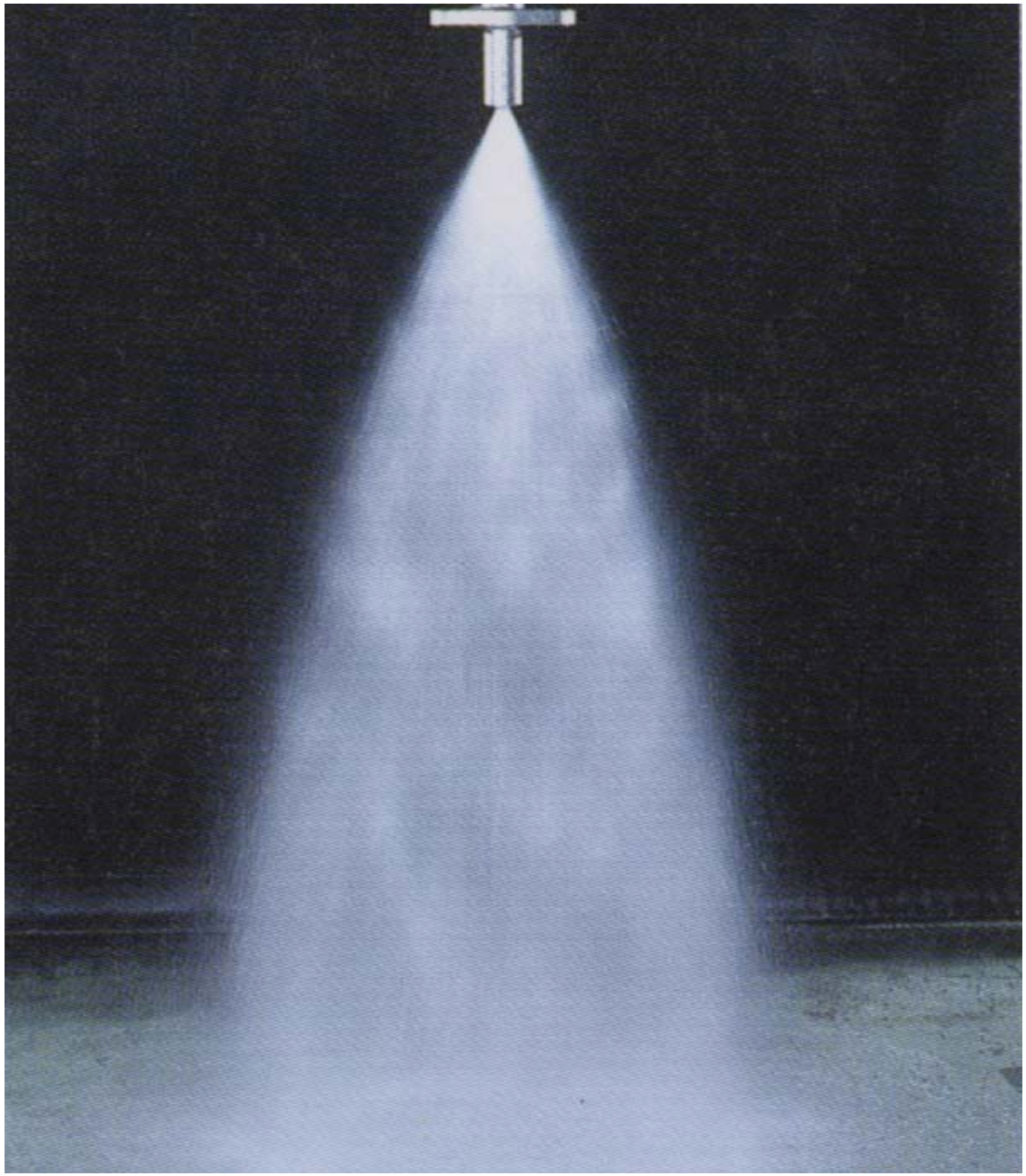
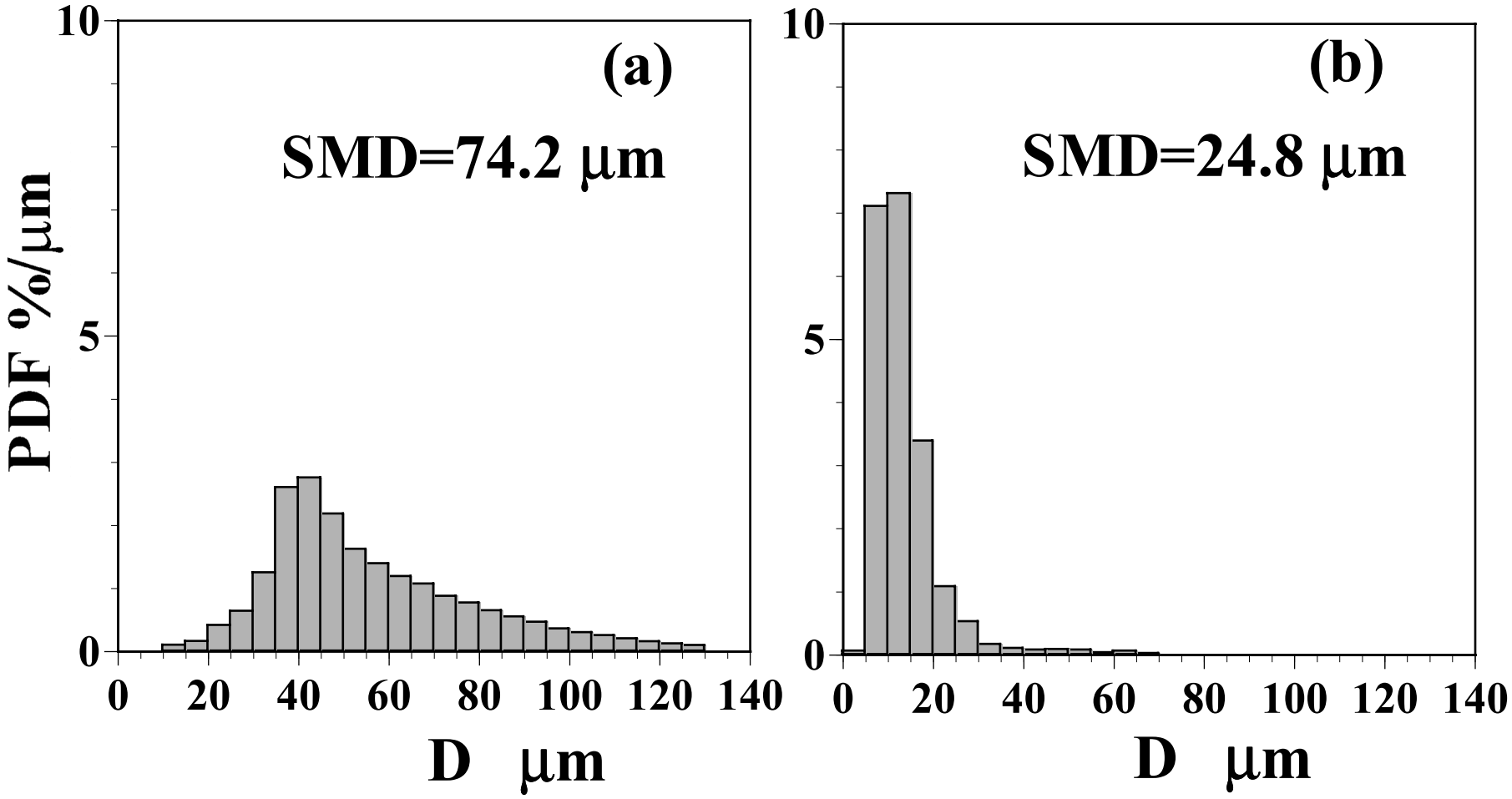
噴霧火炎と
その光学計測

