Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

(2)

AD-A267 266

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a.	1b. RESTRICTIVE MARKINGS
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	3. DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
4. PERFORMING ORGANIZATION REPORT NUMBER(S) AFOSR-89-0552 (Annual Technical Report)	5. MONITORING ORGANIZATION REPORT NUMBER(S) AFOSR
6a. NAME OF PERFORMING ORGANIZATION Graduate Aeronautical Labs Calif. Institute of Tech. 6b. OFFICE SYMBOL (If applicable)	7a. NAME OF MONITORING ORGANIZATION AFOSR
6c. ADDRESS (City, State, and ZIP Code) 1201 E. California Boulevard Pasadena, CA 91125	7b. ADDRESS (City, State, and ZIP Code) Building 410 Bolling Air Force Base Washington, DC 20332-6448
8a. NAME OF FUNDING/SPONSORING ORGANIZATION AFOSR 8b. OFFICE SYMBOL (If applicable)	9. PROCUREMENT INSTRUMENT IDENTIFICATION AFOSR-89-0552
8c. ADDRESS (City, State, and ZIP Code) Building 410 Bolling Air Force Base Washington, DC 20332-6448	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. 2307/A2 / TASK NO 2307/Y1

DTIC ELECTE JUL 28 1993 S E D

93-16921

11. TITLE (Include Security Classification)

Transmission of Light Through a Turbulent Mixing Layer (unclassified)

12. PERSONAL AUTHOR(S)

Anatol Roshko; John Wissler

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
~~Annual Technical~~ FINAL	FROM 9/30/89 TO 6/30/92	1992 August 14	4

16. SUPPLEMENTARY NOTATION

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	Aero-optics; turbulent structure

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Light transmission through incompressible gaseous turbulent mixing layers was investigated with the objective of understanding the effects of large-scale coherent structures and mixing transition on the optical quality of the mixing layer. Experiments were done in a vertically flowing mixing layer which is enclosed inside a pressure tank and fed by two banks of high-pressure gas bottles. The study considered both the unequal density (high-speed He and low-speed N_2) and equal density (high-speed N_2 and low-speed He-Ar) cases; the mixing of dissimilar gases is the source of the optical aberrations. Large-scale Reynolds numbers ranged between 3500 and 80000 over pressures from 2 to 6 bar. Light transmission characteristics were first studied qualitatively using a network of thin sheets of short-exposure ($\sim 1 \mu$sec) white light which were aberrated by the mixing layer and then imaged directly onto photographic film. Light transmission characteristics were then studied quantitatively using a lateral effect detector to dynamically track a thin He-Ne laser beam as it wandered under the influence of the passing coherent structures.

(over)

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL Dr. James M. McMichael	22b. TELEPHONE (Include Area Code) (202) 767-4936 / 22c. OFFICE SYMBOL AFOSR/NA

DD Form 1473, JUN 86 Previous editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

Unclassified

19. ABSTRACT (continued)

The study found that the spanwise coherent structures generate systematic deflections of the light beam in the streamwise direction; the greatest deflections occur near the trailing edges of the structures at a formation called the cusp, where the high-speed fluid and low-speed fluid are entrained into the vortex core. The streamwise coherent structures, which form later in the mixing layer's development than the spanwise structures, generate substantial beam deflections in the spanwise direction which are closely associated with the streamwise streaks in plan-view shadowgraphs. The rms fluctuations of the streamwise and spanwise deflection angles increase rapidly during mixing transition, peaking at 380 high-speed side momentum thicknesses downstream from the splitter plate, then decrease far downstream to asympototic values of 0.6 to 0.8 as scaled by the static pressure and the Gladstone-Dale constant shift across the mixing layer. The data suggest that a possible mechanism for the deflections is the interaction of the beam with the thin interfaces which bound relatively uniform bodies of fluid inside the structures.

FINAL TECHNICAL REPORT

for the period ending 30 June 1992

TRANSMISSION OF LIGHT THROUGH A TURBULENT MIXING LAYER

AFOSR Grant No. AFOSR-89-0552

1. Abstract

This is the final technical report of research on the transmission of light through a turbulent mixing layer conducted on Grant No. AFOSR-89-0552 to the California Institute of Technology during the period 9/30/89 to 6/30/92.

