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Large Aperture Interferometers With Small Beam Dividers

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This paper shows some practical interferometers for testing very large and very small specimens. This is accomplished by using a particular type of beam divider that operates near the vertex of a convergent or divergent beam of light that permits almost unlimited size fields of view. Thus very large or very small specimens can be tested. Also, the wave front reversing properties of this beam divider permit tests to be made without the necessity of using standards of reference, thus eliminating the requirement for large standards that are usually expensive and require large working areas. The principles of these interferometers are so closely related to previously described instruments that very little additional explanation is required for an understanding of their operation. Several variations of the Kösters prism type of interferometer are shown schematically.

The testing of large specimens such as massive optical elements has previously required large aperture interferometers. The sizes of interferometers, such as the Mach-Zehnder [1] [1] for wind tunnel work and the Twyman-Green [2] for testing large optical elements, have been limited primarily by the size of precision beam dividers that could be made. Large beam dividers require high grade optical glass and high precision surfaces. The distortion of large beam divider elements by gravity is also a significant factor.

The application of divergent [3] and convergent beam interferometers permits the realization of much larger working spaces than can be obtained in the above-mentioned forms. The limit in aperture size is equal to the aperture of the largest lenses and/or mirrors that can be produced. This paper illustrates a method for producing very large aperture interferometers, with small beam dividers, that do not require reference standards.

One example of a large field (or aperture) interferometer for wind tunnel work is that described by Williams [4]. The beam divider of this instrument is a modified Kösters double-image prism. This prism can be quite small and the end mirror can be quite large.

The Kösters double-image prism and other modifications [5] of it provide small beam dividers for a variety of large aperture interferometers. This prism has been used as the beam divider for a variety of interferometers whose aperture equals that of the prism. Figure 1a shows one of the earliest applications [6] of this prism.

The difficulty of producing accurate prisms of large size and the difficulty of making optical glass sufficiently homogeneous in large pieces limits the size of this prism for precision interferometers. However, large prisms are no longer required. They may be replaced by a small prism and large lens or mirror.

[1] Figures in brackets indicate the literature references at the end of this paper.

The small size Kösters prisms may be constructed and adjusted to a high degree of precision. Figure 1b shows the arrangement of a prism-lens combination that may replace the arrangement of figure 1a. The aperture of this interferometer (fig. 1b) is limited only by the size of the lens and optical flat. Chromatic aberration in the lens does not affect the fringe pattern if monochromatic light is used. Spherical aberration does not affect the fringes or observed results if the indicated rays (in the zone that includes the reference point) are collimated. Chromatic and astigmatic aberrations are negligible if the lens has axial symmetry and the source is located on the axis. Consequently, axial symmetry (assuming the axis to lie in the dividing plane) is the only critical requirement for the lens. Any accurately centered, machine-polished lens, made of good glass, will meet the required specifications.

A large interferometer for wind tunnel tests is shown in figure 2. This interferometer, with a different form of prism, was described by Williams [4].

The principal difference between the methods of analysis of data with a divergent beam interferometer such as that shown in figure 2 and conventional (parallel beam) interferometers for wind tunnel and other tests, is that spherical coordinate geometry is used for the former and rectangular coordinate geometry is used for the latter.

Since the Kösters double-image prism is so well compensated, most interferometers in which it is applied may be used with white light. Also, when the optical path difference is near zero and the light beams suffer both division and recombination in one or two prisms, extended sources may be used. These two features permit high intensity and high visibility both of which are favorable for instantaneous photography of results. When beam division or recombination occurs only once in a prism, as in the alinement interferometers [7] of figure 3, the size of the source must be limited in one direction to a narrow slit or point.

