N84 20543

VELOCITY VISUALIZATION IN GASEOUS FLOWS

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Techniques yielding simultaneous, multiple-point measurements of velocity in reacting or nonreacting flowfields have the potential to significantly impact basic and applied studies of fluid mechanics. This research program is aimed at investigating several candidate schemes which could provide such measurement capability. The concepts under study have in common the use of a laser source (to illuminate a column, a grid, a plane or a volume in the flow) and the collection of light at right angles (from Mie scattering, fluorescence, phosphorescence or chemiluminescence) using a multi-element solid-state camera (100 x 100 array of photodiodes).

The talk will include an overview and a status report of work in progress with particular emphasis on the method of Doppler-modulated absorption. This technique involves monitoring fluorescence from a plane in the flow which is illuminated with a sheet of light from a tunable, narrow-linewidth laser source. The laser wavelength is set to coincide with an absorption transition of a seeded molecular species, usually iodine, which is Doppler-shifted according to the local velocity of the gas (relative to the direction of the laser beam). The resulting velocity-induced variations in absorption appear directly as variations in the fluorescence intensity, and hence quantitative, simultaneous measurements of fluorescence intensity at a large number of flowfield points can be used to infer the velocity at these points. Separate techniques and results are reported for supersonic and subsonic flows near room temperature.

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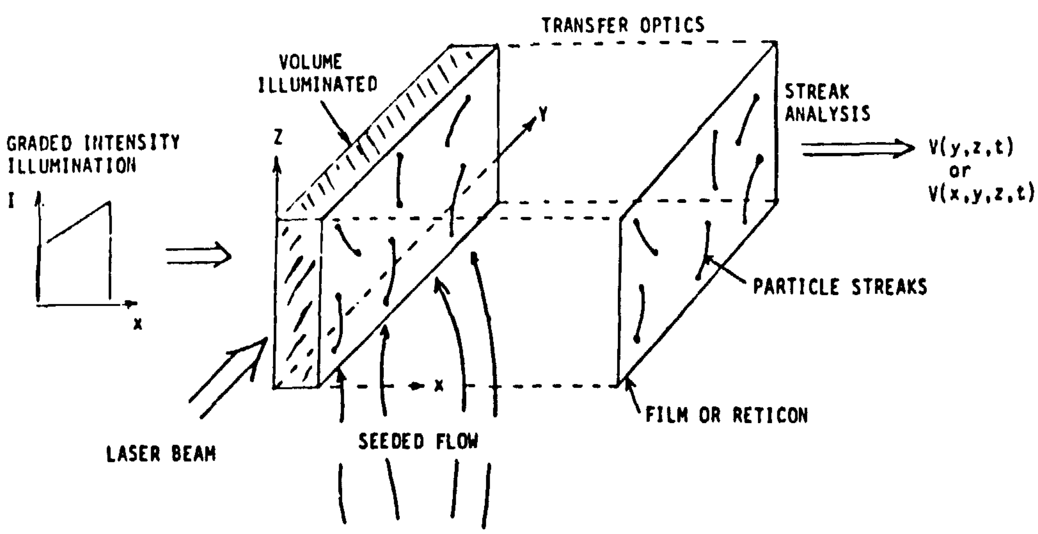
OUTLINE OF PRESENTATION

- MOTIVATION (NEED FOR MULTIPLE-POINT MEASUREMENTS)
- SUMMARY: TECHNIQUES UNDER INVESTIGATION
  - STREAK RECORDING
    - MIE SCATTERING
    - LASER-INDUCED PHOSPHORESCENCE
  - *LASER MARKING
  - *DOPPLER-MODULATED ABSORPTION/FLUORESCENCE (DMA/F)
    - SUPERSONIC FLOWS
    - SUBSONIC FLOWS
- EXPERIMENTAL RESULTS
- RELATED RESULTS ON SPECIES/TEMPERATURE VISUALIZATION (AFOSR)

STREAK RECORDING

- SEEDED PARTICLES (DROPS) ARE ILLUMINATED BY CW LASER SHEET
- MIE SCATTERING GIVES STREAKS ON FILM (RETICON)
- GRADED INTENSITY BEAM (TRANSVERSE TO SHEET) GIVES POTENTIAL FOR 3-D RECORDING, IF PARTICLES ARE SPHERICAL