燃焼工学講座
赤松　史光

Fuel atomization



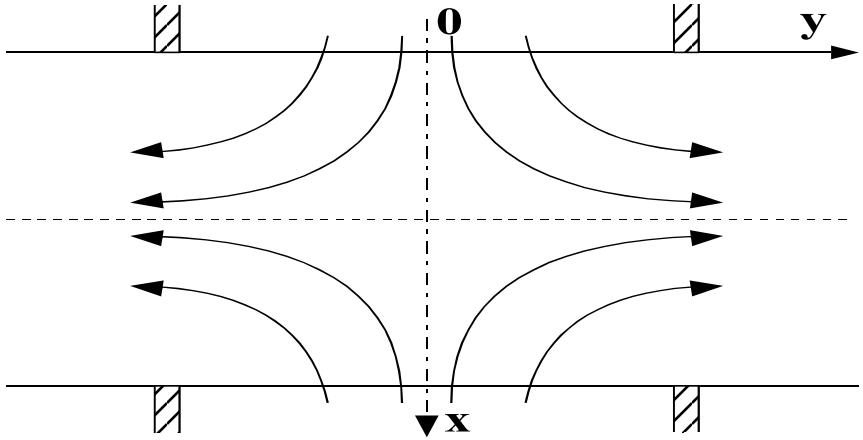
Droplet size distribution



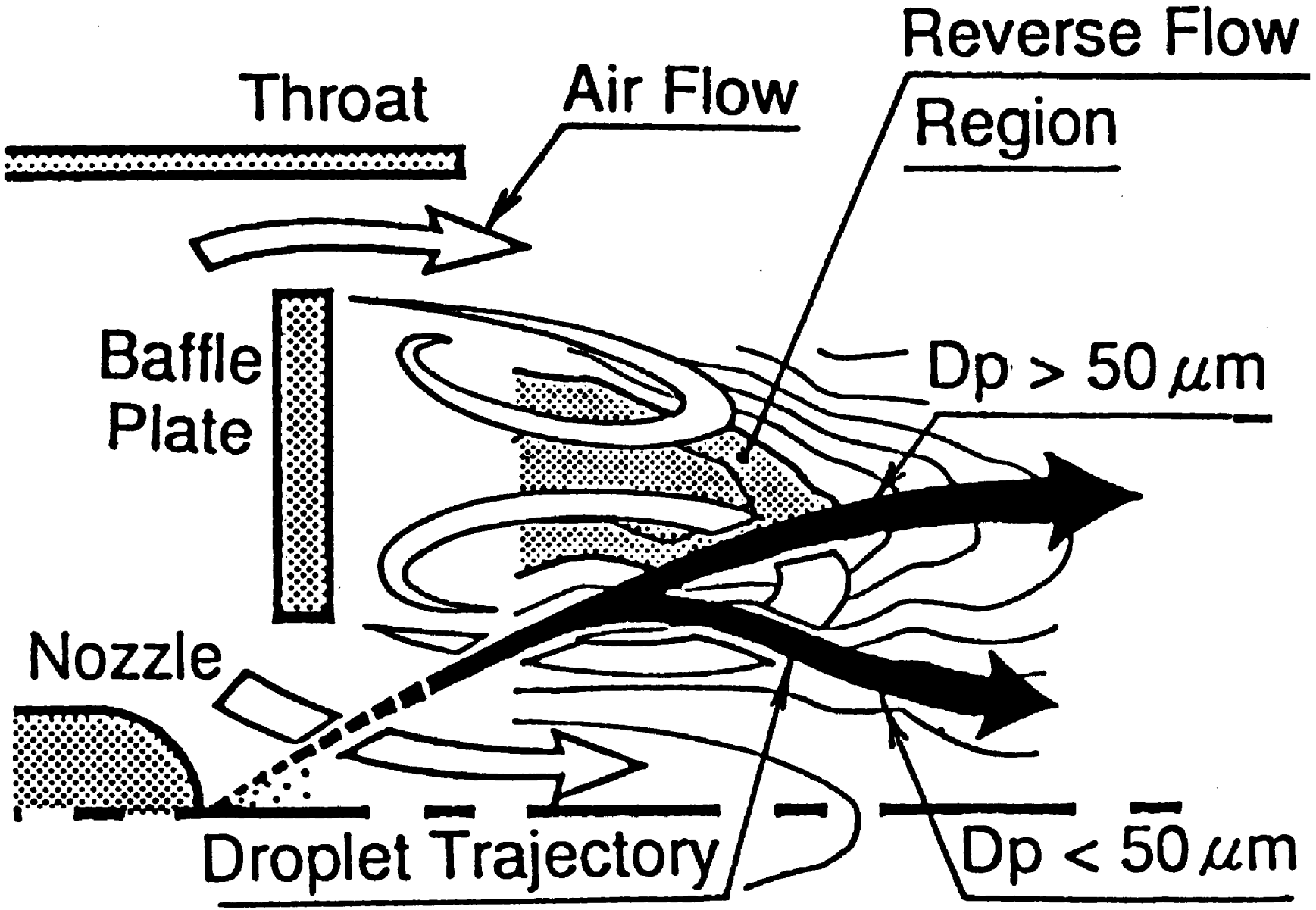
Complicated structure of spray flame

Gaseous fuel flame

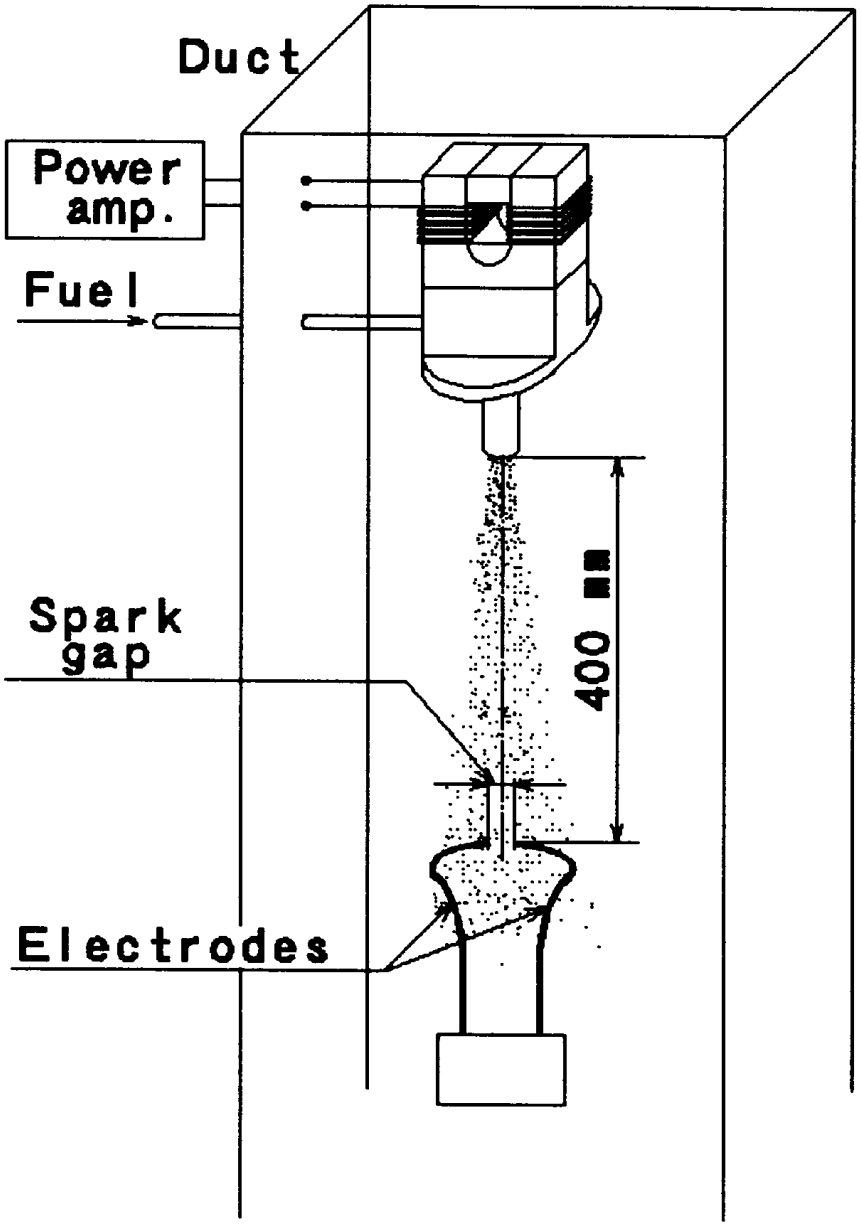
Spray flame



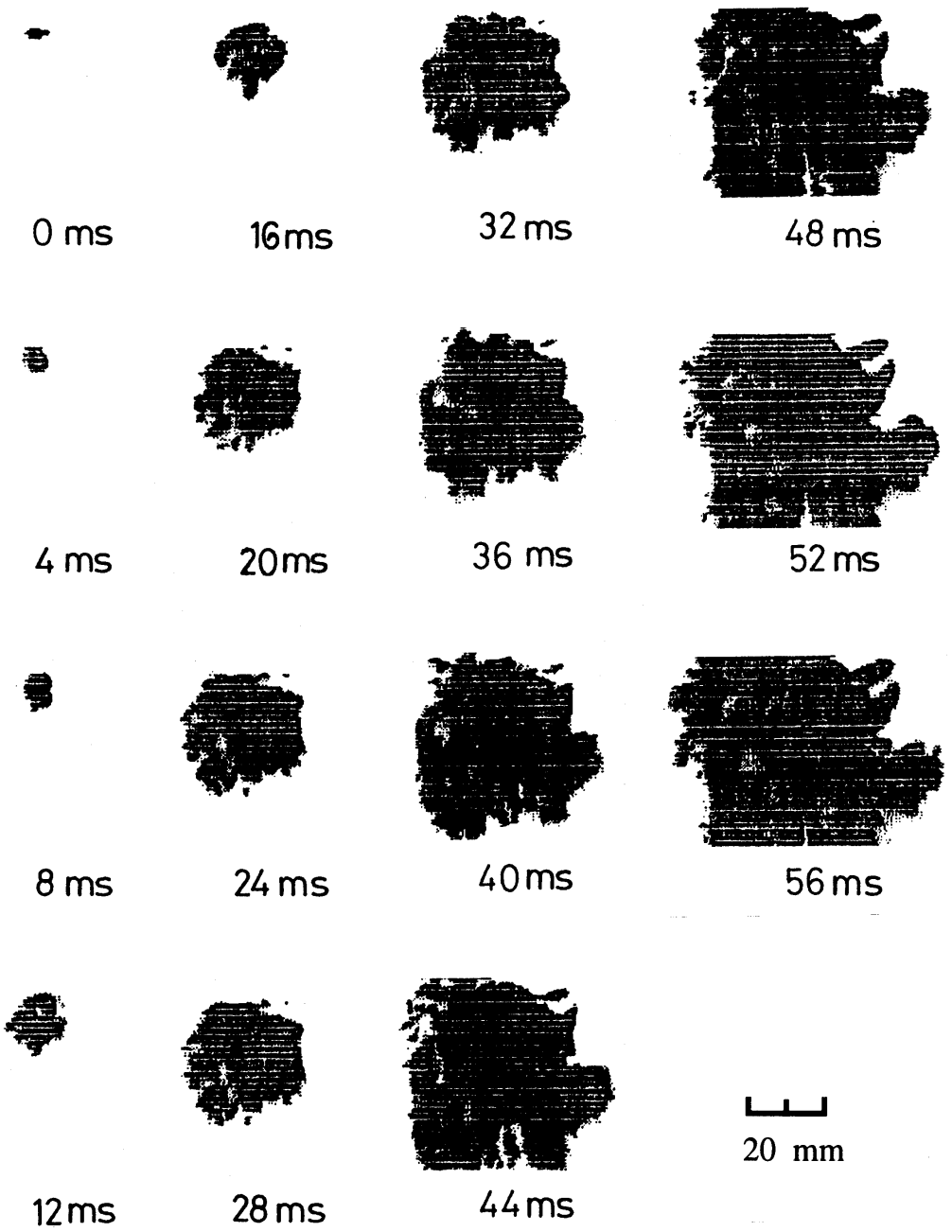
Example of actual spray burner



Experimental apparatus

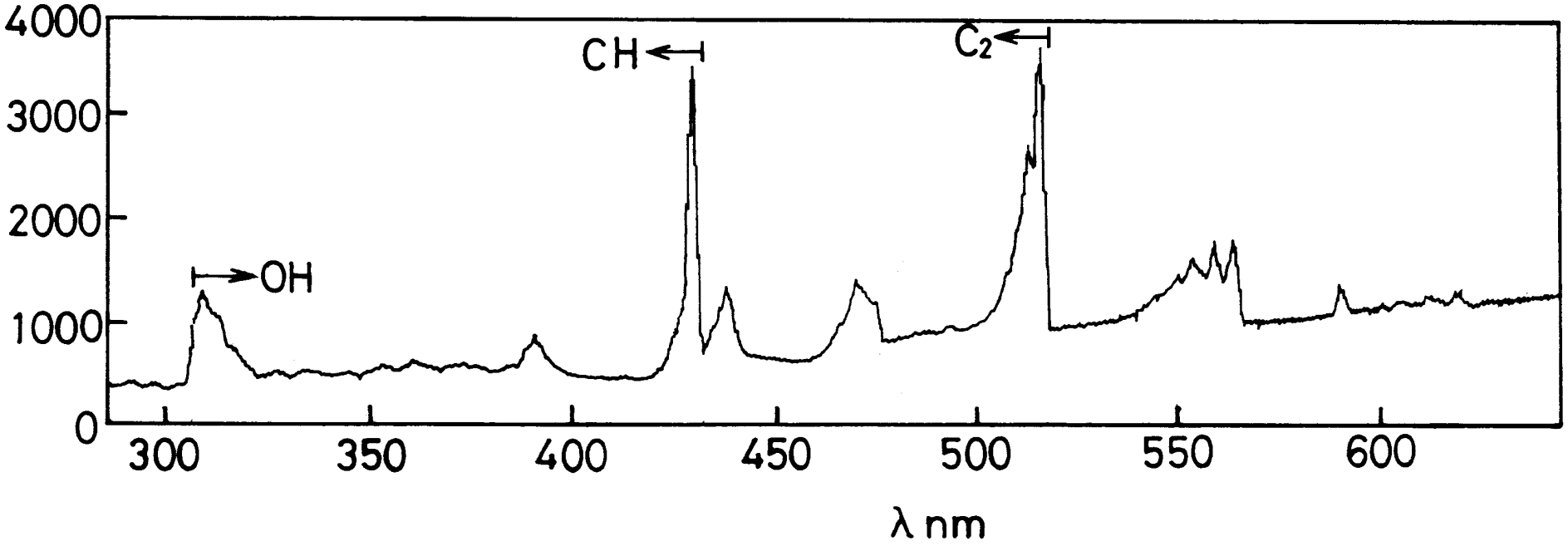


Time-series flame images



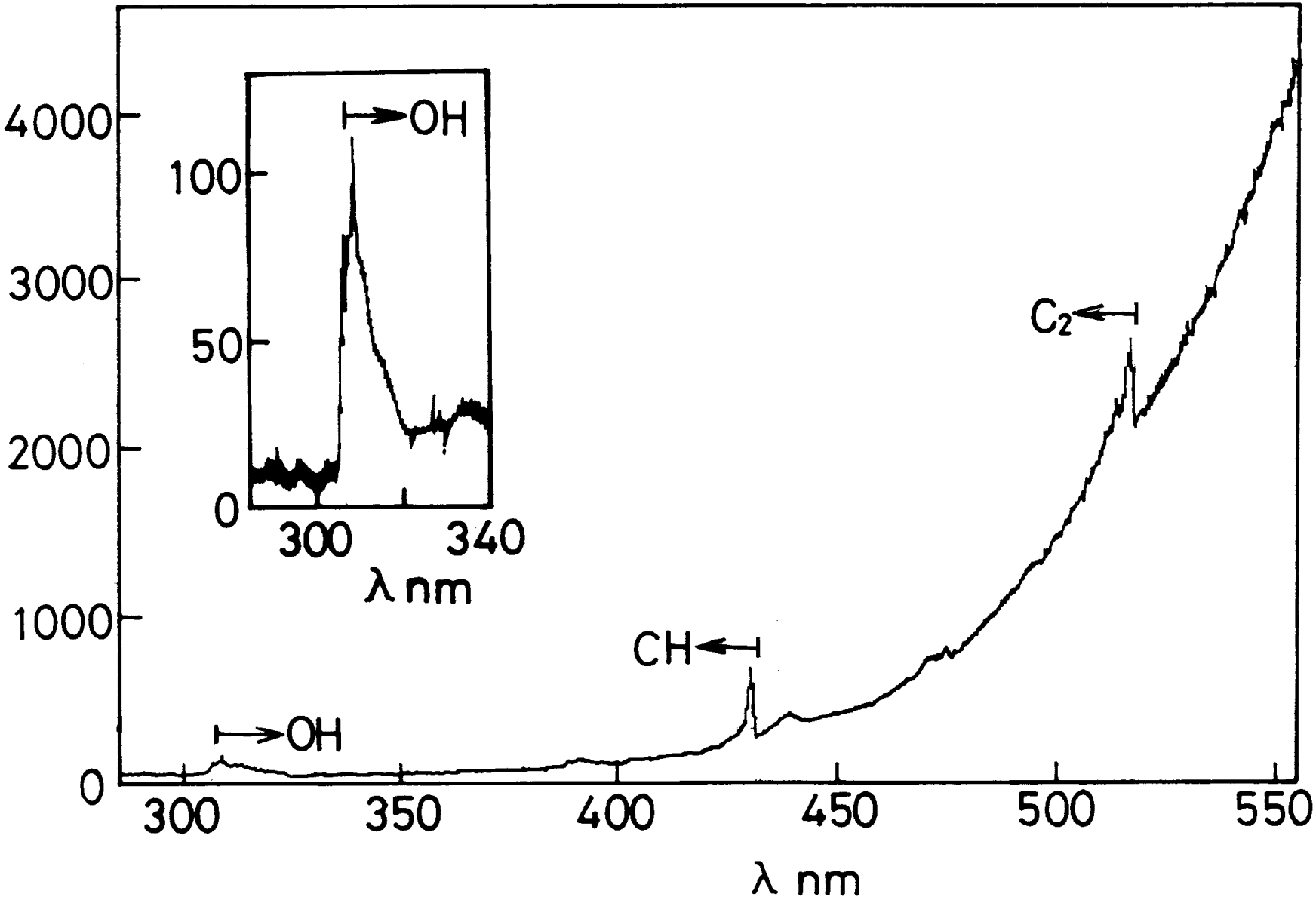
Spectrum of flame luminosity

Non-luminous flame



Spectrum of flame luminosity

Luminous flame



Chemiluminescence

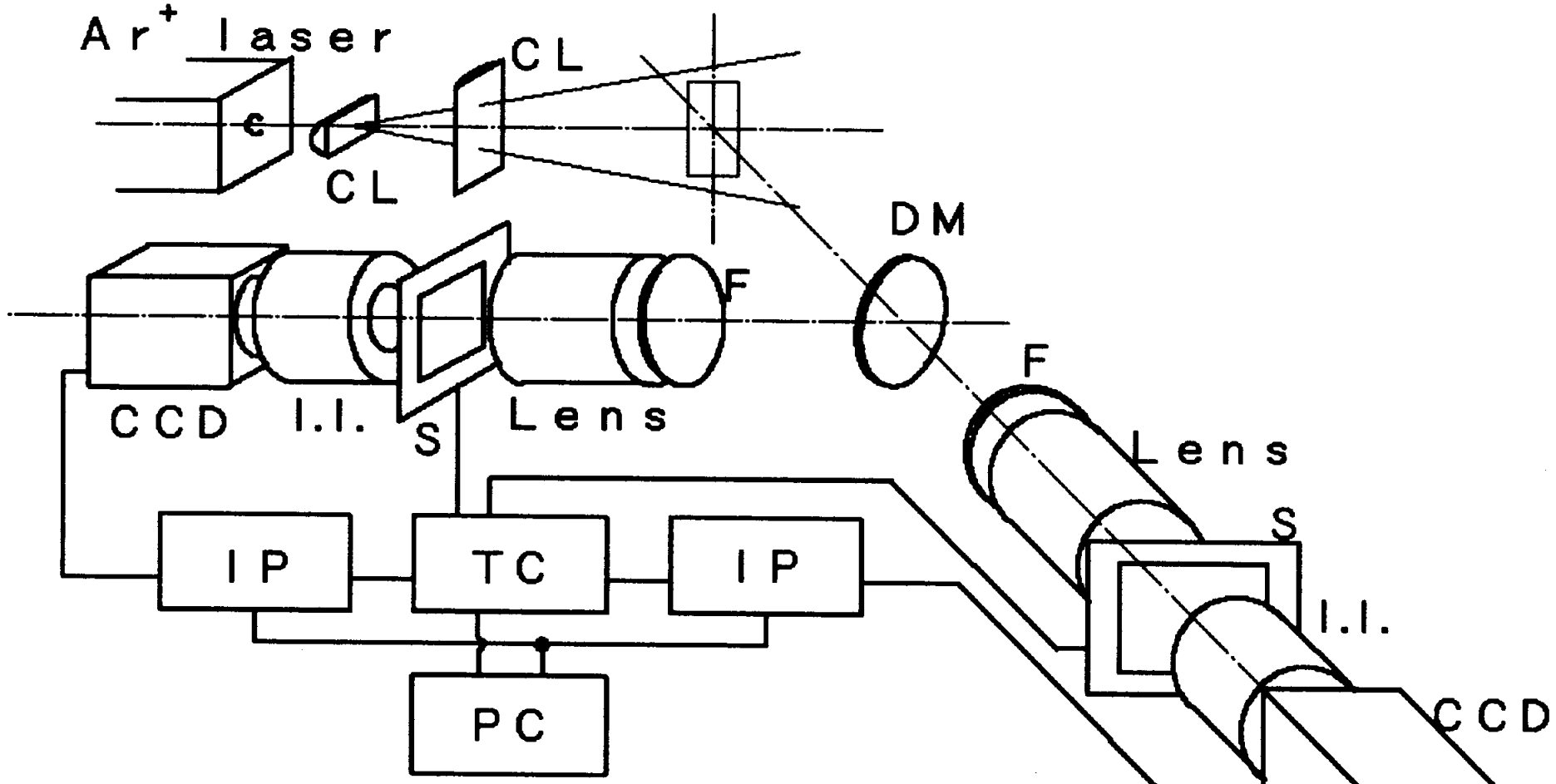
OH chemiluminescence is emitted in the deactivation course (2) of OH* produced from the reaction (1).