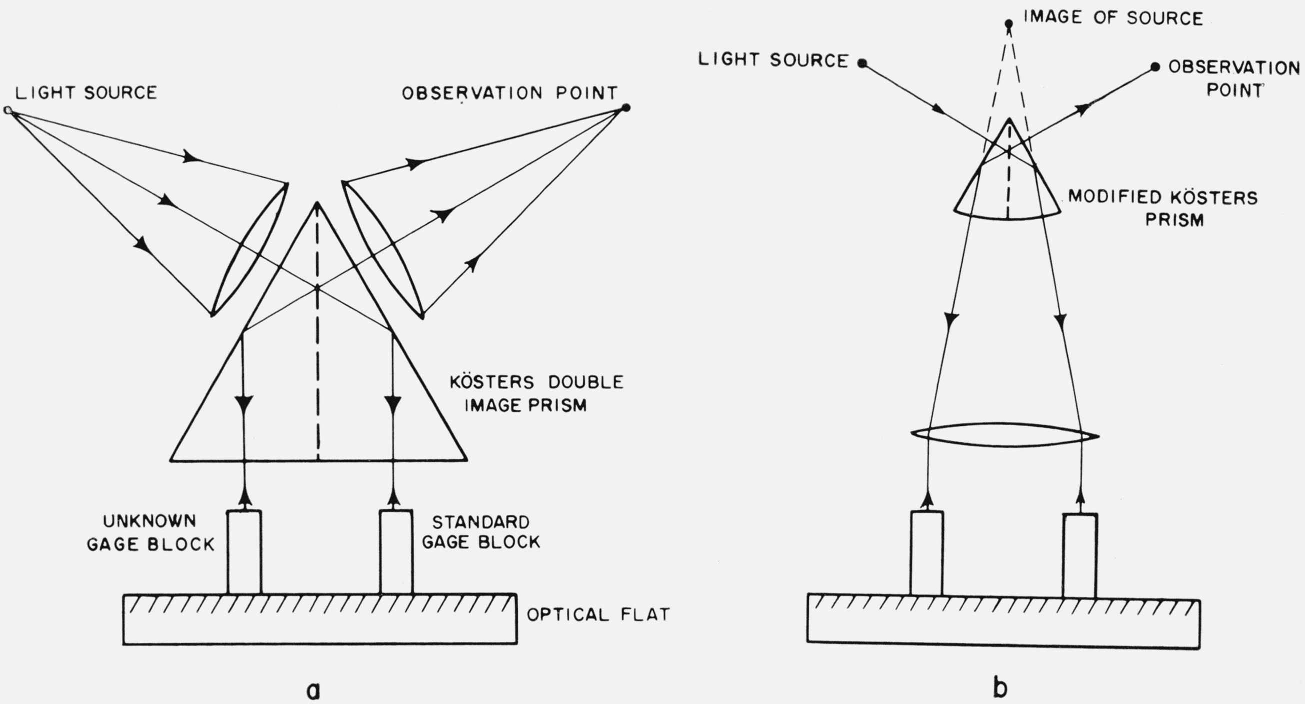

FIGURE 1. a. *An interferometer for measuring the parallelism of gage blocks.*
b. *Same as a, but modified to permit larger apertures.*

