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MEASUREMENTS OF THE INITIAL DENSITY DISTRIBUTION OF GAS PUFF LINERS BY USING RAYLEIGH SCATTERING

Yu. G. Kalinin, A. Yu. Shashkov

Russian Research Centre "Kurchatov Institute", 123182, Kurchatov sq. 2, Moscow, Russia

Various optical techniques are available to measure distributions of the gas concentration in supersonic jet. The interferometry using two-dimensional interferograms seems to be the most informative one. Unfortunately, this method provides only the density values that are averaged along the probing beam. In the case of axially symmetrical jets one can determine the distribution of gas concentration after routine mathematical treatment of interferograms (solution of Abel equation). This treatment produces a tolerable error only in the case of the monotonic distribution of the density, i.e. without any inner spaces. Finally, the sensitivity of the two-dimensional image interferometer is very often not sufficient to investigate jets with low concentrations of particles. Objects of this kind require using of photoelectric interferometers. But great increase of sensitivity involves a rather complicated devices.

For measuring of initial density distribution of a gas-puff liner authors propose to use Rayleigh scattering of the laser beam in the gas jet. There is the fundamental difference of this diagnostic from abovementioned ones: the scattering provides the local measurements. Basic scheme of this method is presented below. The laser beam passes through the gas-liner along its diameter. The lens forms the image of the laser beam in the scattered light. The light intensity in the image is proportional to the gas concentration in the corresponding points. This technique is more sensitive, permits to measure the concentration at the point and makes possible to carry out an absolute calibration of all the system.

Let us compare the sensitivities of both methods.

1. Interferometry. For a plane layer with thickness L and absolute refractive index n, pass length difference δ may be written as

$$\delta = L(n-1) = k\lambda.$$

Here λ is wavelength, k - the order of interference. For example, for *XeCl* laser ($\lambda = 308$ nm) fringe shift $k = 0.1$ and layer thickness $L = 1$ cm

$$n - 1 = k\lambda/L \sim 3 \cdot 10^{-6}.$$

Using this value one can estimate the minimal detectable concentration of gases (see the table).

2. Rayleigh scattering. In the capacity of receiver it's profitable to use ICT. Its spatial resolution element dimensions are about 0.02 x 0.02 sq. cm. If the gain ICT is high enough, it's possible to fix each photoelectron radiated from the resolution unit. The number of photoelectrons is

$$I_{ph.e.} = \eta\, I_o\, \sigma N \Delta l\, \Omega \Delta h/h$$

Here $\eta \sim 10^{-1} - 5 \cdot 10^{-2}$ is quantum yield of the photocathode, I_o - the number of quanta of the incident beam, $\Omega < 4 \cdot 10^{-3}$ - the solid angle, h - the vertical dimension of the probing beam, Δl and Δh are the space resolution dimensions, N is the concentration and σ - the Rayleigh scattering cross-section related to the single molecule. The σ value may be presented by the following equation [1]:

$$\sigma = 32/3\, \pi^3 (n-1)^2 N_L^{-2} \lambda^{-4}$$

Here N_L is the Loschmidt number, λ - the wavelength. For our case

$$\sigma = 5 \cdot 10^{-19} (n-1)^2.$$

In order to obtain the accuracy about 10%, it's required to have $I_{ph.e.} = 10^2$ from the resolution unit. Thus,

$$N_{min} \sim 10^9 (n-1)^{-2}.$$

The results of the estimation of the sensicivity are presented in the table.

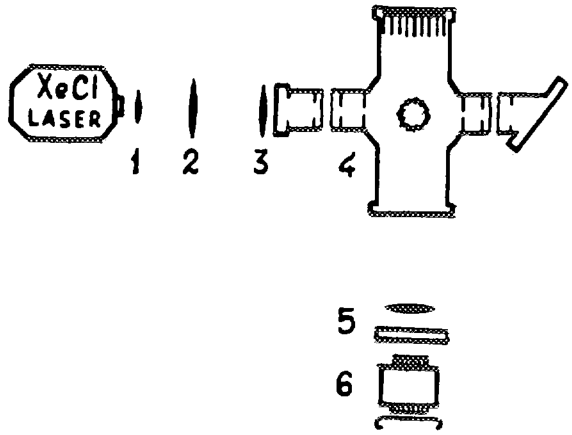

Fig. 1.

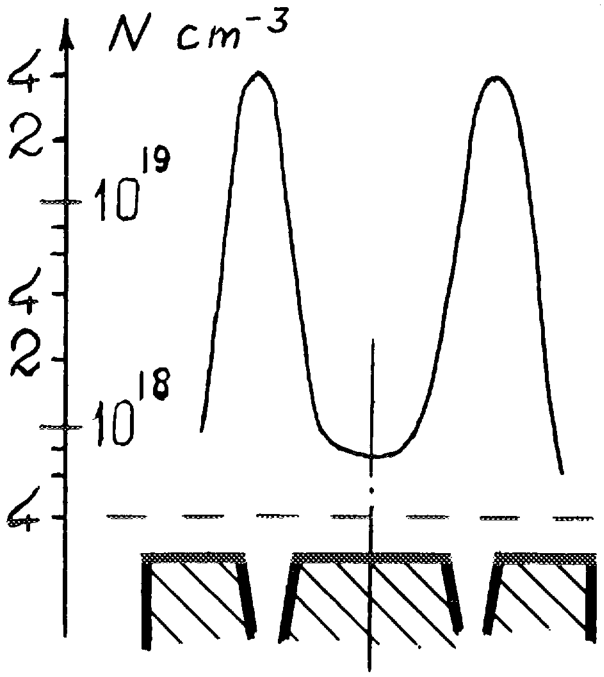

Fig. 4.

