PARTICLE DATA REDUCTION IN JAPAN

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1. INTRODUCTION

The author is engaged in research of the characterization of atomized particles generated by various atomizer (Refs. 1.2) and the mechanisms of their evaporation and combustion processes (Refs. 3, 4, 5, 6, 7)

In the course of his research, he has felt the needs for visualizing the internal structures of flames including evaporation and combustion processes as well as for a better way of understanding spray particle generation mechanisms and internal structures, and for the information of the system user, he is using a particle sizer based on a Fraunhofer diffraction for detecting particle size and in-line Fraunhofer holograms for observation of local spray particles. Recently, he has developed a novel visualizing technique based on Computed Technology for these fields (Refs. 6, 8).

For measuring spray, various technique are available including such methods as liquid immersion, freezing, trace, molton-wax, and microscopic. And ideal conditions of measurement include (Ref. 9);

1. Should not disturb the fuel spray pattern or atomization.
2. Should provide a rapid means of sampling.

3. Should provide a rapid means of counting the samples obtained.
4. Should be enough to provide meanigful data in the less than 10um.
5. Should permit the variation of liquid and ambient gas properties.
6. Should permit one to obtain drop size distribution in space.
7. Should permit one to obtain the drop size distribution produced by the nozzle in a given time.

Many novel laser diagnostics such methods as LDV, Scattering, Diffraction, Holography, etc. are satisfying above items. Pulse laser holography which meets all the requirements listed above excluding 3, is expected to be an effective means for spray measurements. However, past works suggest that in the case of high space particle density, such as of a diesel spray, measurement is only possible in the extra-low density field of peripheral regions and that much time and labor are required for reduction of particle diameter from the hologram. This will account for it being less frequently used when compared with its application field, such as in vibration or material research.

Of various combuston system, combustion spray is widely used in diesel engine, gas turbine and boilers. For analysis of combustion mechanism using intermittent sprays, such as in a diesel engine, obtaining detailed information on sprays is of vital importance.

2. HOLOGRAPHIC RESEARCH OF PARTICLE/COMBUSTION IN JAPAN

Generally, works on holography cover two fields, its recording and reconstruction, which is also in Japan. And regarding the subject of this work shop, namely, works on holography of spray particles, these can be classified into those from the point of optical or instrumental engineering and those of combustion engineering. Of course, the former places emphasis on research and development of systems and the latter on analysis usig such systems.

As for recent moves in Japan, the Ministory of Education adopted **"DYNAMIC MODELING AND LASER DIAGNOSIS OF COMBUSTION"** as a theme of special 3-years research project starting in April 1983 and associated works are under way with a fund of approximately 2 million dollars. About 60 researchers representing combustion engineering, chemical analysis, numerical calculation, instrumentation engineering other field are participating in the project. Among them, there are ten researchers dedicated to particle study and five dealing with holography, but a few researchers are engaged in data reduction.

Works under way at various universities in the following.

KYUSHU UNIVERSITY (**Professor T. Murakami, et al.**)

With development of optic instrumentation and its application, the activities of the group are well known. They have published many papers as follows:

(1) Establishment of recording and reconstruction techniques of fuel injection spray by diesel nozzles in normal and elevated ambient pressure using in-line holography with a pulse laser (Refs. 10, 11). Fig.1 shows an original in-line hologram of diesel injection and reconstruction region is presented.

(2) Holographic measurements of size and velocity of particles by means of two pulsed dye lasers of different wavelength (Ref.12).

(3) Development of dierect analysis method of particle size and position from hologram using an image analyser (Ref.12). The radial distribution of holographic intensity I(r) on the plane at distance Z from the particle of diameter d is given by using the Fresnel approximation. The typical patterns of log I(R) are shown in Fig.2.

The reduced fringe diameters, $\tilde{D}max$=Dmax/d and $\tilde{D}min$=Dmin/d are uniquely related the far feild nuber N in Fig.3. They proposed that they can be determine the N value with observed ratio $\tilde{H}$ (=$\tilde{H}obs$), then get Dmax or Dmin for corresponding to N. Consequently, the diameter d and the distance Z are obtained by using the observed Dmax or Dmin as d=Dmax/$\tilde{D}min$ or =Dmin/$\tilde{D}min$, and as $z=d^2N/\lambda$, respectively. An examle of particle data and a digital intensity distribution are shown in Fig.4, and on upper left corner on CRT the data of particle position and size are pictured.