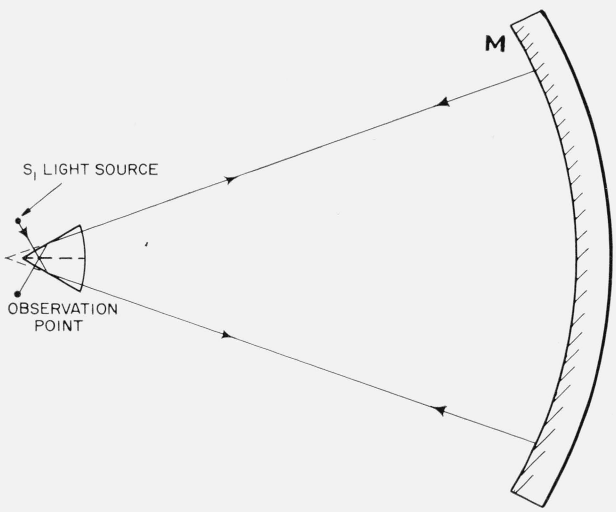

FIGURE 2. *Interferometer for wind tunnel measurement of density gradients.*

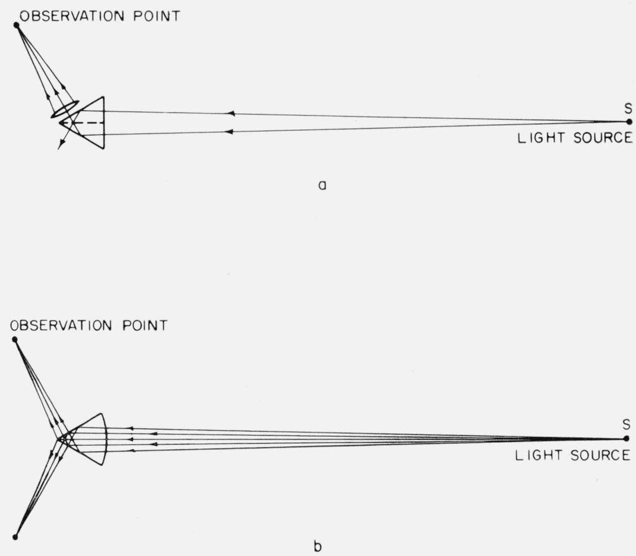

FIGURE 3. *An alinement interferometer.*

a. Conventional type Kösters double-image prism.
b. Modified (spherical base) prism.

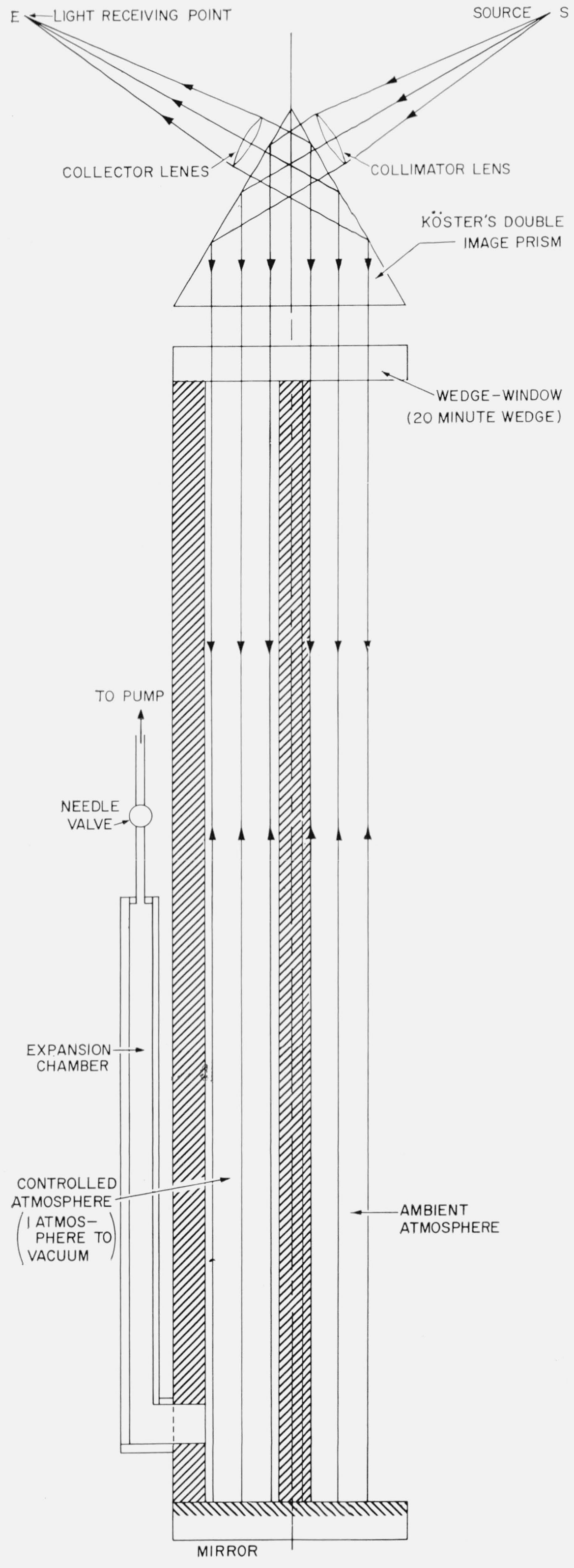

Figure 4. *An interferometer for measuring the refraction of gases.*

Figure 4 shows the arrangements of optical elements of a refraction interferometer that was designed for measuring the wavelength of light under ambient conditions. It is also quite practical for measuring the refractive indices of gases. The two coherent and parallel beams of light from the Kösters prism are affected differently by having one traverse a 1-m path that is controlled (either evacuated or filled with standard air) and the other traverse the same geometrical distance in ambient air. If the standard air space is evacuated the order of interference is a measure of the wavelength of light in the ambient air.