$$CH + O_2 \text{ ---> } CO + OH^* \qquad (1)$$

$$OH^* \text{ ---> } OH + h\nu \qquad (2)$$

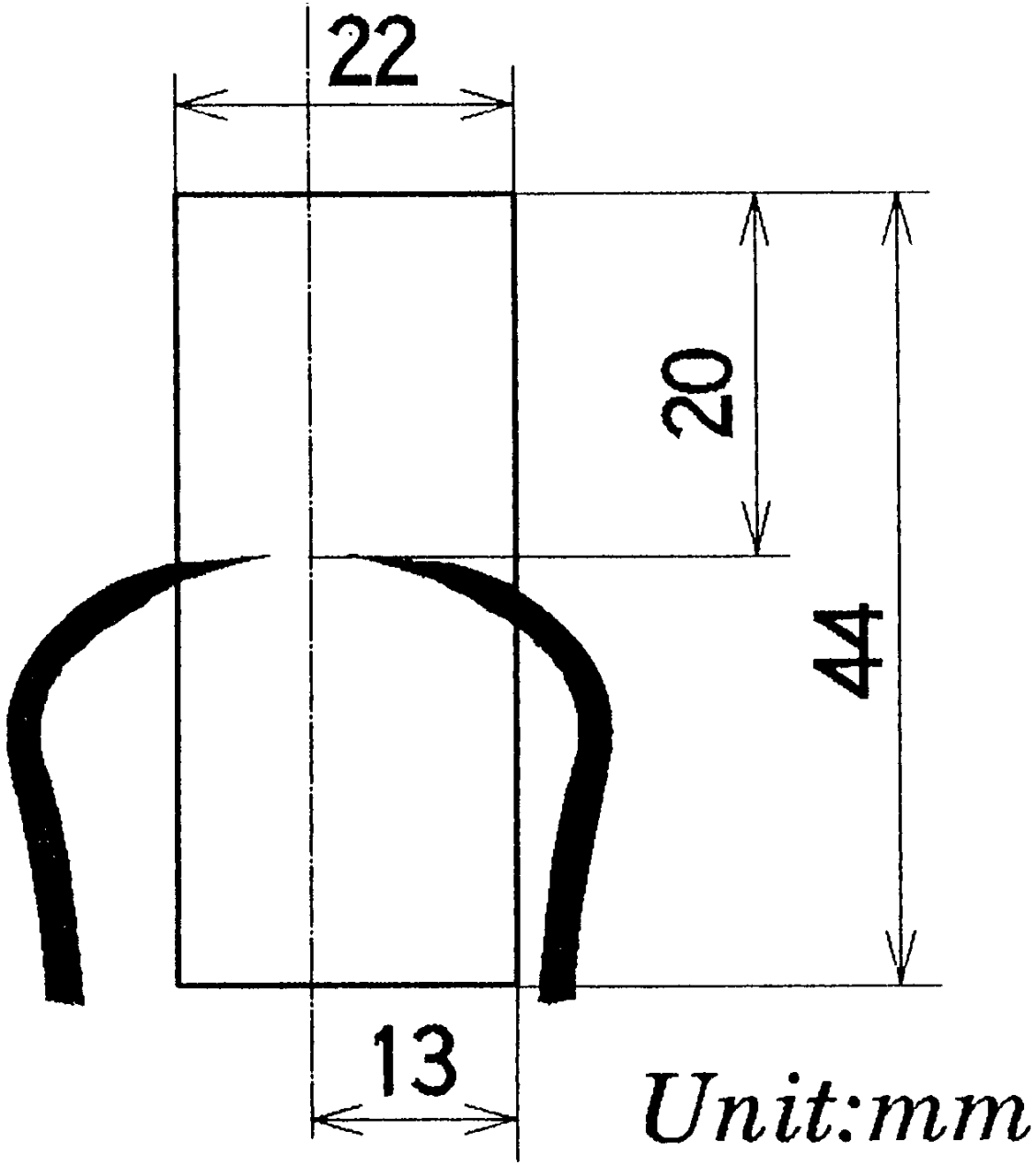
where the superscript * denotes an excited state, *h* is the Plank's constant, and ν is the frequency of the chemiluminescence.

Simultaneous imaging system

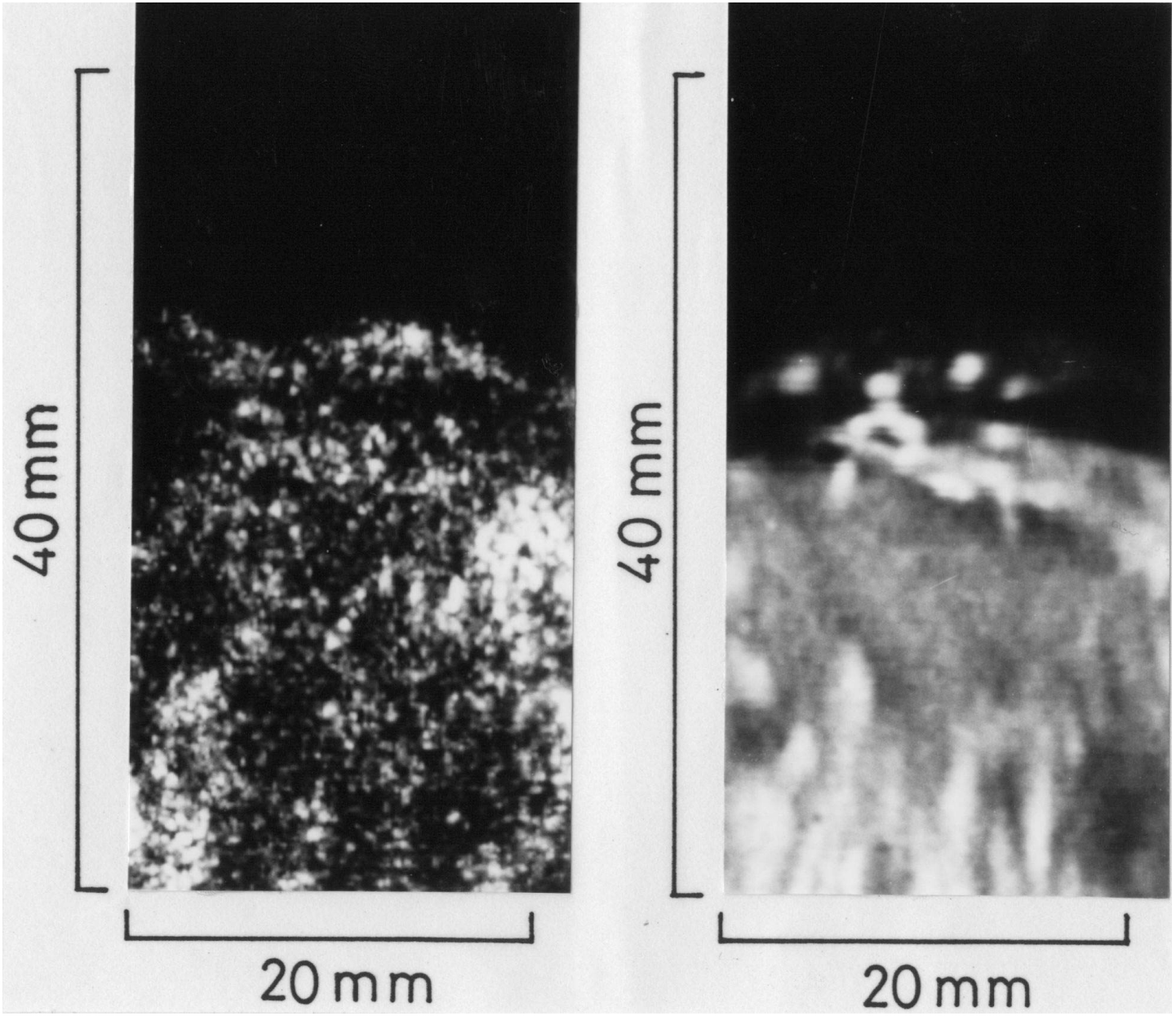


I.I. : Image intensifier
I P : Image processor
T C : Trigger controller
S : Shutter
F : Optical filter
D M : Dichroic mirror
C L : Cylindrical lens

