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LASER INTERFEROMETER FOR MASS TRANSFER BOUNDARY LAYER STUDIES

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The Mach-Zehnder interferometer has long been used for the study of refractive index fields in heat transfer[1] and mass transfer processes. It is the most versatile of the interferometers as it allows one to observe two-dimensional refractive index fields and to arbitrarily localize and orient fringes. When used with conventional monochromatic light sources, alignment of the instrument requires the use of tedious procedures[2] to insure that light from any given point in the source which traverses one of the two arms of the interferometer arrives at the same point in the image plane and at the same time as light traversing the other arm. Otherwise, due to the time and space dependence of the phase of light emitted from incoherent sources, no interference phenomena can be observed. The use of laser sources[3] for double beam interferometers greatly relaxes these stringent requirements. Because of the complete lateral (spatial) coherence of a single mode beam, any part of its cross section interferes with any other part in a stable way. The great longitudinal (temporal) coherence of a laser permits the introduction of path differences in the two arms in the order of meters without loss of the interference phenomenon.

The design of the modified Mach-Zehnder interferometer reported here[4] and shown in Fig. 1 takes advantage of the flexibilities offered by the use of a laser source. The interferometer is tailored for the photographic observation of thin mass transfer boundary layers in the unsteady state. Such measurements require a compact, rugged construction for the scanning

of extended objects without adjustment of a reference cell, high geometrical resolution, and short exposure times. In contrast to the traditional version of this instrument, the beam-splitting plate has been omitted and the two mutually coherent light beams are derived from the opposite ends of a He-Ne gas laser (A) placed in one arm of the interferometer.[5] Positioning of the beam uniter plate (E) behind the objective (D) allows the use of lenses with high numerical aperture and associated resolution. The location of the beam uniter makes the reference lens (H) necessary.

Spurious diffraction patterns, due to light scattering from optical imperfections, such as dust particles, are a common problem with laser illumination. The spatial filter (F) located in the rear focal plane of objective and reference lenses, removes scattered waves which would result in undesired patterns. The spatial filter consists of a slit with its long dimension oriented in the direction in which the full resolution of the objective is desired. The geometrical resolution parallel to the spatial filter slit is at present 5×10^{-4} cm. The fringe pattern is photographed by a camera back (G) with focal plane shutter. Exposure times of 0.001 sec are sufficient.

A theoretical analysis of light propagation in mass transfer boundary layers has shown that due to the curved light path in such refractive index fields, valid concentration profiles frequently cannot be derived in a simple way from the observed interferograms. For the compensation of light deflection errors, the position of the plane of focus must be precisely known. As a reference for focussing and magnification a 0.5 mm reticule has been scribed on the inner surface of the glass wall furthest from the objective lens of the mass transfer cell.

FOOTNOTES

*This work was supported by the United States Atomic Energy Commission.

1. M. Paranjpe, Proc. Ind. Acad. Sci., A-4, 639 (1936).

2. G. Hansen, Z. Instr. kunde 60, 325 (1940).

3. R. Goldstein, Rev. Sci. Instr., 36, 1408 (1965).

4. K. W. Beach, UCRL-18037 (1968).

5. The mutual coherence of beams derived from opposite ends of a CW gas laser has been shown by M. Kameko, M. Takashima, and T. Asakura, Oyo Bitsuri, 34, 181 (1965).

Fig. 1. Laser Interferometer. A- HeNe gas laser (Electro Optics Assoc. LAS-101) B- adjustable deflection mirrors (metal coated), C- experimental cell space, D- objective lens, E- beam uniter, F- spatial filer, G- motor driven camera back (Nikon F), H- reference lens, I- aluminum mounting block (30 inches wide, 20 inches high and 5 inches thick), J- lathe bed for moving interferometer.

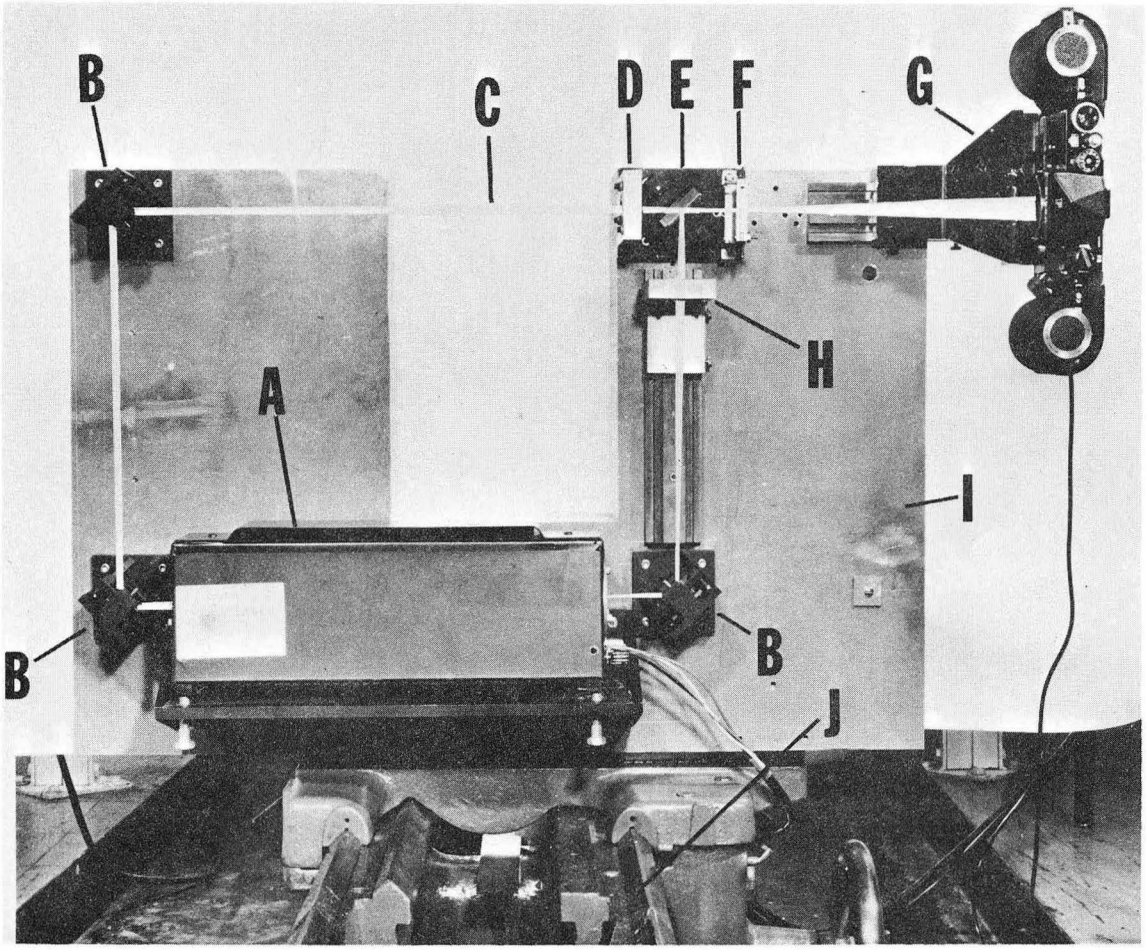

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Fig. 1

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