A simple procedure for obtaining a column of air having an optical density equivalent to that of standard air in the controlled space, is to start with the controlled space evacuated and the ambient space controlled to some desired temperature. Air is slowly introduced into the controlled space. This causes a change in the optical path difference and consequently the order of interference. The geometrical path in the controlled space and its change with temperature are known from previous measurements. Consequently, the difference in optical path, between vacuum and standard air in this space is known. The corresponding change in order of interference is obtained by adjusting the density in the controlled space to that of standard atmosphere. The space is then sealed by closing the inlet valve. The measured order of interference is then a measure of the difference in optical path between standard and ambient air.

The aperture of this interferometer may be increased by using a spherical base prism with a lens or mirror in the same manner as that illustrated in figure 1.

Figure 5a represents the optics of an interferometer [8] for testing long gage blocks. Lenses or mirrors may also be used to increase the aperture of this interferometer, as is shown in figure 5b for use in wind tunnel optics, and for measuring the parallelism of faces on bodies of large cross section. Figure 6 shows the same instrument formed with parabolic mirrors replacing the lenses of figure 5b.

Figures 2 and 7 indicate the range in size of spherical surfaces that may be tested interferometrically for departure from true spheres. The spherical surface, M, in figure 2 can be as large as the largest mirror ever made. The size of the ball, B, in figure 7 may have a diameter of only a fraction of a millimeter.

The aperture of the surface plate interferometer [11], as previously described, is limited to approximately 2 in. For testing large surface plates of 12 to 20 ft in length a larger aperture is desirable. The method of increasing apertures, described here, is equally applicable to that of the surface plate interferometer.

The usual functions of the interferometers described above (and also that of most other interferometers) are either to compare a standard length or surface with an unknown, or the variation of density of fluids in one space with a homogenous space, or the difference in optical path between the