Imaging area



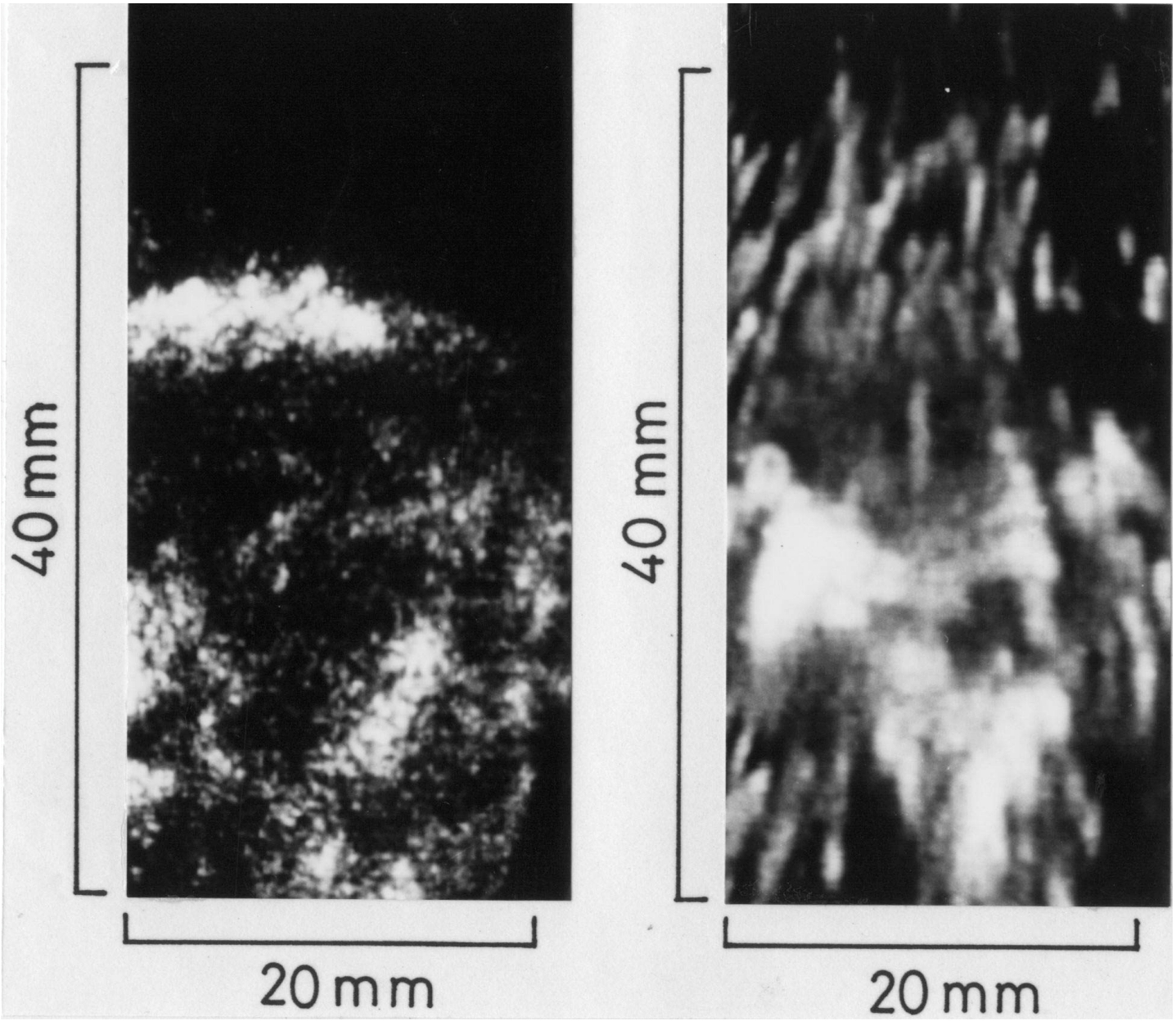
Simultaneous images



OH chemiluminescence

C2-band luminosity

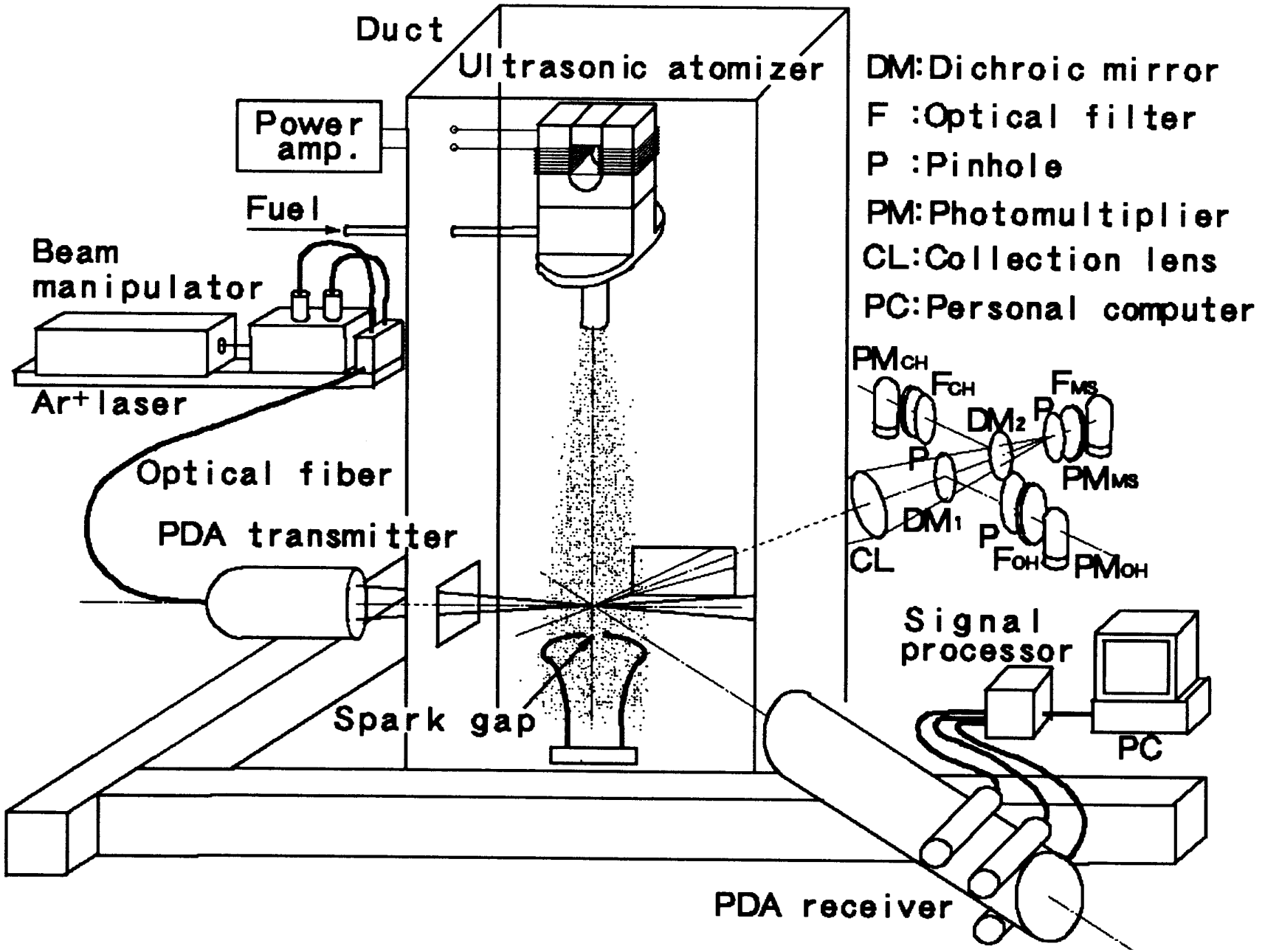
Simultaneous images



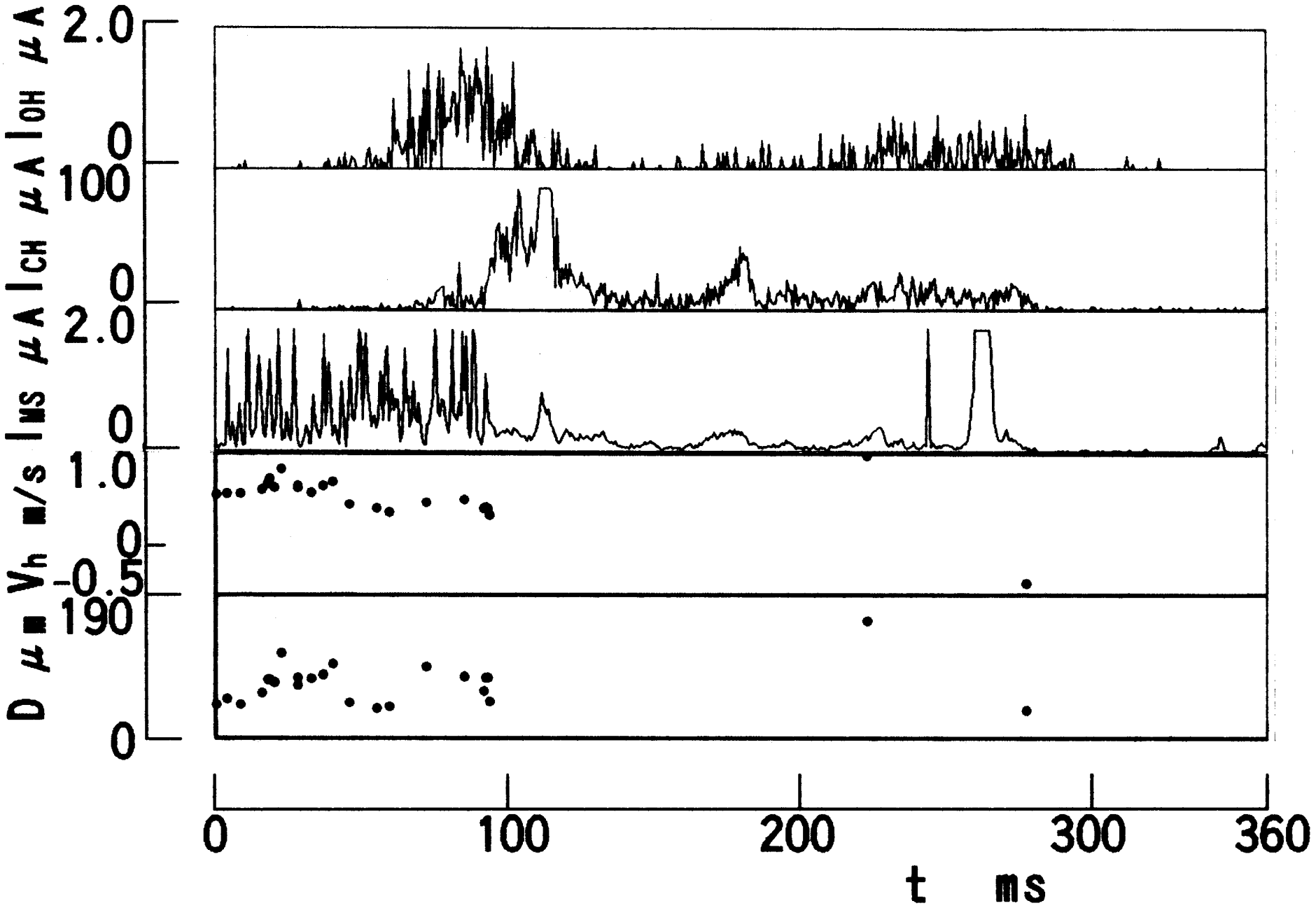
OH chemiluminescence

Droplet Mie scattering

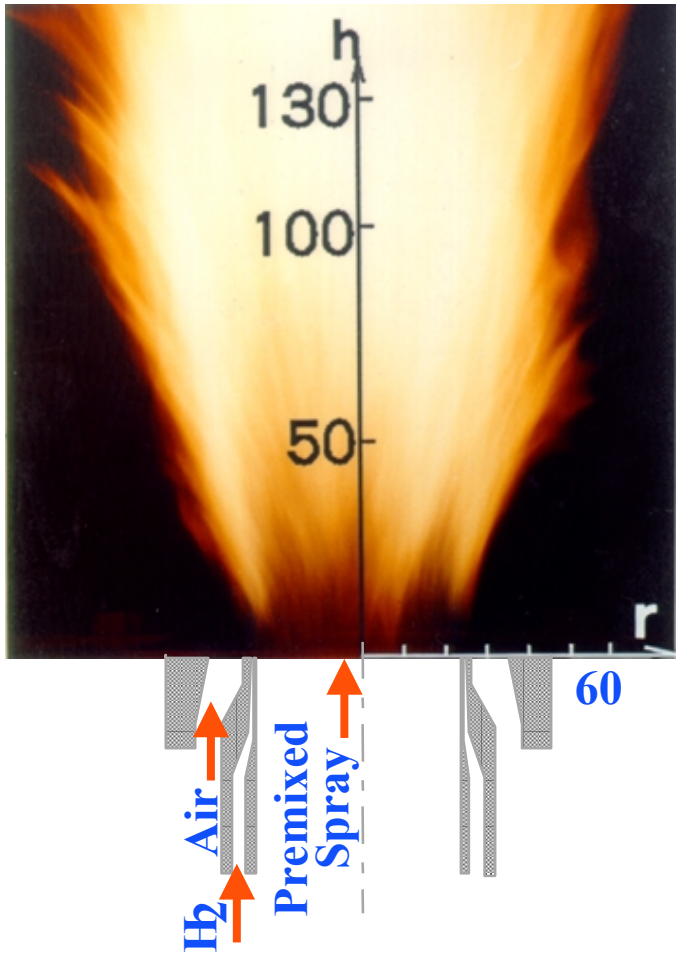
Point measurement system



Time-series data of point measurement



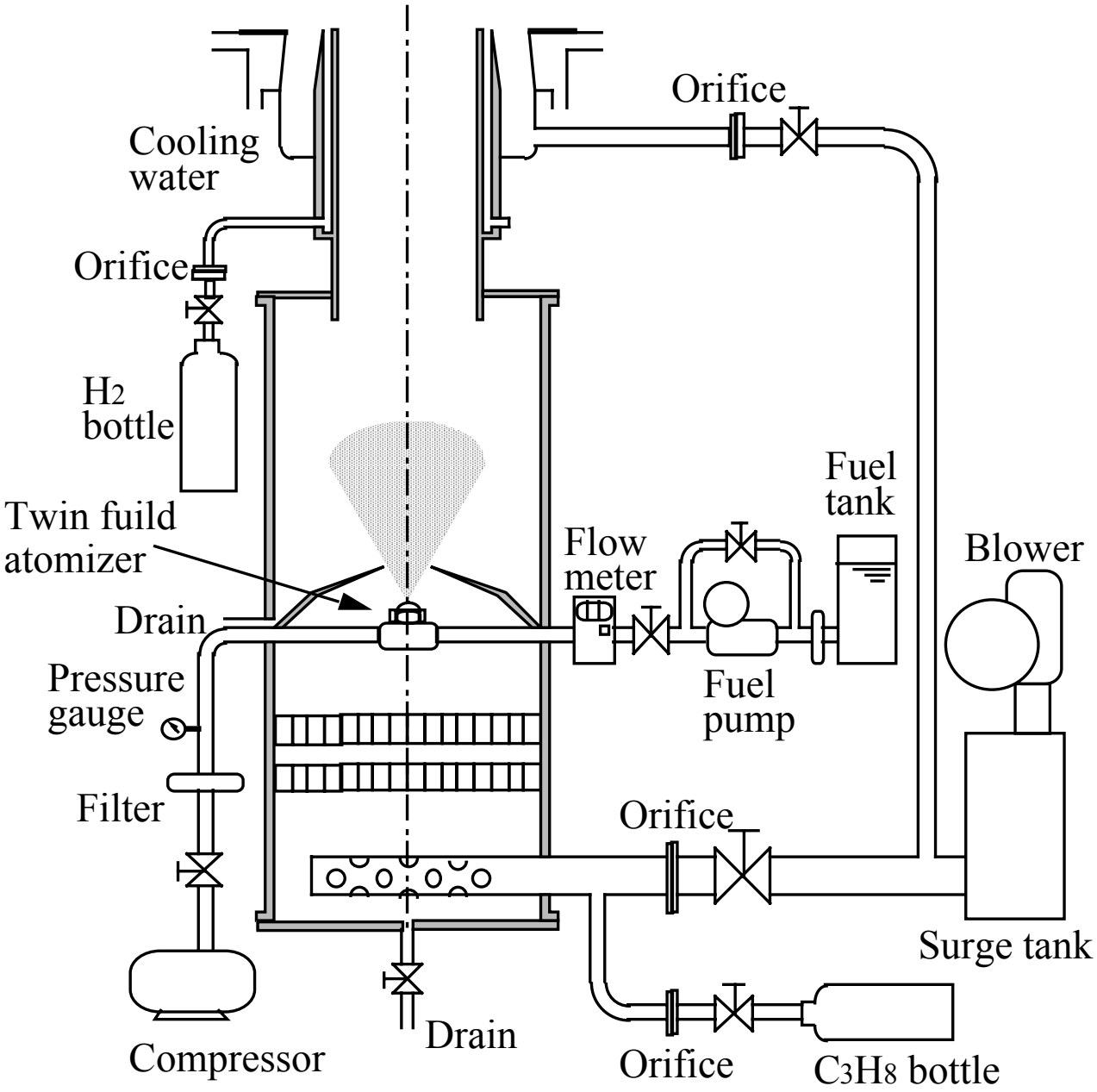
Premixed-spray flame



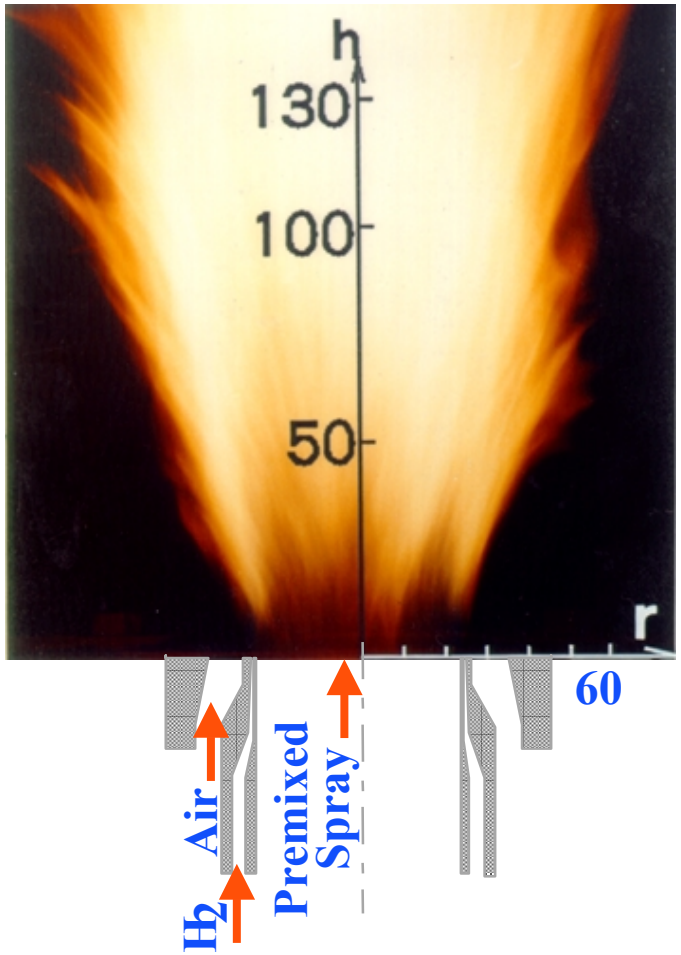
Long-exposure (1/15 s)

$\overline{U}$= 5.5 m/s, Re=19400, Φ=0.045kg_{fuel}/kg_{air}

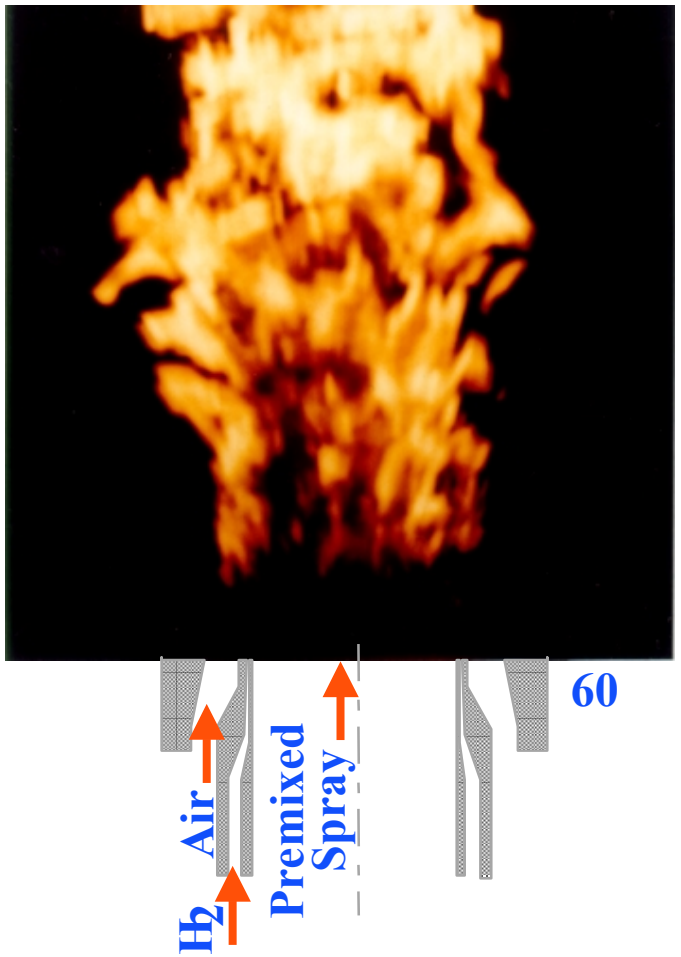
Burner configuration



Premixed-spray flame



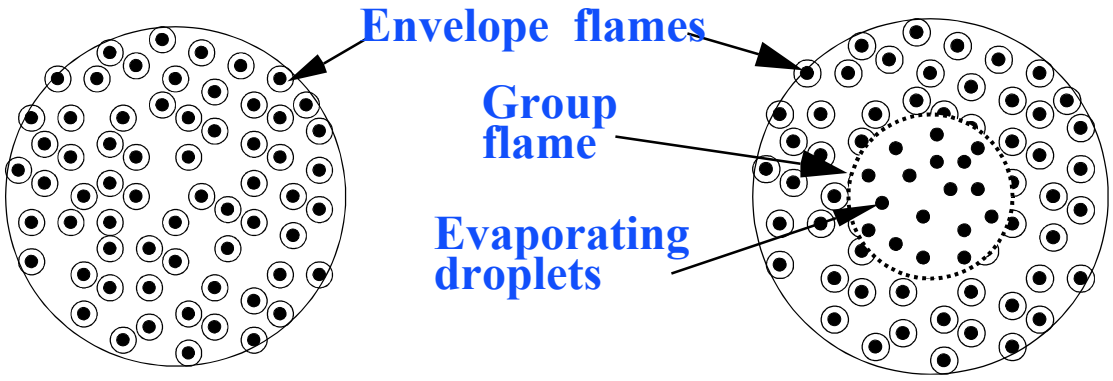
Long-exposure (1/15 s)