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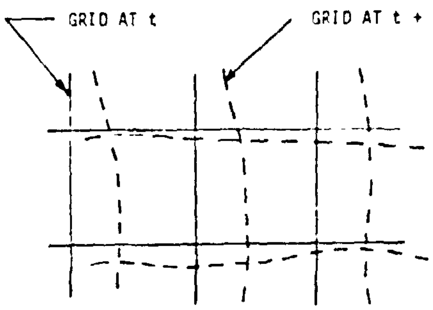
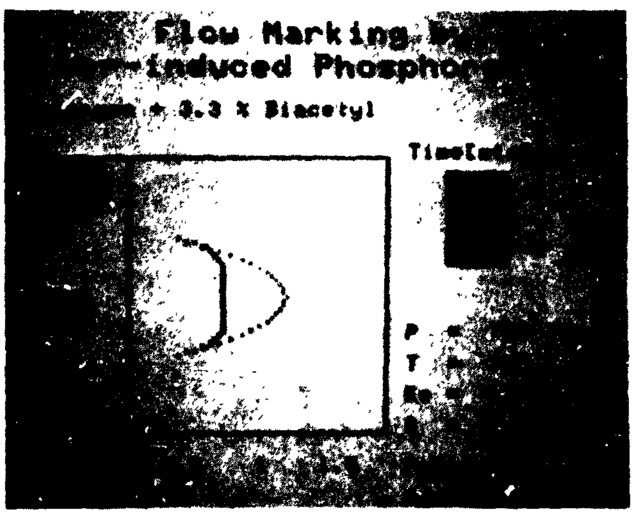
LASER MARKING CONCEPTS

- A PULSED TUNABLE LASER IS USED TO "MARK" A LINE OR A GRID IN THE FLOWFIELD
- LASER-INDUCED PHOSPHORESCENCE (OR CHEMILUMINESCENCE) PROVIDES LONG-LIVED RADIATION FROM EXCITED FLUID ELEMENTS, OR
- LASER-INDUCED PARTICULATE FORMATION ENABLES TRACKING BY MIE SCATTERING
- MULTIPLE EXPOSURE OF GRID PATTERNS ARE RECORDED ON A SINGLE FRAME OF RETICON CAMERA (OR FILM)
- CANDIDATE MATERIALS. BIACETYL (DROPLET OR VAPOR) FOR PHOSPHORESCENCE
  NO_2/CO FOR CHEMILUMINESCENCE
  SF_6 FOR PARTICLE FORMATION





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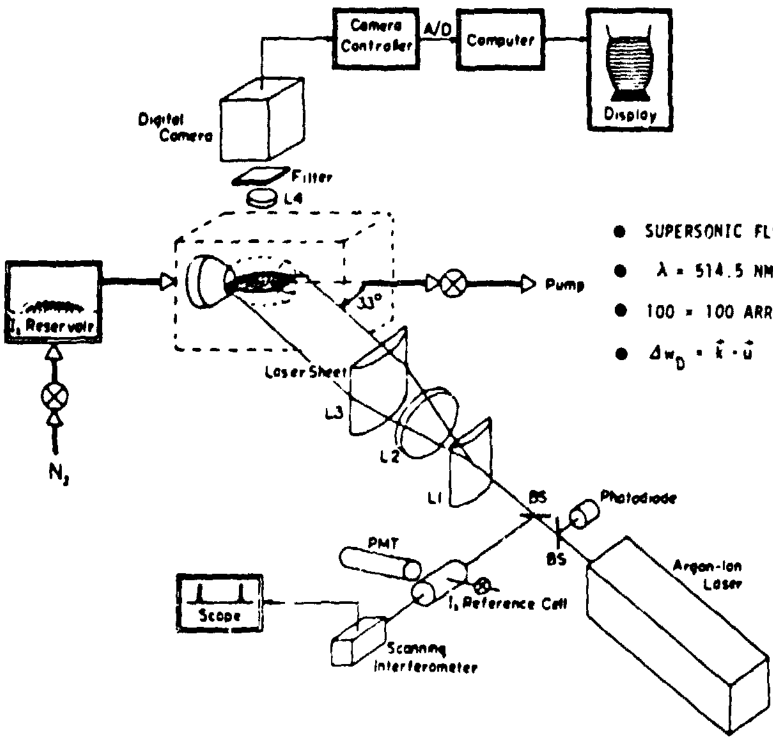
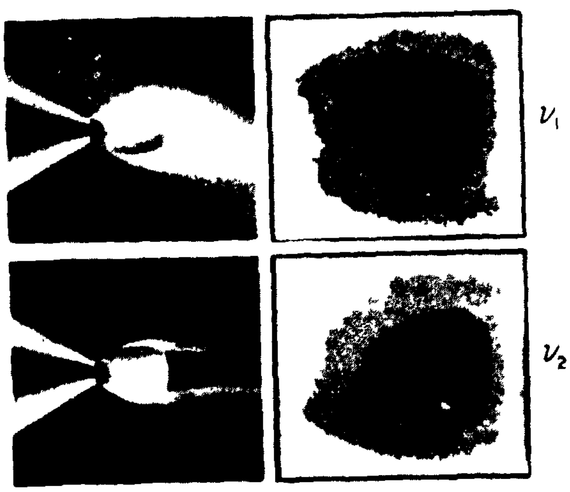
DOPPLER-MODULATED ABSORPTION/FLUORESCENCE (DMA/F)