TOKAI UNIVERSITY (Professor T. Uemura, Y. Yamamoto and H. Yokota)

Holographic research is being conducted fron the view point of optical and instrumentation engineering. They have made positive progress in the fields of in-line and off-axis holography with unique works on high speed photography and holography. Holograms of non-burning and burning fuels injected under atomospheric condition have been taken (Ref.13) and combustion state has been observed with aceton in place of fuel, fed to a model 4-cycle SI engine having transparent cylinders (Ref.14). Also information has been furnished on change of spray particle size by back pressure recorded as fuel was injected fron diesel nozzle into a high pressure vessel (Ref.15).

HIROSHIMA UNIVERSITY (Professor H. Hiroyasu, et al.)

Modeling and simulation for diesel spray combustion, diesel engine performances etc., activities of this university are well known. As for research into holography which was only recently started, they are using double pulse lasers and the off-axis method to measure diesel injection sprays injected in to high temperature (up to 733K), and high pressure atomosphere (up to 3.0Mpa). Fig.5 shows the example result of reconstructed image of the diesel spray injected into elevated pressure and temperatures. At around 773K, droplets can not be found and the puffing of liquid vapor was observed.

GUNMA UNIVERSITY (Professor M. Nakayama, et al.)

Researches on spray particle generation mechanism and internal structure of spray using various nozzles as well as researches on internal strucure in the evaporation and combustion processes are under way. The subjects covered include diesel combustion, gas turbine combustion and pulverized coal combustion. In the course of these studies, visualization technique of spray, solid particle or their combustion flames was found and hence,

[1] Observation of local spray particles by in-line Fraunhofer holograms.

[2] Measurements of particle size by a Fraunhofer diffraction principle (Refs. 4, 5, 7).

[3] Measurements of evaporating constant rate utilizing time and positional change rate of diffraction energy (Refs. 5, 7).

[4] Detection of transmitted light intensity distribution for computed tomography by means of computer Television Camera system (Refs 6, 9).

[5] Development and prototype fabrication of automatic data reduction systen for hologram.

are also under way. Their researches will be shown later section.

3. PROBLEMS ASSOCIATED WITH HOLOGRAPHY

3.1 Non-burning Atomosphere   Research results of the author and co-workers or other researchers in Japan indicate that there will not be significant problems so long as the space density is relatively low such as in the case of swirl chamber atomizer for boiler or gas turbine combustor application. If the space density is high as with spray particles from diesel nozzles, however, it appears that the particle information available from an in-line hologram system is limitted to local very low density peripheral regions of spray.

3.2 Combustion field of Particles   On open flames there will be no significant problems such as small spray combustion, but there will be difficult on closed combustion such as diesel spray. It is owing to the limitation of window size and optical set up.

Deterioration of reproduced image quality due to fluctuation or sub-micron vapor is unavoidable regardless of normal or high temperature/pressure atomosphere.

3.3 Data Reduction   One of reasons which have prevented the extension of holography is owing to work time, that is, the reconstruction process takes appreciable time even enough a TV system used.

The author et al. adopts the image hologram method produce holograms, and is now developing and fabricating prototype of automated data reduction system. It will be completed in September, 1985.

4. IMAGE ANALYSIS OF INTERMITTENT SPRAY

Holograms of diesel injection sprays by in-line Fraunhofer holography cannot be an adequate method for high density spray. However, in view of the importance of establishing the limit of effective density, application of Computed Tomography using transmitted light intensity distribution to acquire particle information is now under study (Refs. 7, 8). It appears that there is correlation between hologram images and CT images. Fig.6 shows density distribution of a spray at an arbitrary spray section reconstructed by the CT method of diesel fuel injection into space at normal pressure.The figure shows the density information on section 20, 30, 40 and 50 mm away from nozzle tip derived from shadow photos of spray 1.1 ms after start of injection. Fig.7 presents the data of spray particle density change with time at 30mmm position from nozzle tip. Comparison of Figs. 6 and 7 indicates that, with diesel spray, later sprayed particles catch up with and overtake preceding particles, which suggest that care should be taken in holography.

The regions available where particle information reproducible by hologram are those peripheral regions in Figs. 6 and 7.

Fig.8 shows reconstructed spray concentration of diesel injection which has been recorded in-line hologram. The information of particle size and their distribution has not be analysed in this time. We are undergoing to analyse these problem by using onion peeling model for axi-symmetric spray.