Short-exposure (1/1000 s)

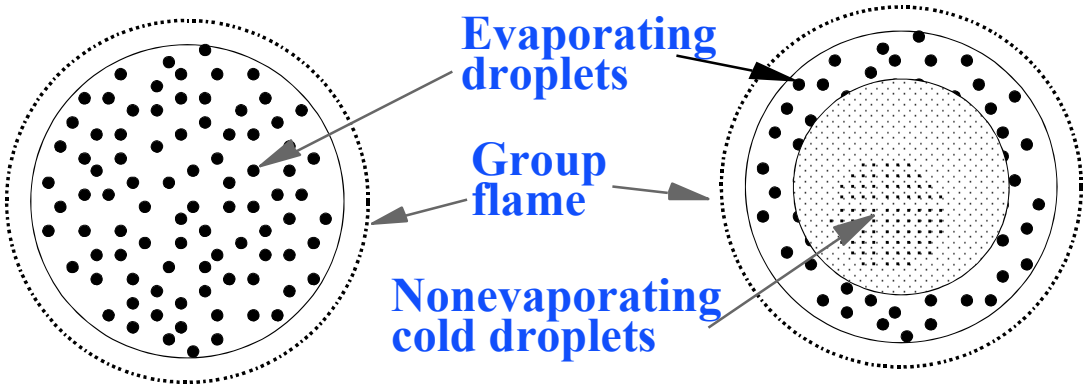
$\overline{U}$= 5.5 m/s, Re=19400, Φ=0.045kg_{fuel}/kg_{air}

Droplet group combustion



Single droplet combustion mode

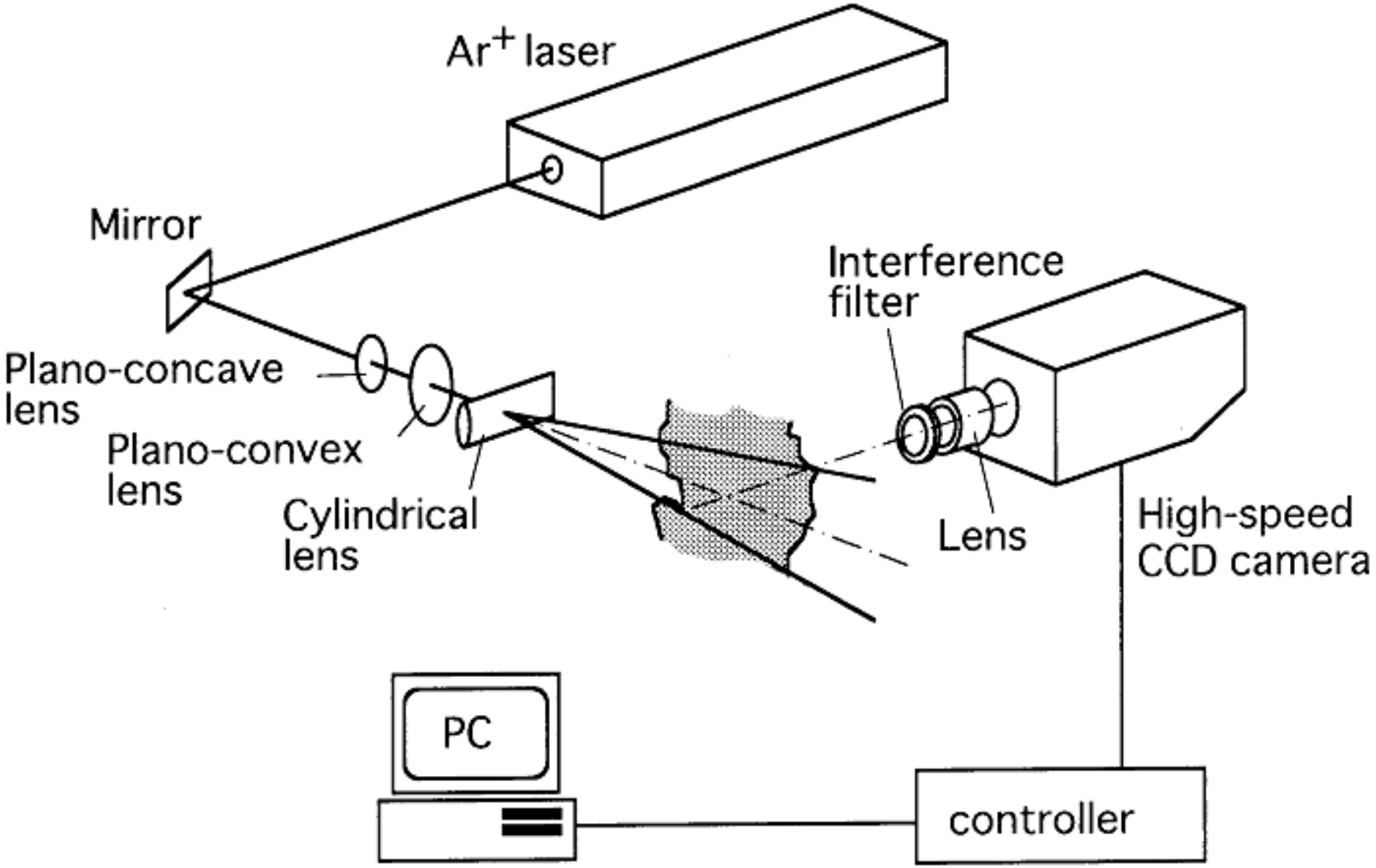
Internal group combustion mode



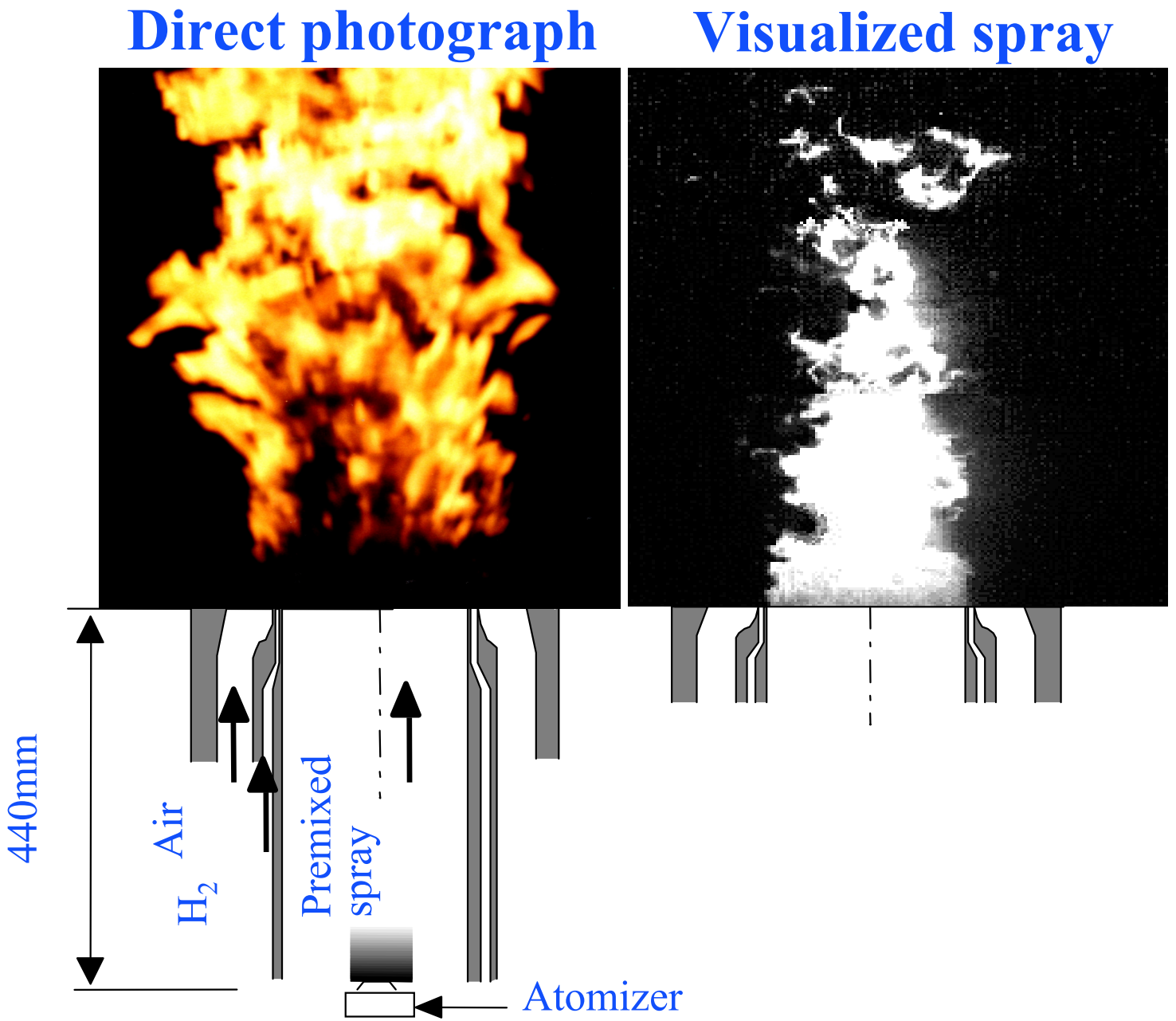
External group combustion mode

External sheath combustion mode

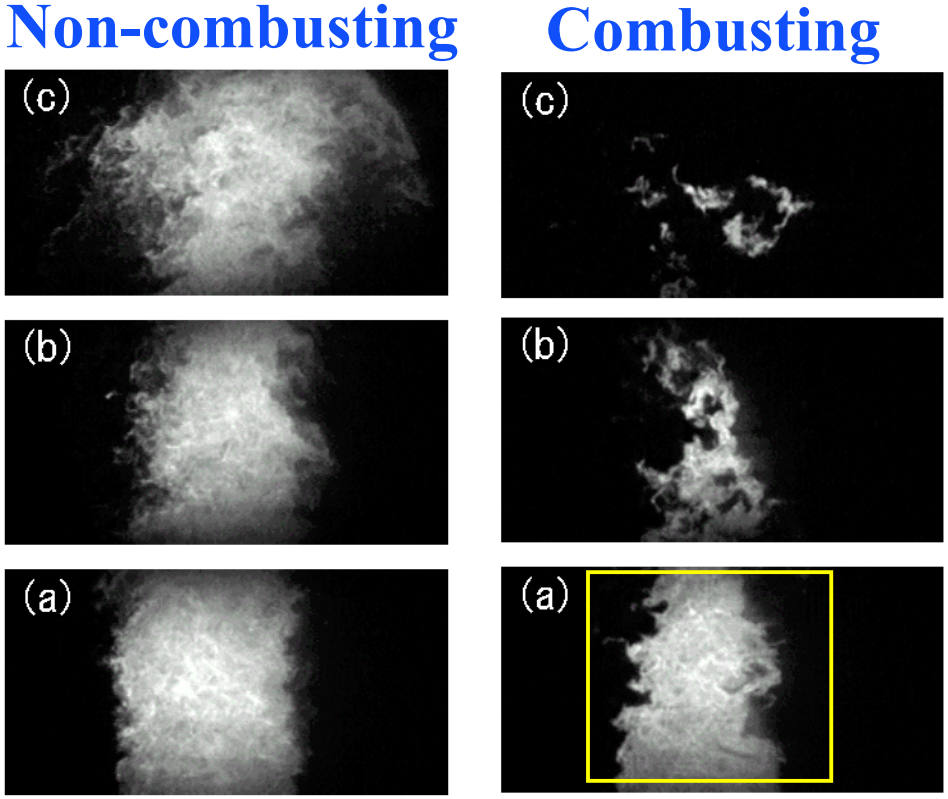
High-speed spray imaging



Burning spray image



Time-series spray image

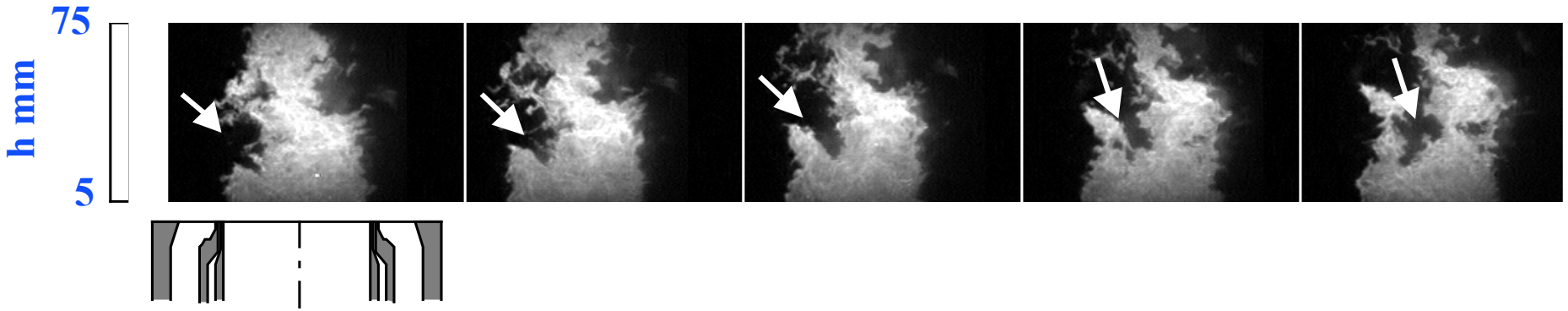


Rapid disappearance of a part of premixed spray

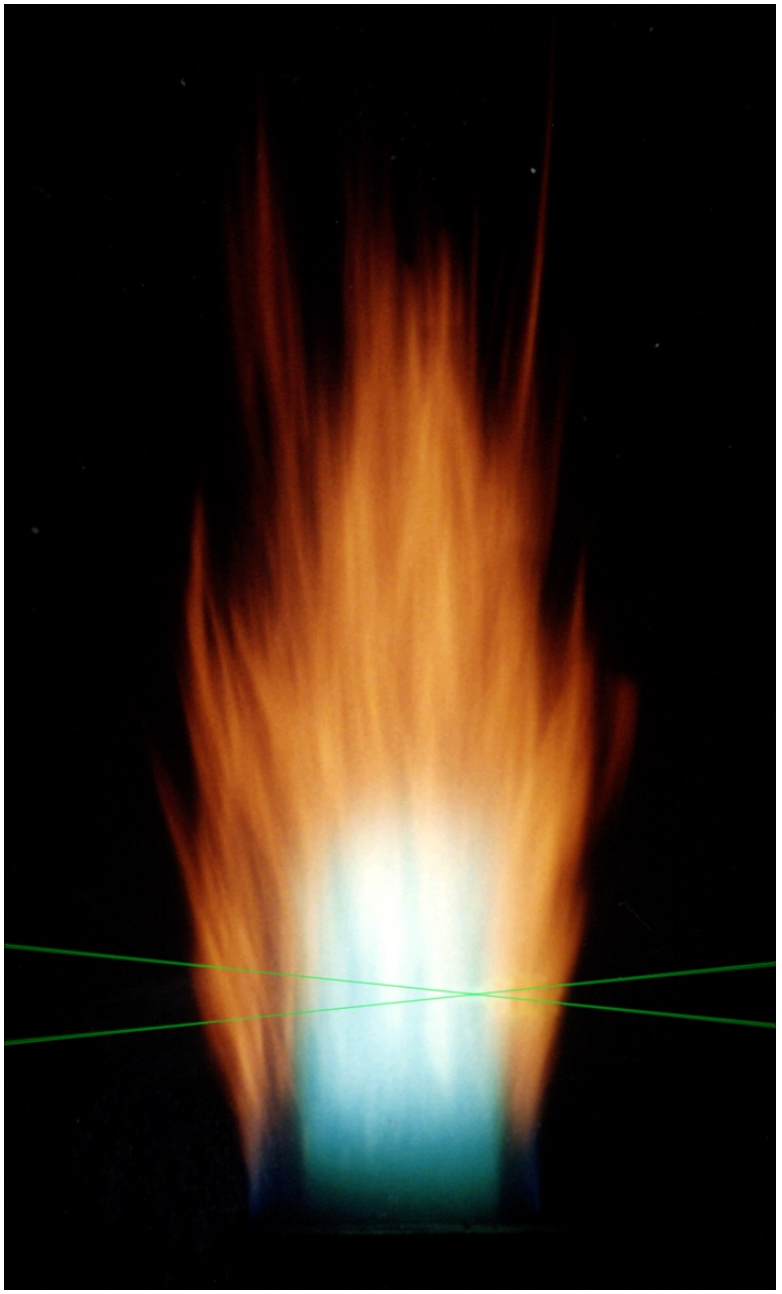
This is caused by ...