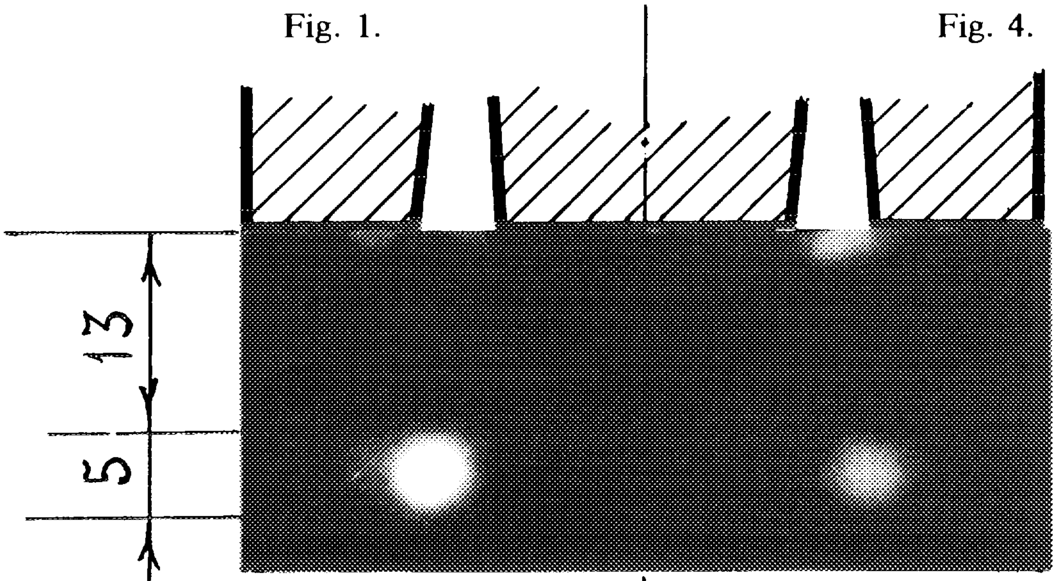

Fig. 2.

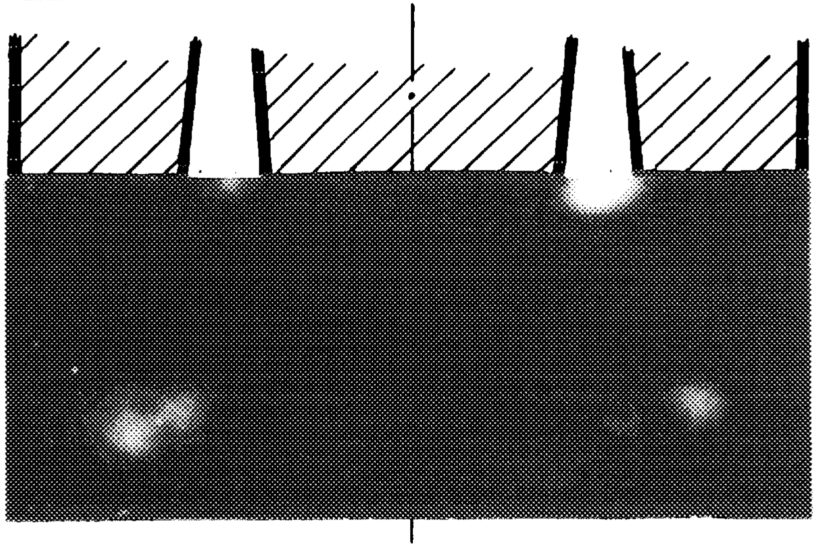

Fig. 3

Table.

Gas	$(n-1)$, 10^{-6}	N_{min}, 10^{18}	
		Interferometry	Rayleigh scattering
H_2	139	0.6	0.04
He	35	2.0	0.8
N_2	279	0.3	0.01

Raileigh scattering optical setup is shown in Fig. 1. The *XeCl* laser produced 70 mJ energy with pulse duration of 25 ns. Telescope 1, 2 and lens 3 formed the profile and guided the probing beam into the scattering chamber. The beam had a profile of a thin band with the cross-section 5 x 1 sq. mm in the region of gas jet. Chamber 4 was equiped by the input and output pipes with windows and a number of inner diaphragms. The light absorber was placed behind the gas jet and opposite to the pipe-hale window. It was done to minimize parasitic scattering of the probing beam. Images of the regions of crossing by the beam and gas-puff liner were formed by the lens with necessary filters 5 onto the MCP brightness amplifier photocathode 6. Solid angle of the lens was $3.5 \cdot 10^{-4}$.

Images of scattering objects are shown in Fig. 2 and Fig. 3. Liner axis is vertical. Top spots appear due to the parasitic scattering by the nozzle edge. Two low spots show scattering regions of the gas-puff liner.

Calibration of the scheme was carried out by filling up the chamber with a suitable gas at 100 or 50 torr pressure. Photofilms obtained were scaned photometrically and the gas jet concentrations were calculated (see Fig. 4).

By using this technique the gas jet stratification was detected in some cases (Fig. 3). One should note that it's impossible to detect similar stratification by using any interferometry.

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[1] C.W.Allen, "Astrophysical quantities", 1973