5. SUMMARY

The author introduced about the works of particle field data reduction in Japan. Many excelent works were done, but we can not get the information of particle characterization in high density particle fields. I think, in near futute, it will be able to get reasonable data of high density particle field such as diesel injection spray.

6. REFERENCES

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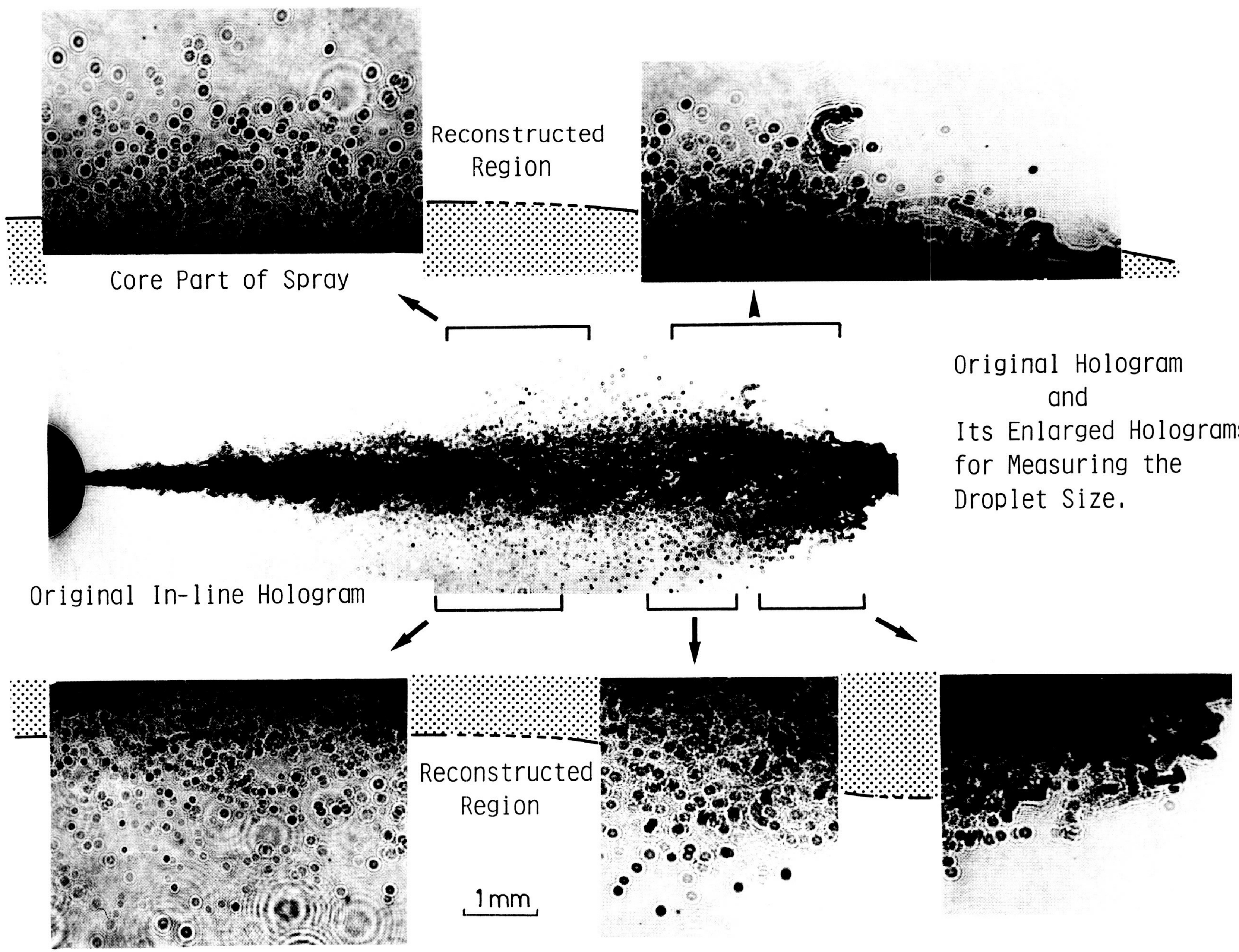
Fig. 1 In-line hologram of diesel injection spray (after Murakami)