Objectives of the research were to conduct an experimental investigation of the transmission of thin light beams through a turbulent shear layer (also called a mixing layer) with the aim of improving understanding of such an interaction, especially as regards the effects of the so-called "coherent" structures and as regards the possibilities of modifying the latter for improving the transmission.

2. Discussion

The experiments were carried out in an existing apparatus with a vertically flowing mixing layer enclosed inside a pressure tank and fed by two banks of bottled gases. The study included two kinds of mixing layer:

(i) between helium and nitrogen streams, which gave a density ratio of 7; and

(ii) between a stream of nitrogen and a stream of mixed helium/argon which had the same density as the nitrogen, giving uniform density. The difference in optical properties of the mixing gases provided the "turbulent" variations of the index of refraction to perturb the transmitted light. Flow velocities up to 10 meters/sec and operating pressures from 2 to 6 atm gave Reynolds numbers ranging from 3500 to 80000.

Light transmission characteristics were studied mainly with a *lateral effect detector* to dynamically track the position (thus the direction) of a thin *He-Ne* laser beam after it had passed through the turbulent mixing region.

It was found that spanwise coherent structures generate systematic deflections of the light beam in the streamwise direction; the greatest deflections occur near the trailing edges of the structures at a formation called the cusp, where the high-speed fluid and low-speed fluid are entrained into the vortex core. The streamwise coherent structures, which form later in the mixing layer's development than the spanwise structures, also generate substantial beam deflections in the spanwise direction. The rms fluctuations of the streamwise and spanwise deflection angles increase rapidly during mixing transition, peaking at a distance of 380 momentum thicknesses θ_1 downstream from the splitter plate, then decrease farther downstream to relative asymptotic values of 0.6 to 0.8 as scaled by the static pressure and the Gladstone-Dale constant shift across the mixing layer. The data suggest that an important mechanism for the deflections is the interaction of the beam with the thin interfaces which bound relatively uniform bodies of fluid inside the structures.

The laser beam deflection time traces were studied in conjunction with signals from a hot wire in the flow, and a model was constructed showing how the position of a primary vortex relative to the beam affects its deflection angle. Calculations on this simple model of coherent vortex structure explain the shape of the characteristic beam deflection signatures obtained in the mixing transition region. Further downstream, higher frequency components appear in the signature, suggesting the appearance of smaller scale structure in the flow, and the maximum rms deflection is decreased as indicated above.

Contrary to what has been generally assumed about light transmission through turbulent mixing layers, the light transmission and beam deflection appear to be the result of a finite number of interactions of the light beam with thin fluid-fluid interfaces (of the order of the Taylor thickness). These interfaces are the major source of the refractive index gradients needed for bending the light beam. The fluid between the interfaces is relatively uniform and thus generates little or no aberrations.

From the point-of-view of light transmission, the above results would indicate two strategies which may be appropriate for minimizing flow-induced optical aberrations. First, it is best to transmit light at low x/θ_1, prior to mixing transition, when the peak aberrations are relatively predictable and confined, and rms values are relatviely low. Second, preference is for light transmission at high x/θ_1, where increased homogenization reduces spanwise variations in light transmission, albeit at higher overall fluctuation levels than in the first case. In any case, it is best for optical transmission to avoid the range of x/θ_1 values between 150 and 500.

The present study has shown that both the streamwise and spanwise large scale structures are as important to light transmission as they are to mixing. Previous statistical models assuming homogeneity and isotropy may therefore be inadequate for reconciling theory and experiment because the anisotropy of the coherent structures and the interfaces may not be taken properly into account.

3. Personnel

The research was carried out principally by Captain John B. Wissler, U.S. Air Force, working under the direction of the Principal Investigator, Professor A. Roshko.

4. Reports and Publications

- Wissler, John B. and Roshko, Anatol (1992) Transmission of Thin Light Beams Through Turbulent Mixing Layers. AIAA Paper 92-0685. Presented at the 30th Aerospace Sciences Meeting, 6–9 January, Reno, NV.

- Wissler, John B. (1992) Transmission of Thin Light Beams Through Turbulent Mixing Layers. Ph. D. thesis, California Institute of Technology.