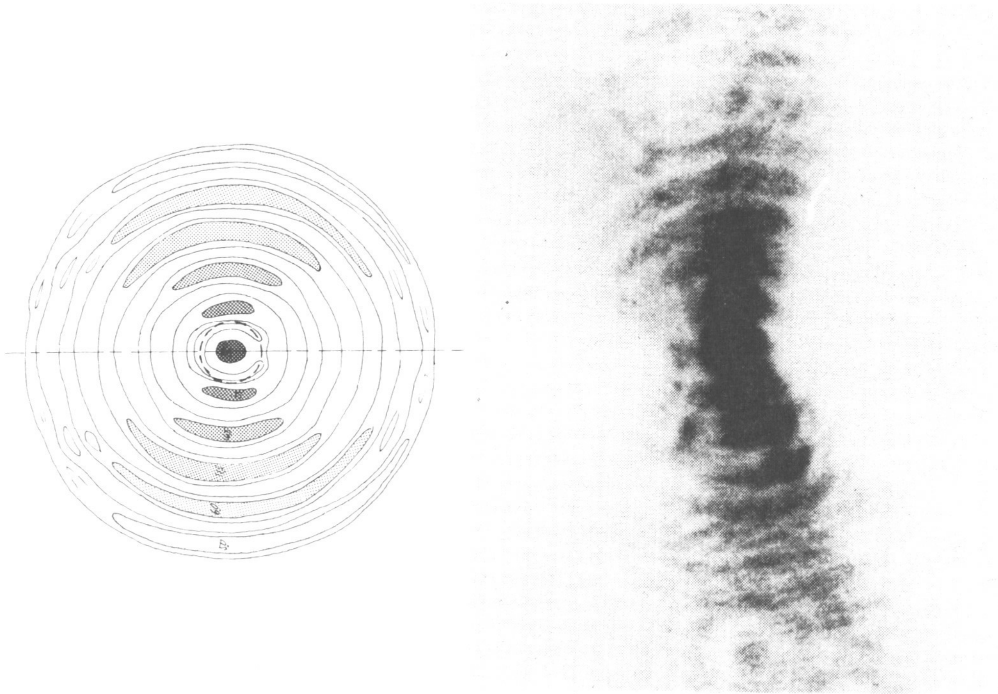


Figure 2–Results of wave analysis and actual photograph.

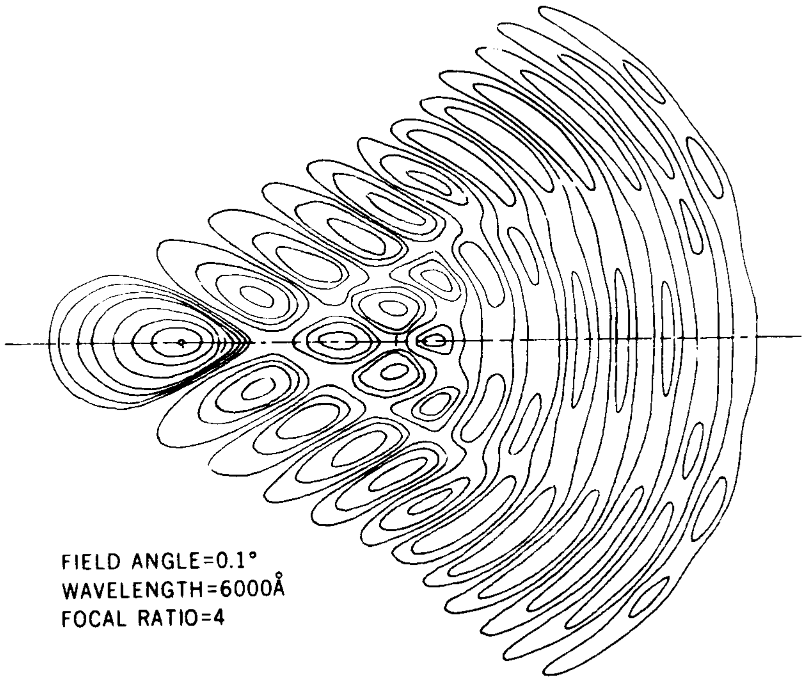


Figure 3—Wave aberrations for 1-m diameter parabola.