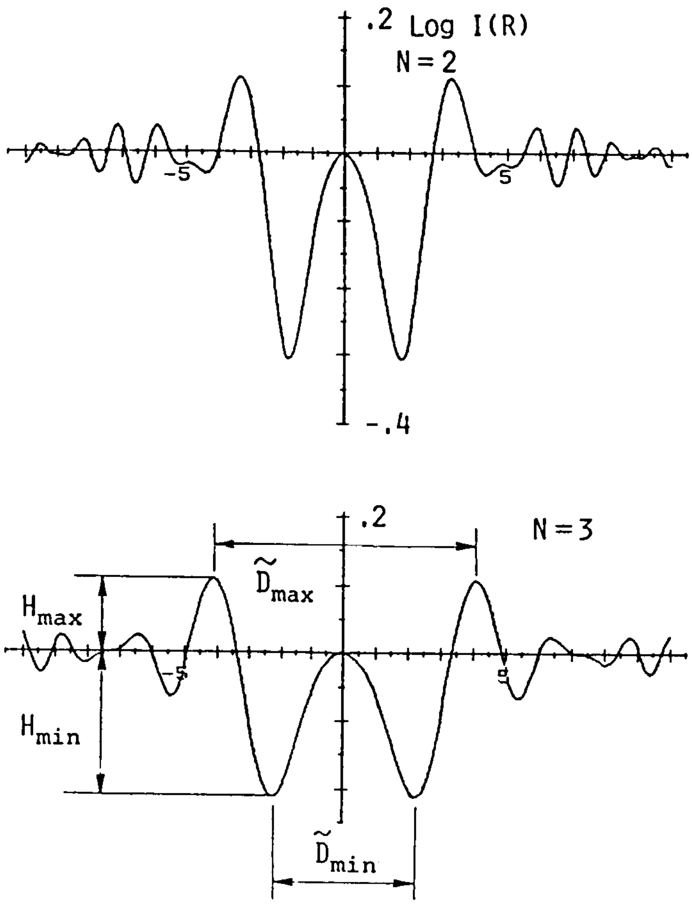


Fig.2 Calculated intensity distribution Log(R) (After Murakami)

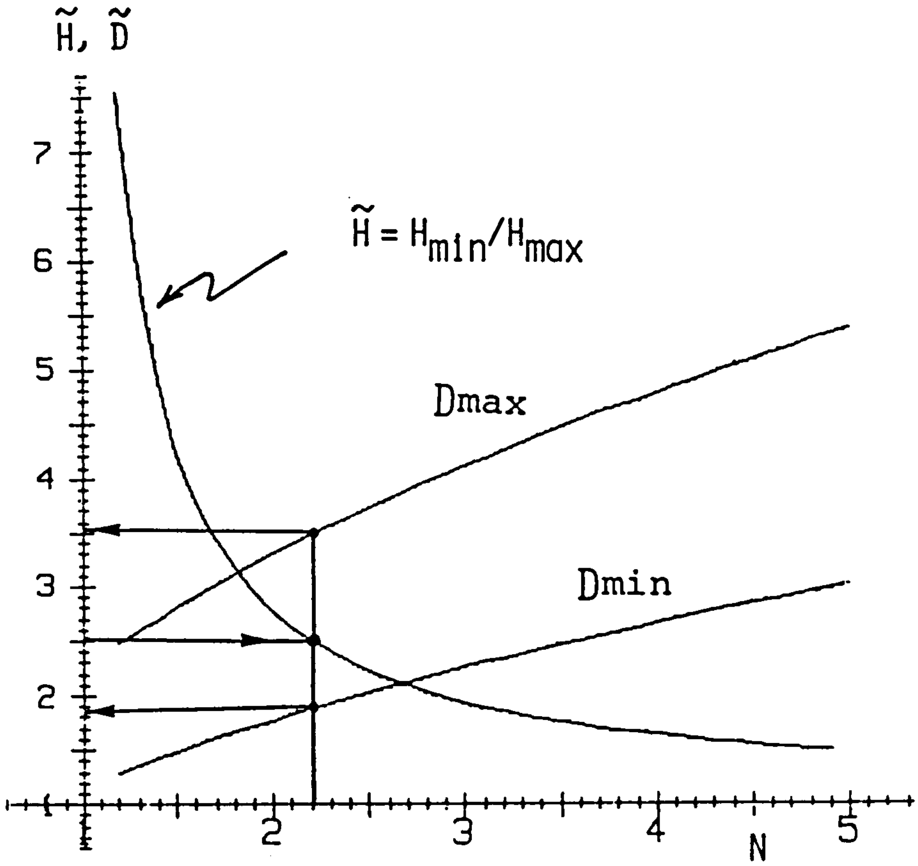
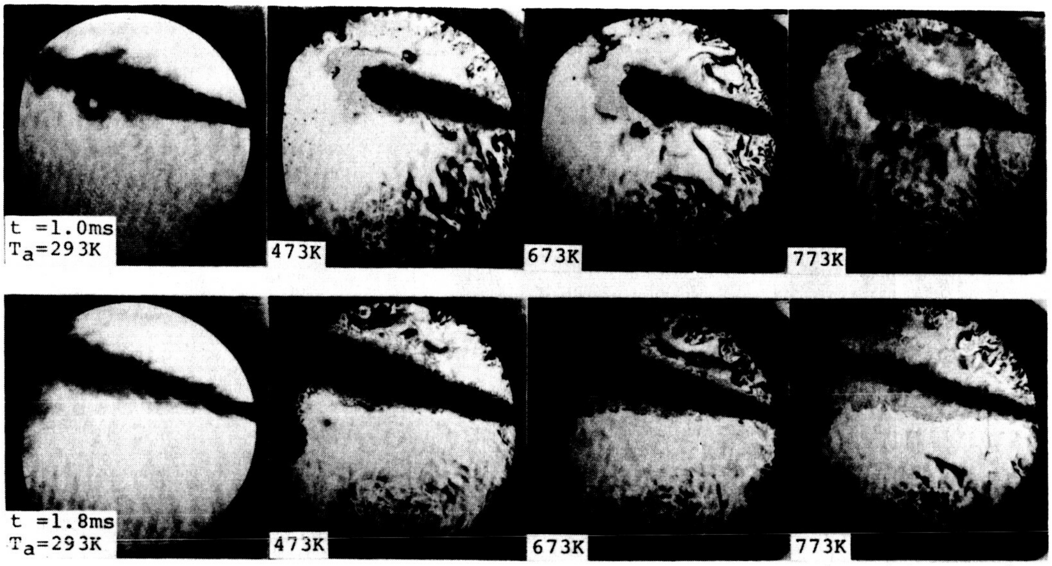