- SUPERSONIC FLOW (N_2/I_2)
- λ = 514.5 NM (TUNABLE SINGLE MODE)
- 100 × 100 ARRAY
- $\Delta w_D = \hat{k} \cdot \hat{u}$



PHOTOGRAPHS AND DIGITAL IMAGES OF FLUORESCENCE DISTRIBUTION AT TWO LASER FREQUENCIES FOR A SUPERSONIC UNDEREXPANDED JET.

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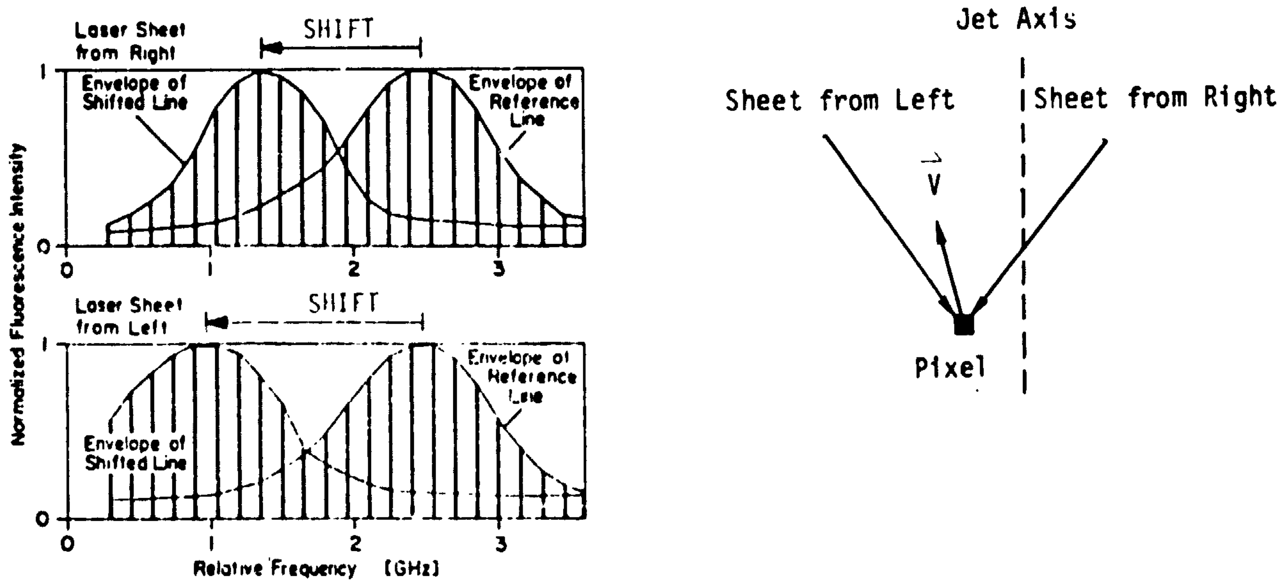
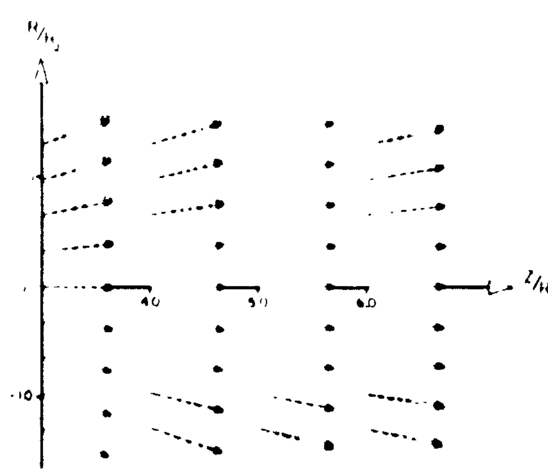
DOPPLER-MODULATED ABSORPTION: SUPERSONIC METHOD