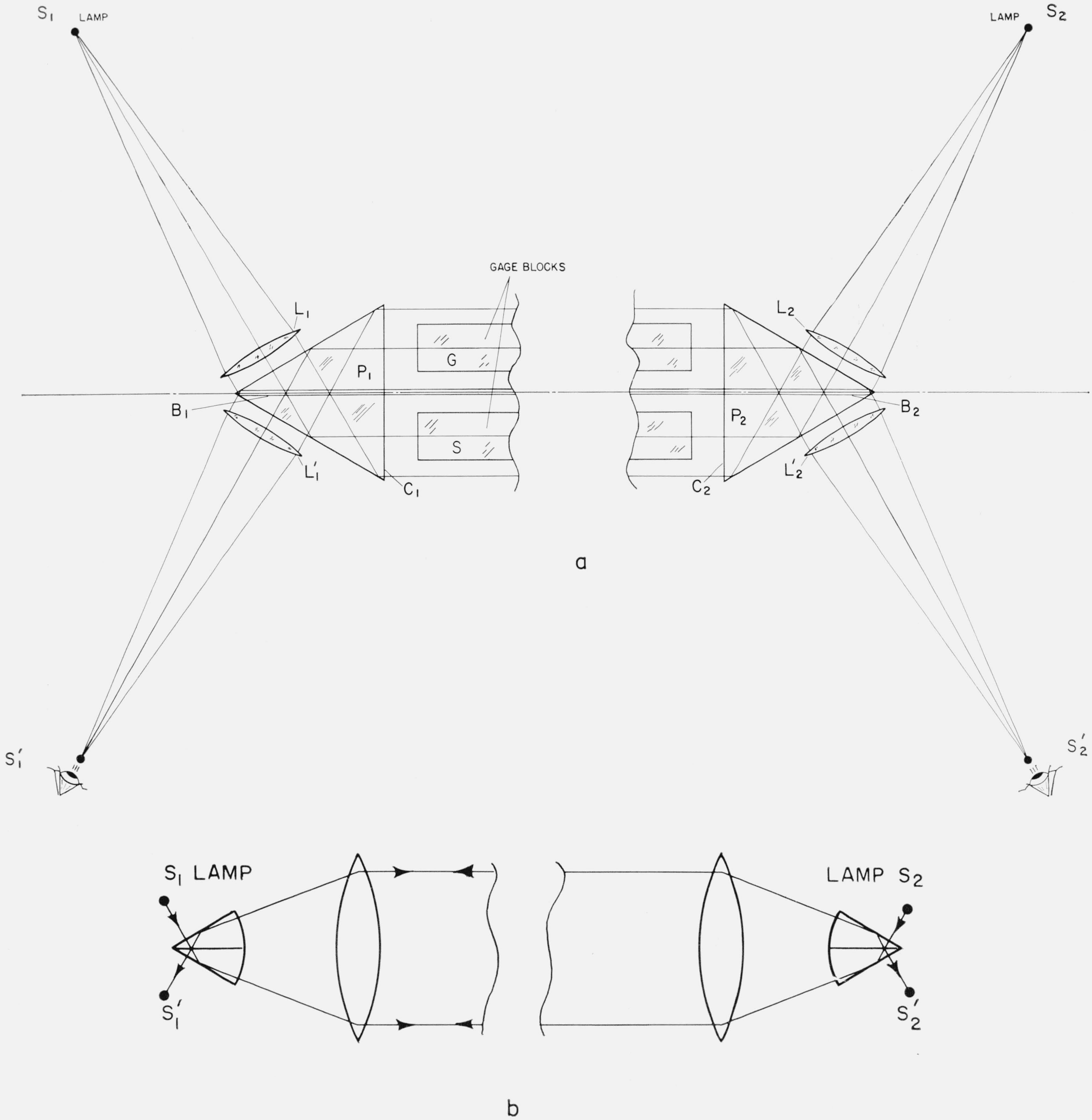

FIGURE 5. a. *A parallelism testing interferometer.*
b. *Same as a, but modified to permit larger apertures.*

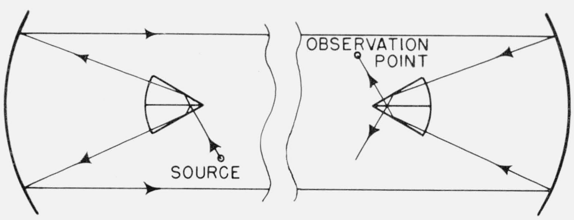

FIGURE 6. *A large aperture interferometer for parallelism testing, wind tunnel optics, etc.*
Mirrors M_1 and M_2 are parabolas.

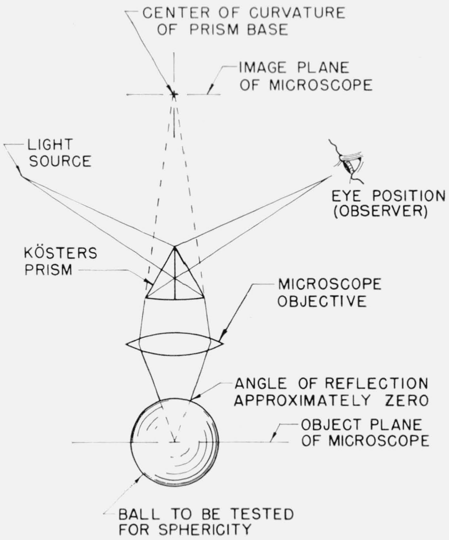

FIGURE 7. *An interferometer for testing the sphericity of small balls.*

two component beams. The wave front reversing [5] properties of these interferometers permit measurements to be made without reference standards. This author [9] has described methods of obtaining many results without the use of standards for reference. The aberrations of lenses and mirrors [10], the homogeneity of optical mediums, etc., may be obtained without reference standards. Consequently, very small prisms can be used with large lenses or mirrors to provide interferometers for testing specimens of all sizes without the use of reference standards.

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