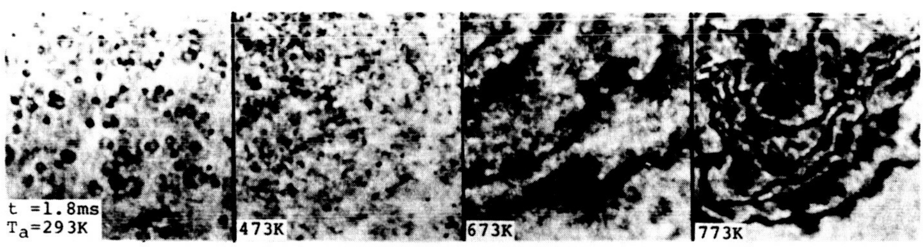
Fig.3 Charactristic diagram of parameter H, Dmax, Dmin vs far field number N (After Murakami)

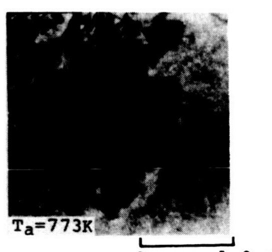


Hiroshima Univ.

Double-pulsed Interferograms of a Diesel Spray

Pulse Interval : 0.2 ms
Atmospheric Density : 13.5 kg/m^3





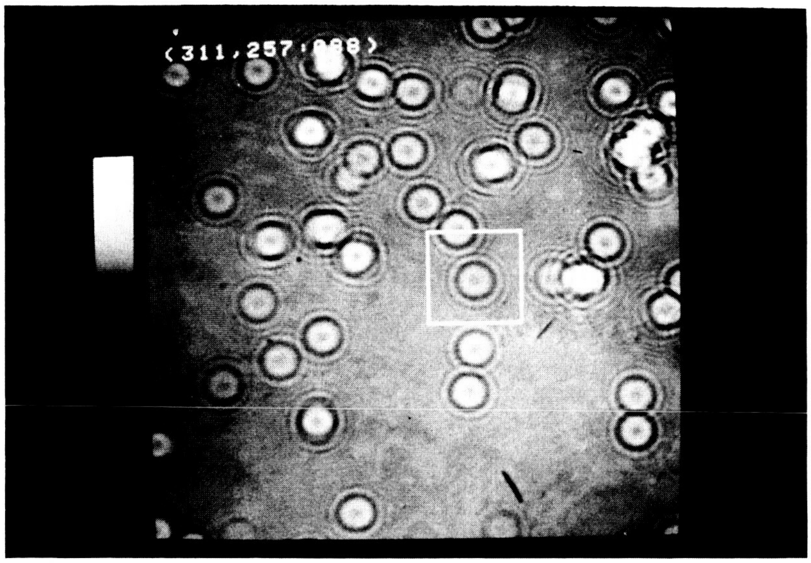
Puffing

Hiroshima Univ.