Turbulence associated with large eddies ?

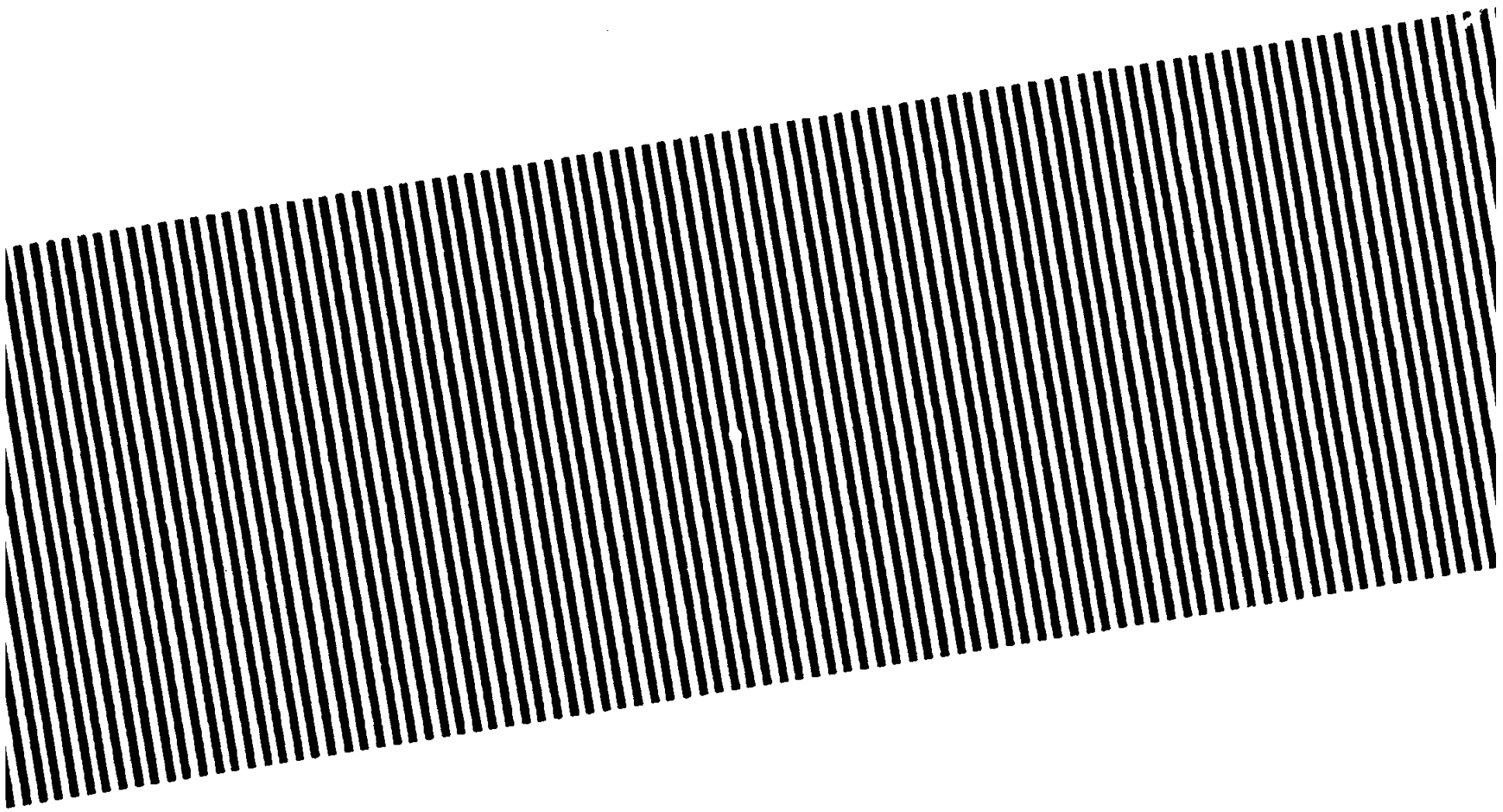
Preferential flame propagation ?