Scans of Fluorescence Intensity vs Laser Frequency
for an Off-Axis Pixel



COMPARISON OF MEASURED AND CALCULATED VELOCITY FIELDS IN NEAR FIELD OF UNDEREXPANDED JET



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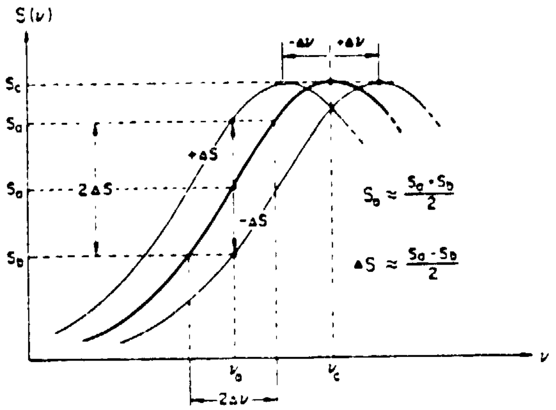
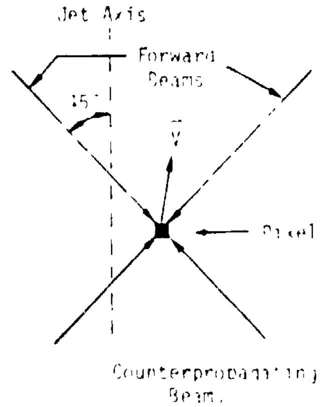
EXTENSION TO SUBSONIC FLOWS

- FIX WAVELENGTH
- MONITOR VARIATION IN INTENSITY BETWEEN FORWARD AND COUNTERPROPAGATING BEAMS TO INFER VELOCITY
- RECORD AT HIGH REPETITION RATE TO DETERMINE U(x,y,t)





$u = c($[illegible]$/$[illegible]$_0)$

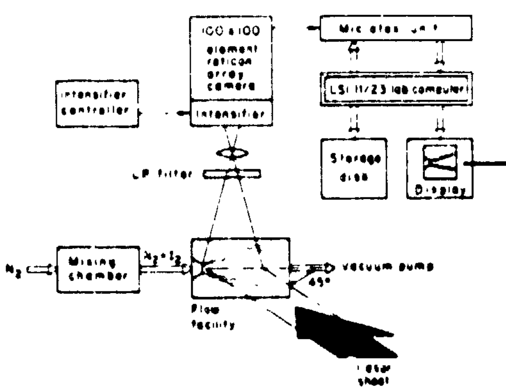
[illegible] $= S/($[illegible]$)_0$

$= ($[illegible]$S/S_0)$ [$g($[illegible]$_0$[illegible] [illegible]]