Enlarged Reconstructions from Double-pulsed Holograms of a Diesel Spray

Pulse Interval : 0.2 ms
Atmospheric Density : 13.5 kg/m^3

Fig.5 Off-axis hologram of diesel injection spray under the condition of high temperature/pressure atomosphere (After Hiroyasu)



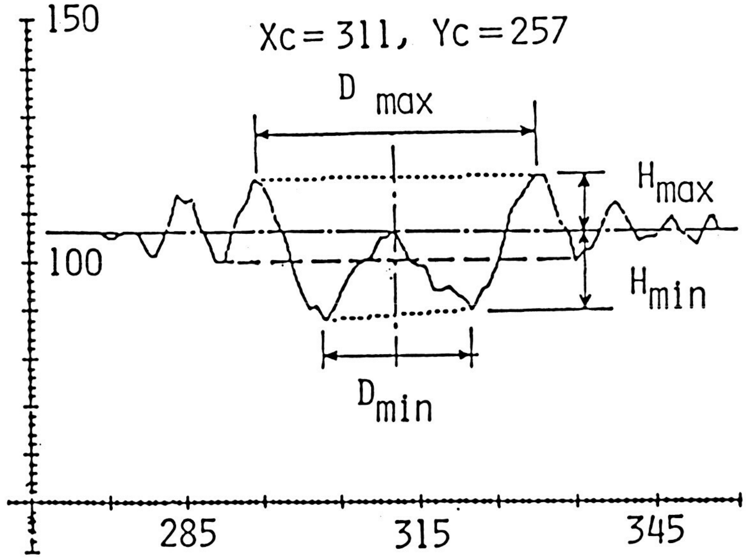
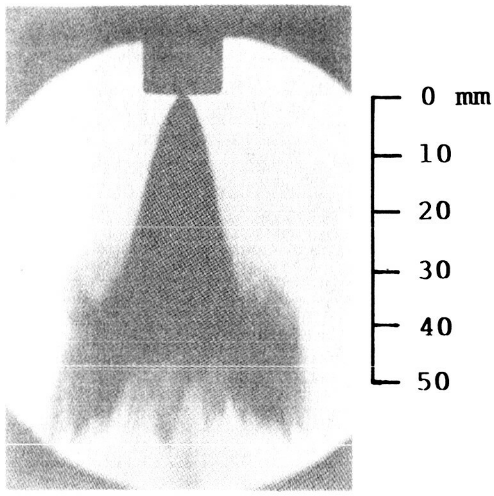
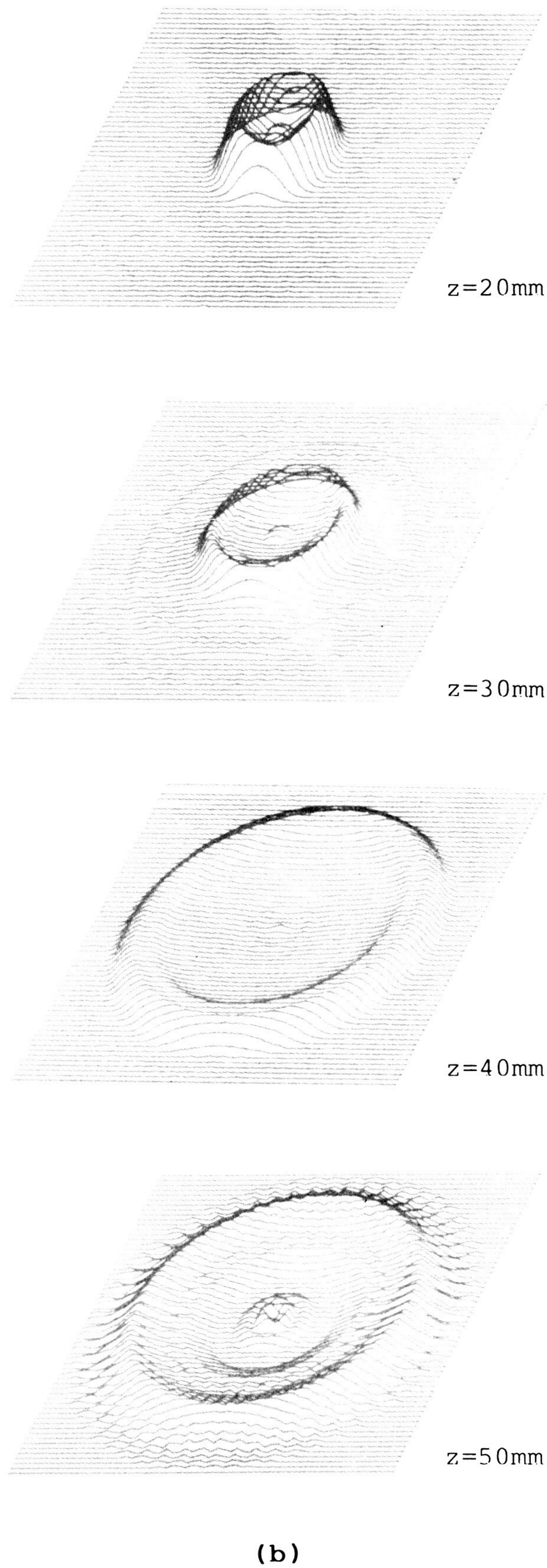