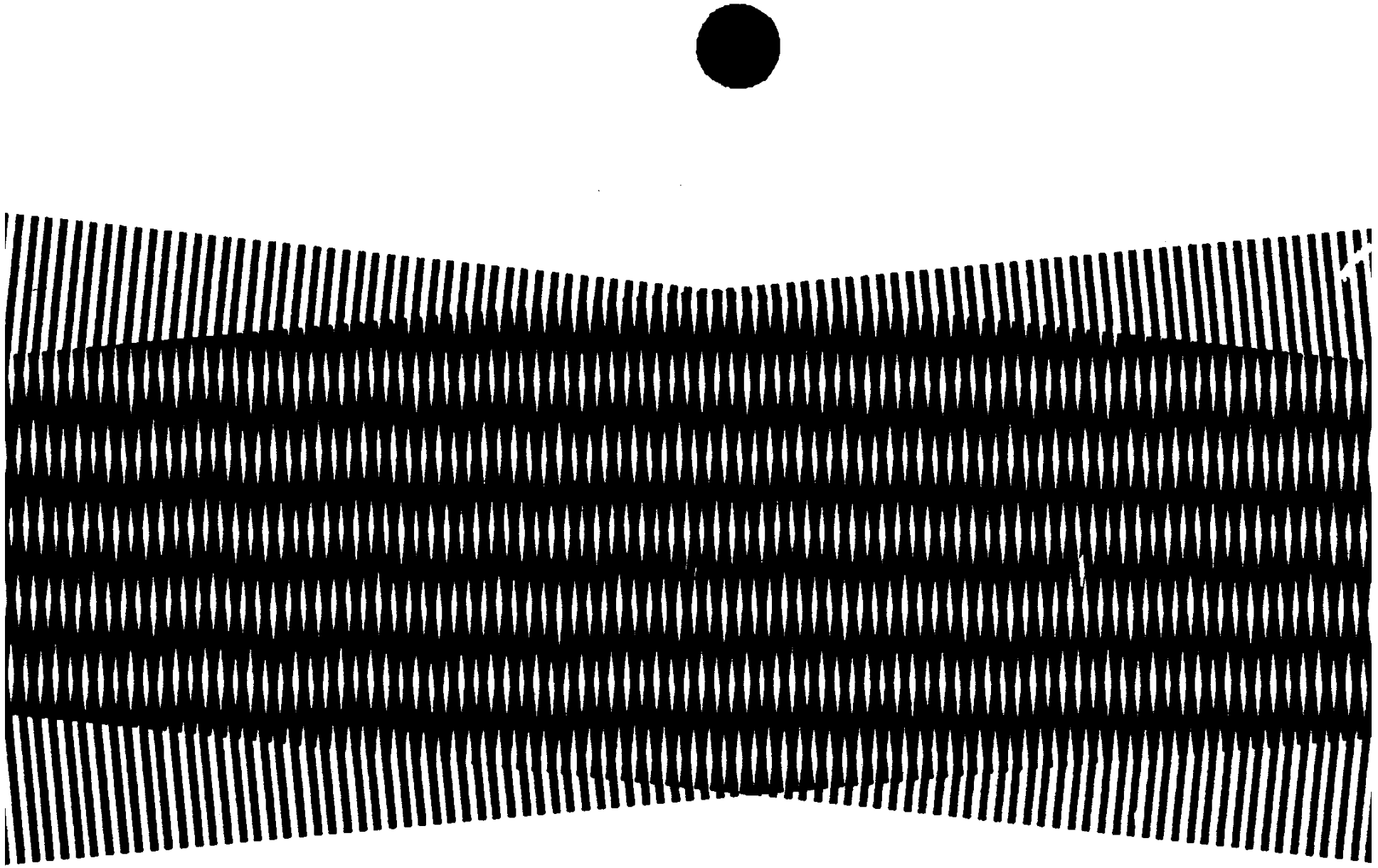
LDV & PDA measurement



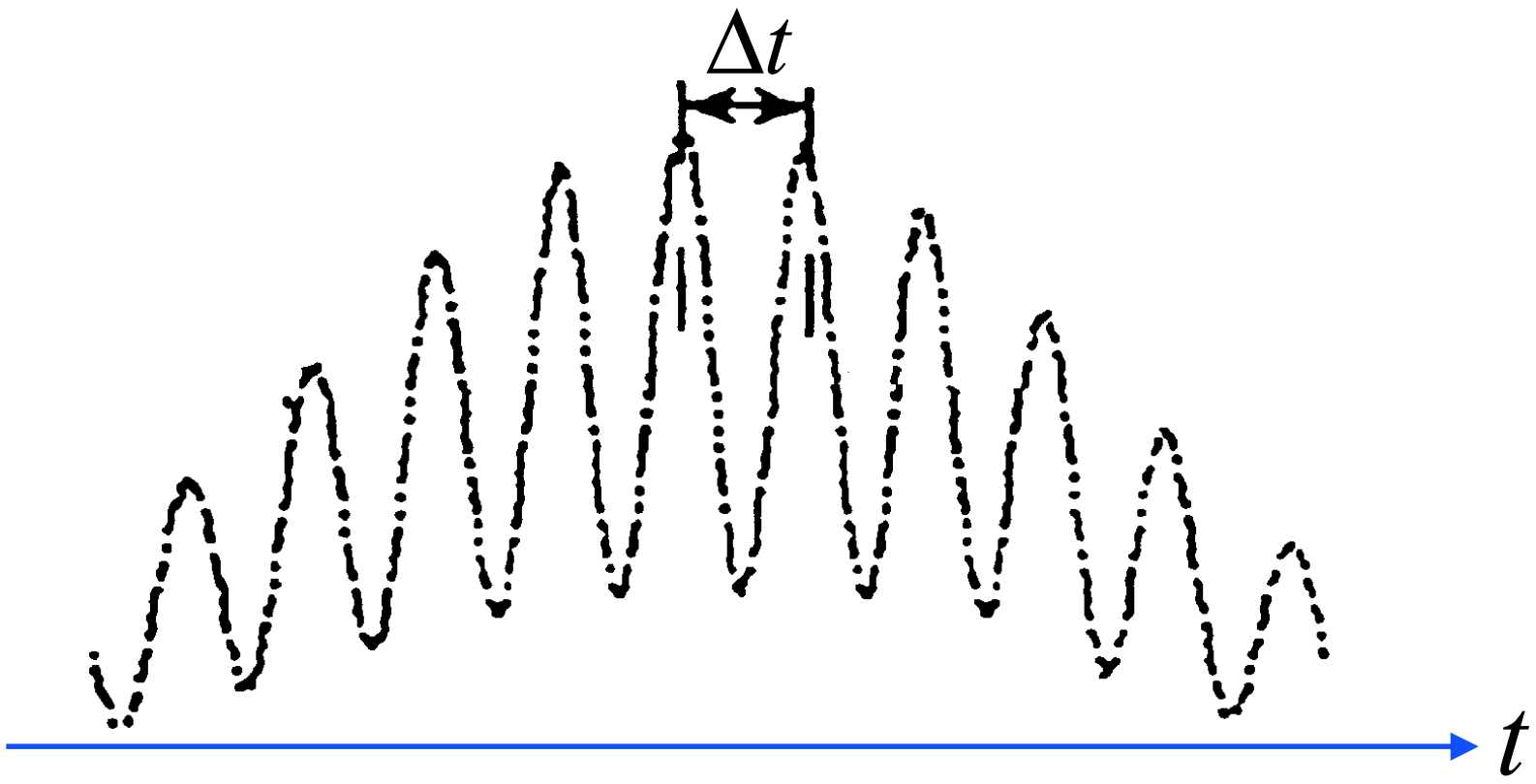
Laser light



Fringes in LDV control volume



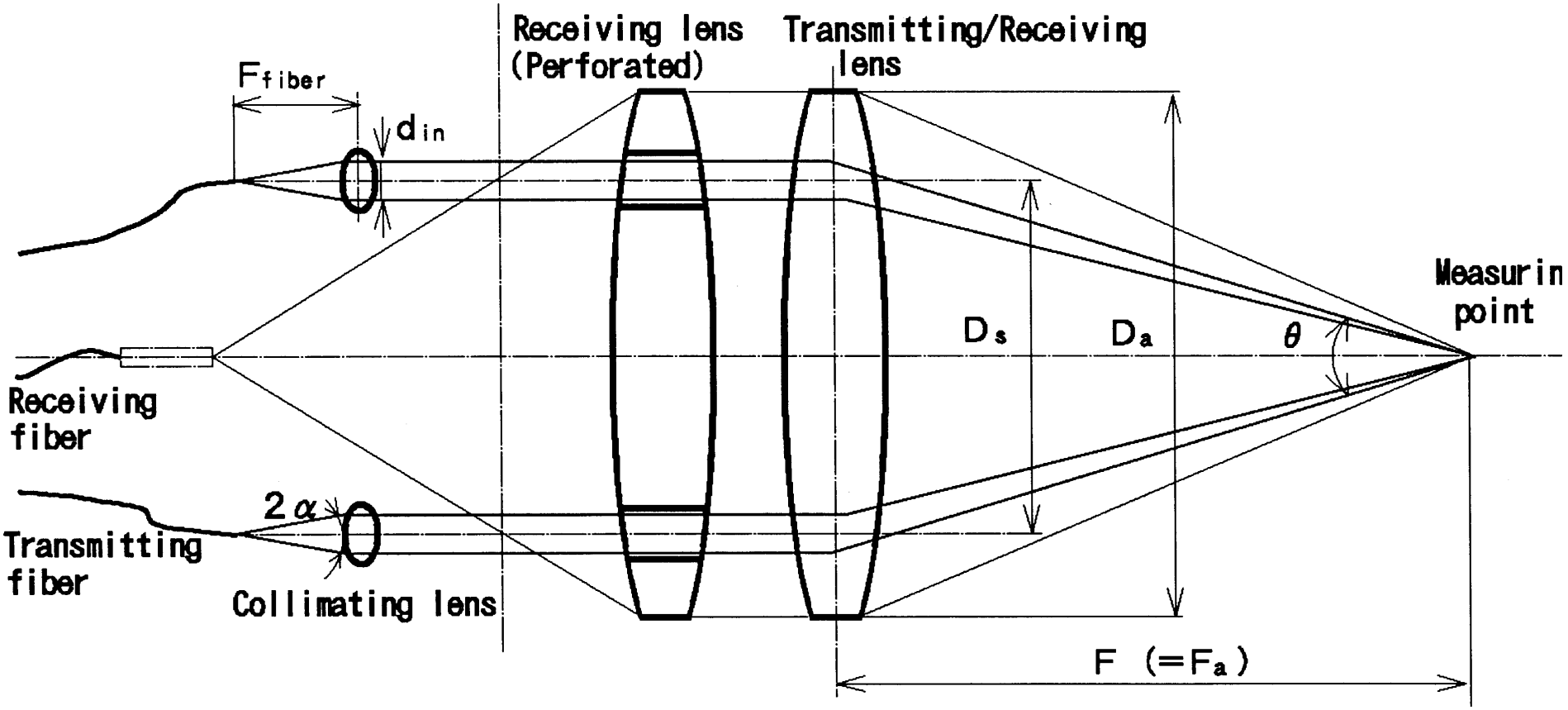
Principle of velocity measurement



$$V = \delta_f / \Delta t = \delta_f \cdot f_d$$

$$\because f_d = 1/\Delta t$$

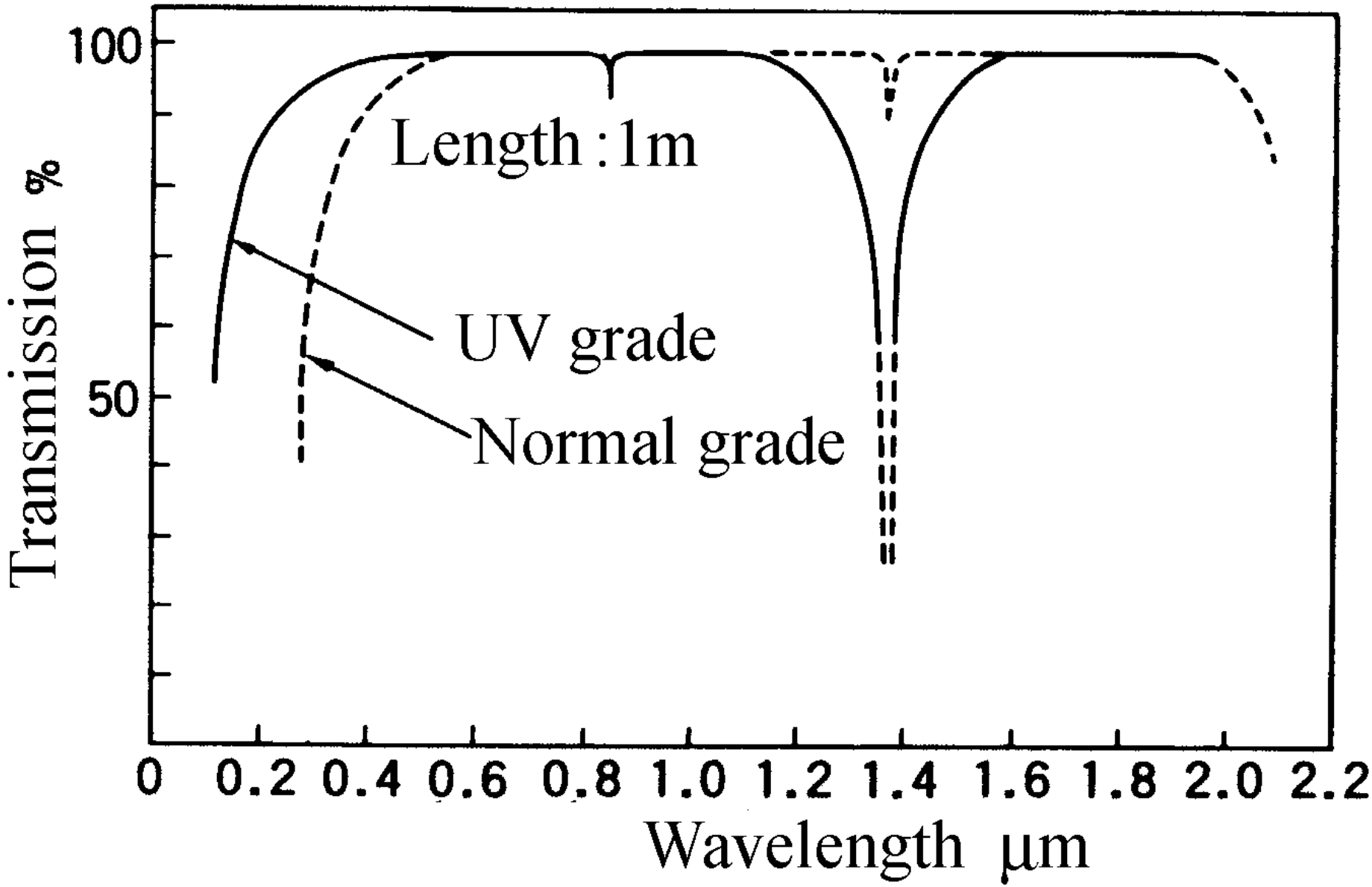
Configurations of FLDV



$$NA = \sin\alpha$$

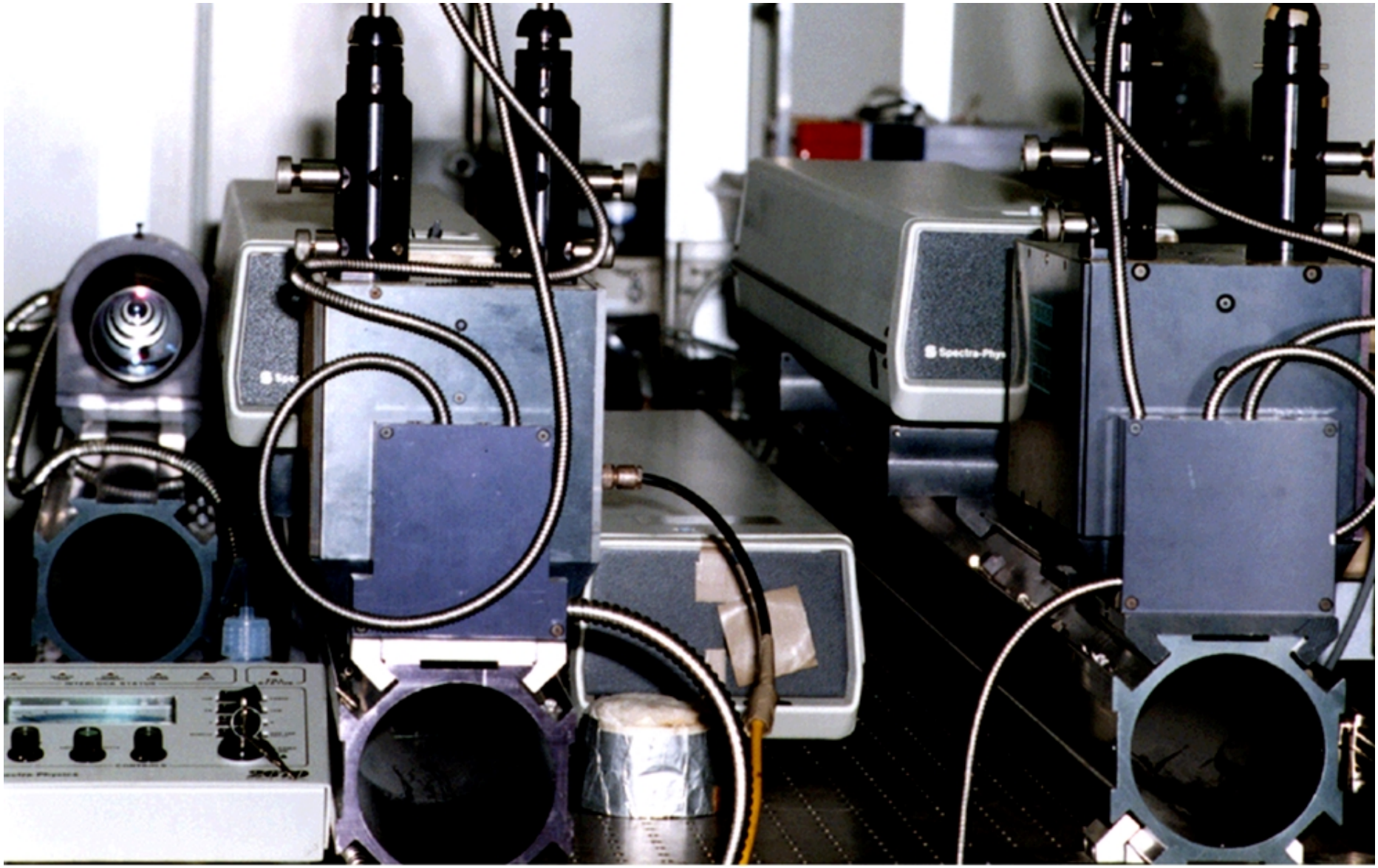
$$F_{fiber} = \frac{d_{in}}{2\tan\alpha}$$