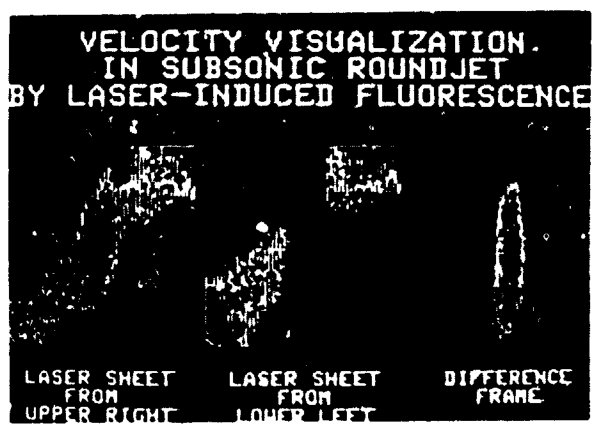
g = lineshape function

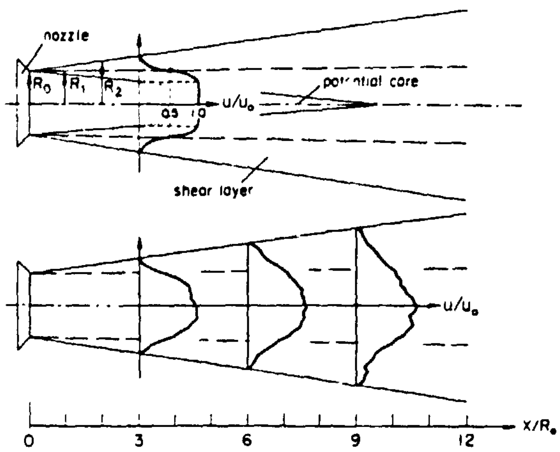
VELOCITY VISUALIZATION

SIMULTANEOUS MULTIPLE-POINT VELOCITY MEASUREMENTS BY
SENSING DOPPLER-MODULATED LASER ABSORPTION WITH A DETECTOR ARRAY

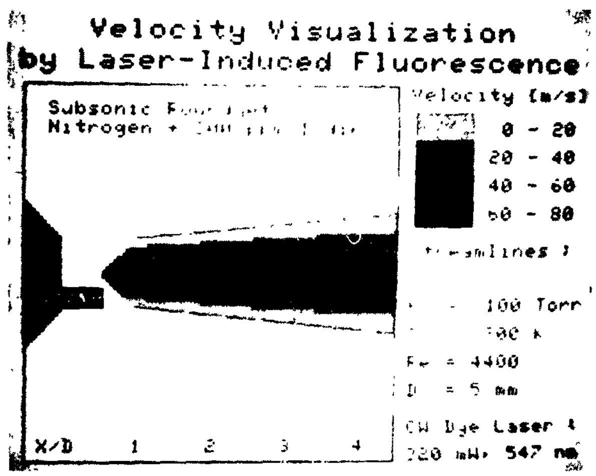


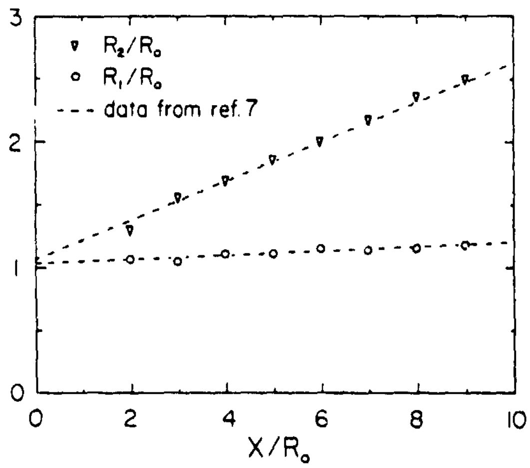
Sketch of detection setup showing the flow field probed by a thin sheet of laser light in the center plane of the jet and the camera imaging the fluorescence distribution perpendicular to the incoming sheet. For clarity only one of the four sheets is drawn.





Flow field of a subsonic round jet near nozzle exit. The important features are the potential core in which the center velocity remains constant and the growing annular turbulent shear layer. Three measured velocity profiles are shown.





Characteristic radii of the subsonic round jet versus axial position. R_0 is the nozzle radius, R_1 is the radius of the half-velocity point, and R_2 is the radius of the shear-layer edge.

SUMMARY

DOPPLER-MODULATED ABSORPTION/FLUORESCENCE

SIGNIFICANCE: MULTIPLE-POINT MEASUREMENTS IN UNSEEDED FLOW

STATUS: FIRST GENERATION EXPERIMENTS COMPLETED SUCCESSFULLY
- SUBSONIC FLOW (FIXED WAVELENGTH)
- SUPERSONIC FLOW (SCANNING CONCEPT)

LIMITATIONS: LENGTHY RECORDING TIMES
LIMITED VELOCITY RESOLUTION (1-5 M/SEC)

FUTURE: IMPROVED TEMPORAL RESOLUTION
STREAMLINED DATA PROCESSING
COMBUSTION MEASUREMENTS