Fig.4 Example of a digital intensity distribution (After Murakami)



(a)



(b)

Fig.6 Spray density distribution by Computed Tomography
Diesel nozzle: Throttle type. Pi: 12Mpa.

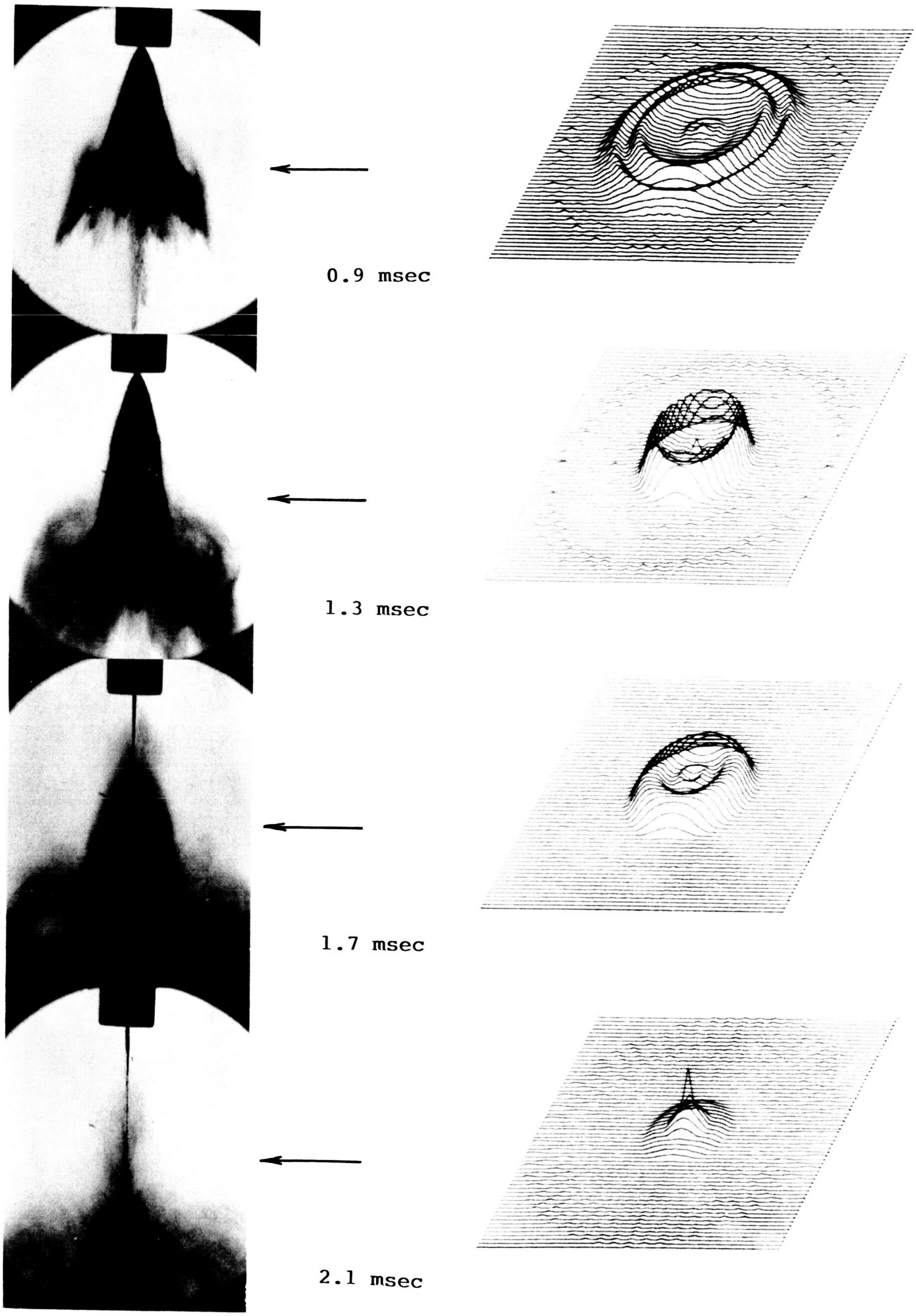


Fig.7 Time dependence of spray density distribution by Computed Tomography
Diesel nozzle: Throttle type. Pi: 12Mpa.

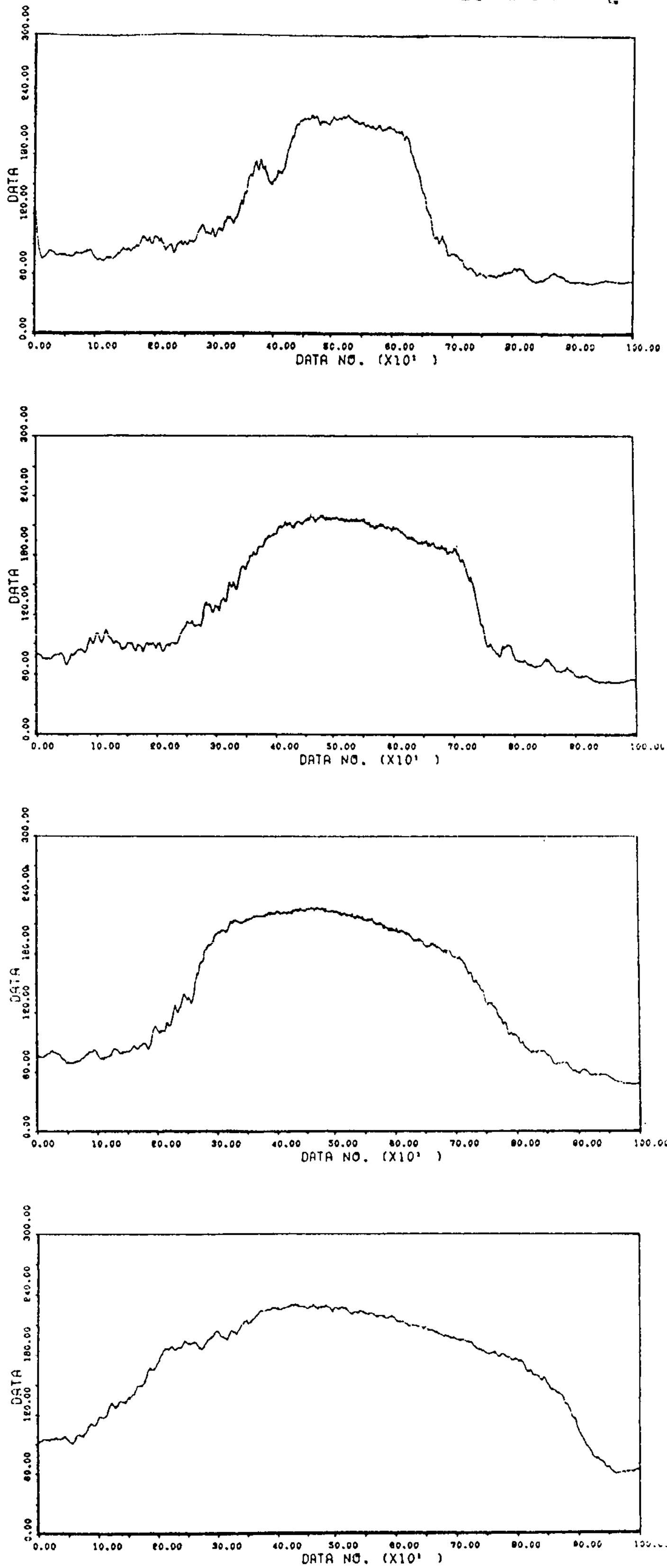


Fig.8 Spray concentration by Computed Tomography
from in-line hologram