Transmission of optical fiber

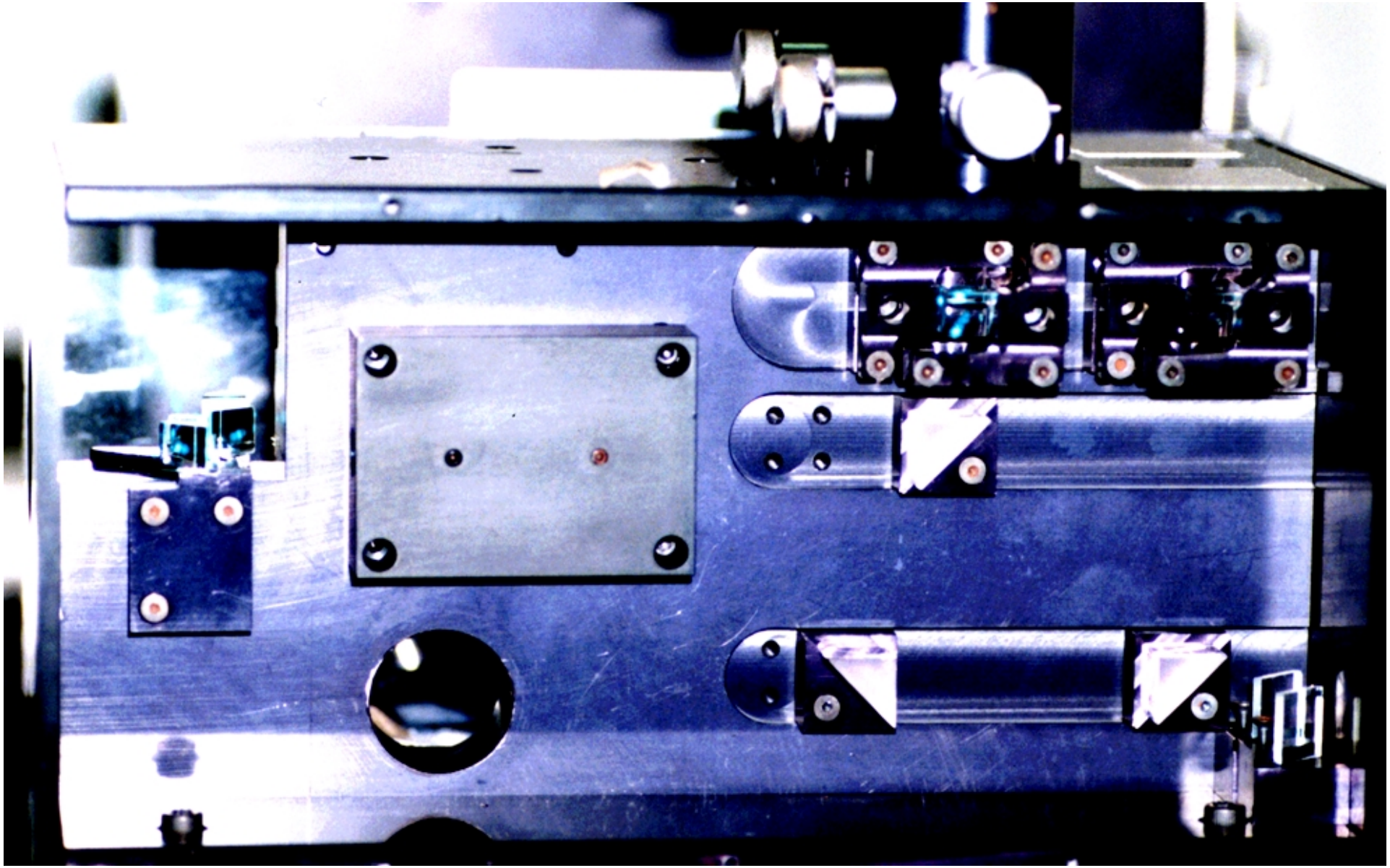


Backscattering type LDV

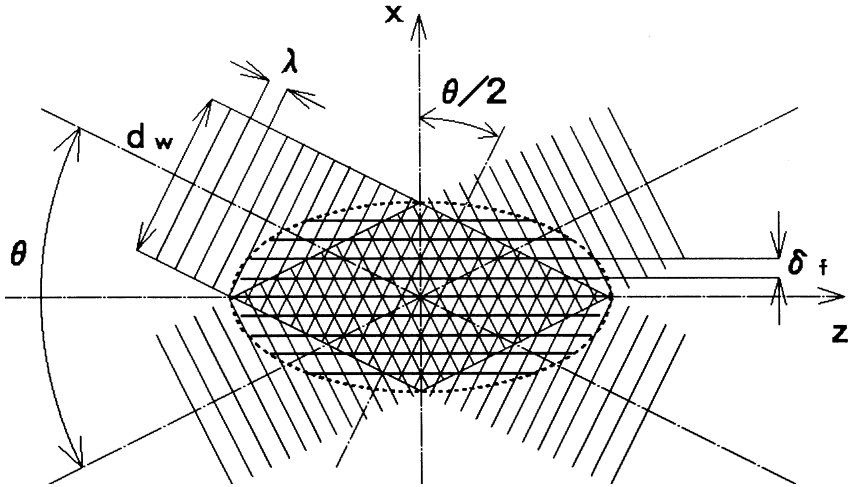
Laser source

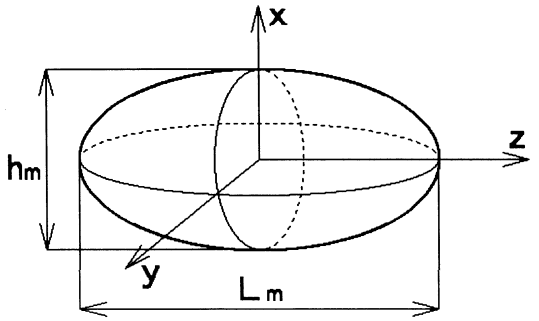


Laser manipulator



Control volume of LDV





$$d_w = \frac{4\lambda F}{\pi d_{in}}$$

$$\delta_f = \frac{\lambda}{2\sin(\theta/2)}$$

$$h_m = \frac{d_w}{\cos(\theta/2)}$$

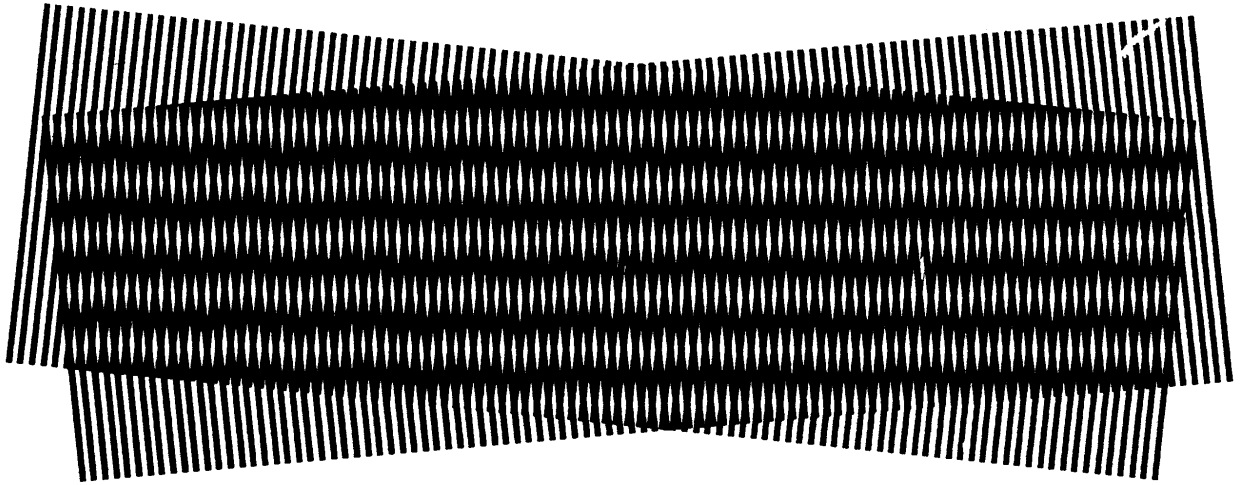
$$L_m = \frac{h_m}{\sin(\theta/2)}$$

$$N_f = \frac{h_m}{\delta_f}$$

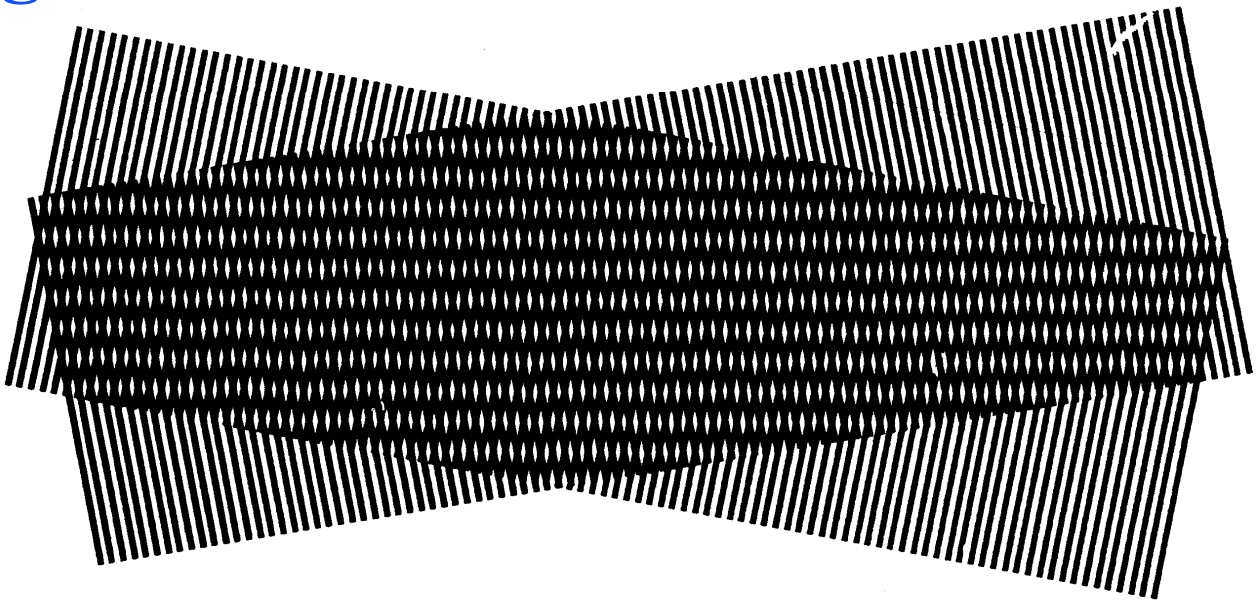
$$V = \delta_f \cdot f_d$$

Difference of fringe spacing

Small crossing angle



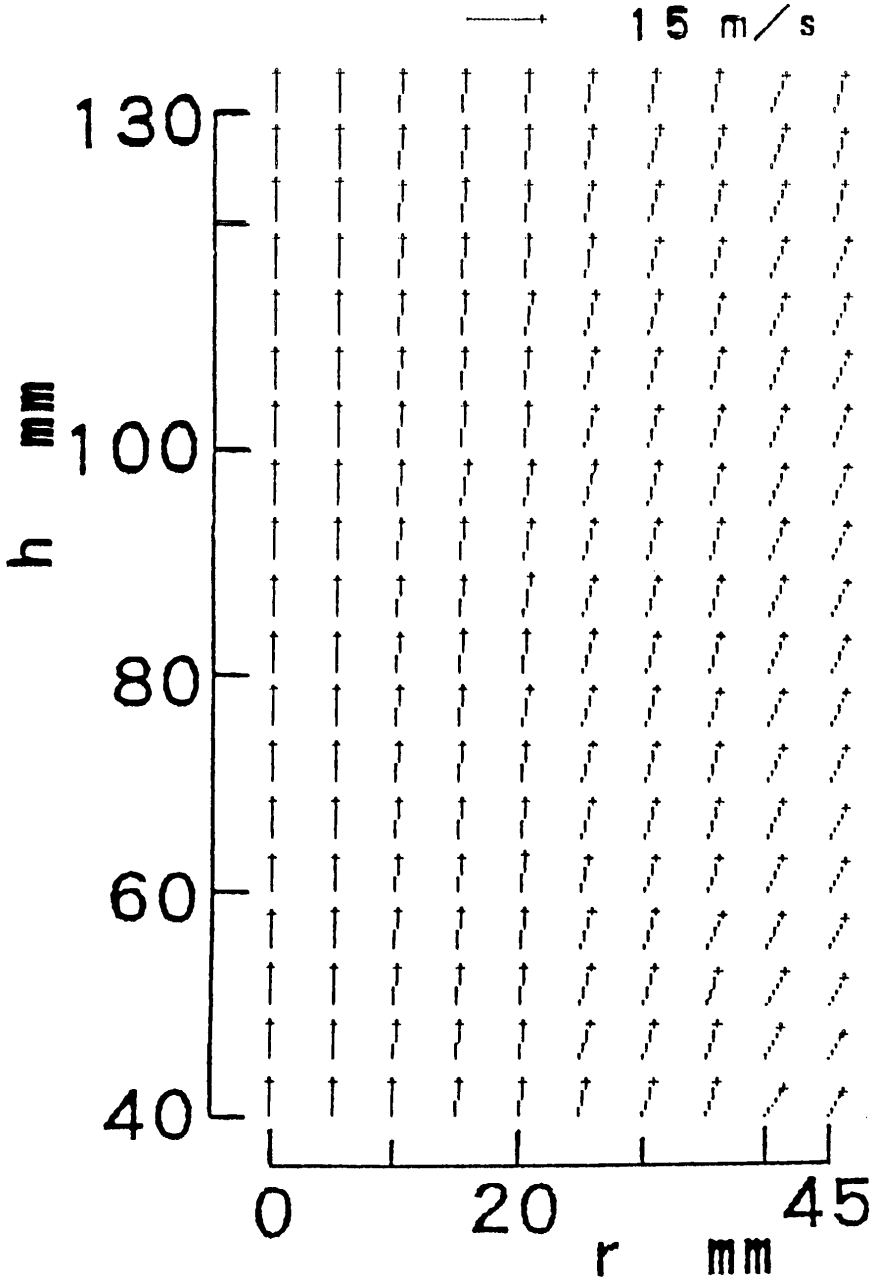
Large crossing angle



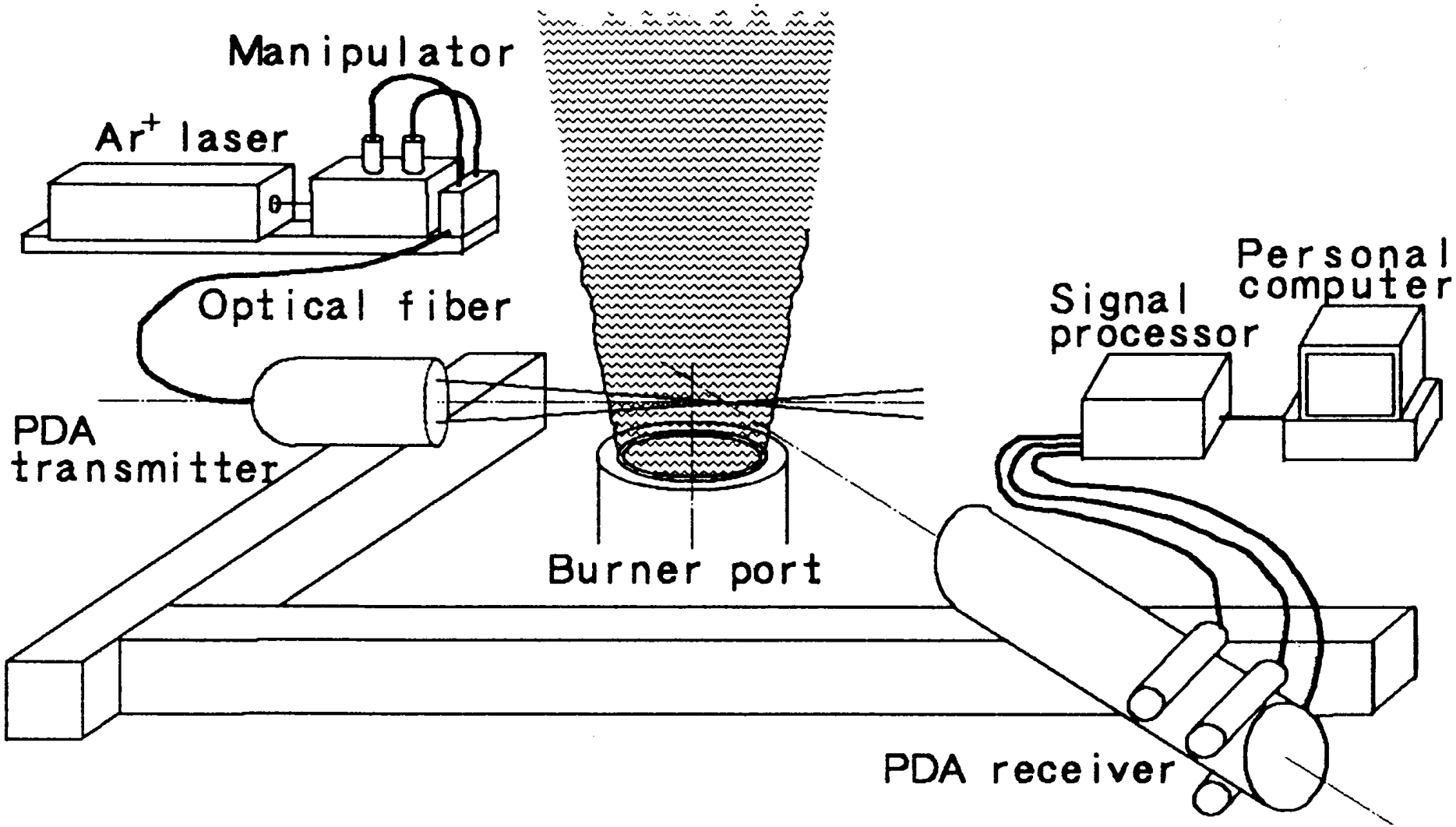
Specification of FLDV

Probe:	Focal length	400	mm
	Spot diameter	68.1	μm
	Fringe spacing	4.16	μm
	Fringe number	16	
Range:	Maximum velocity	12.5	m/s
	Minimum velocity	-4.16	m/s
Wavelength of laser beam		488	nm
Bandwidth of signal processor		4	MHz
Frequency shift		40	MHz

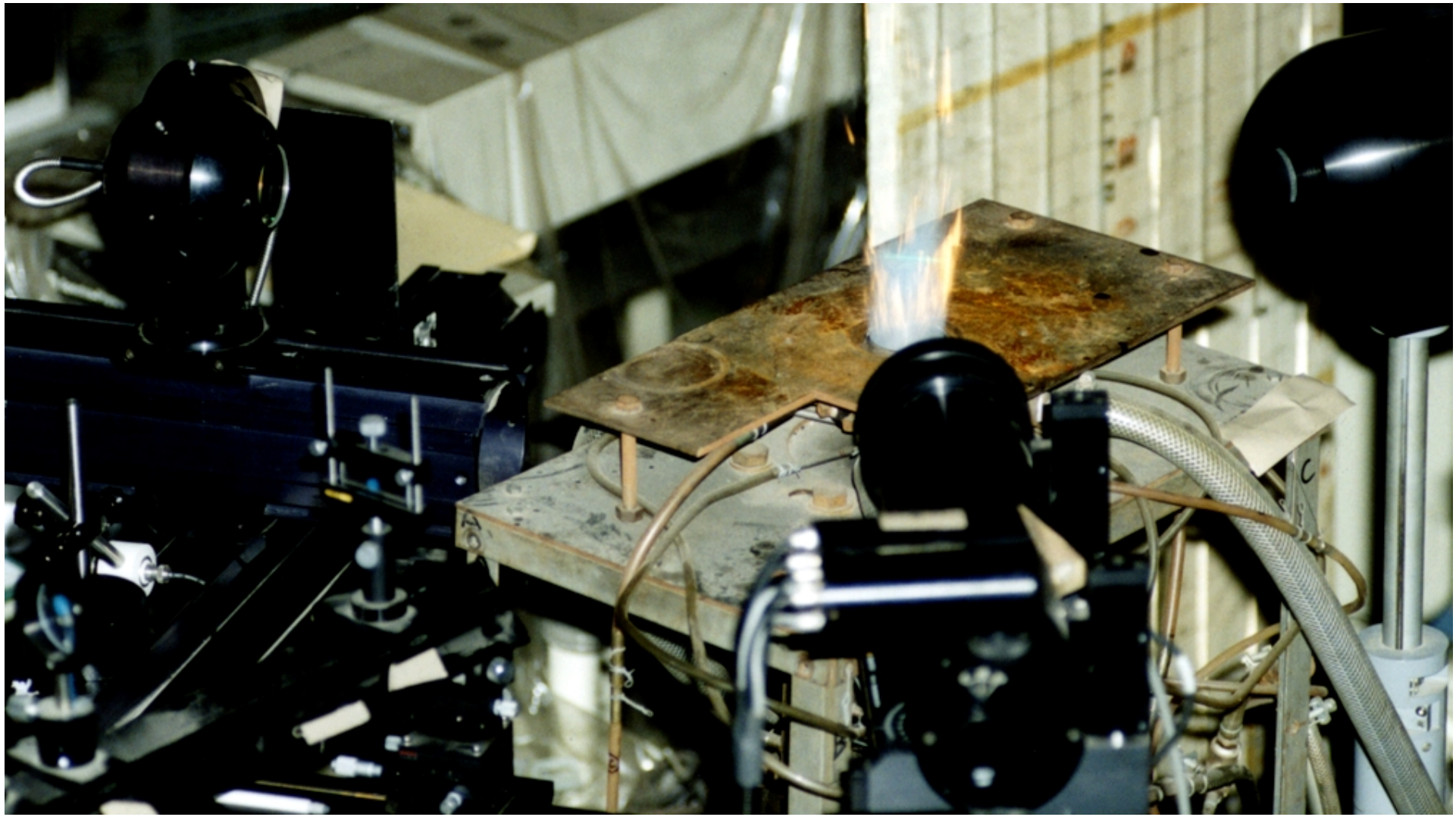
Droplet velocity vectors in flame



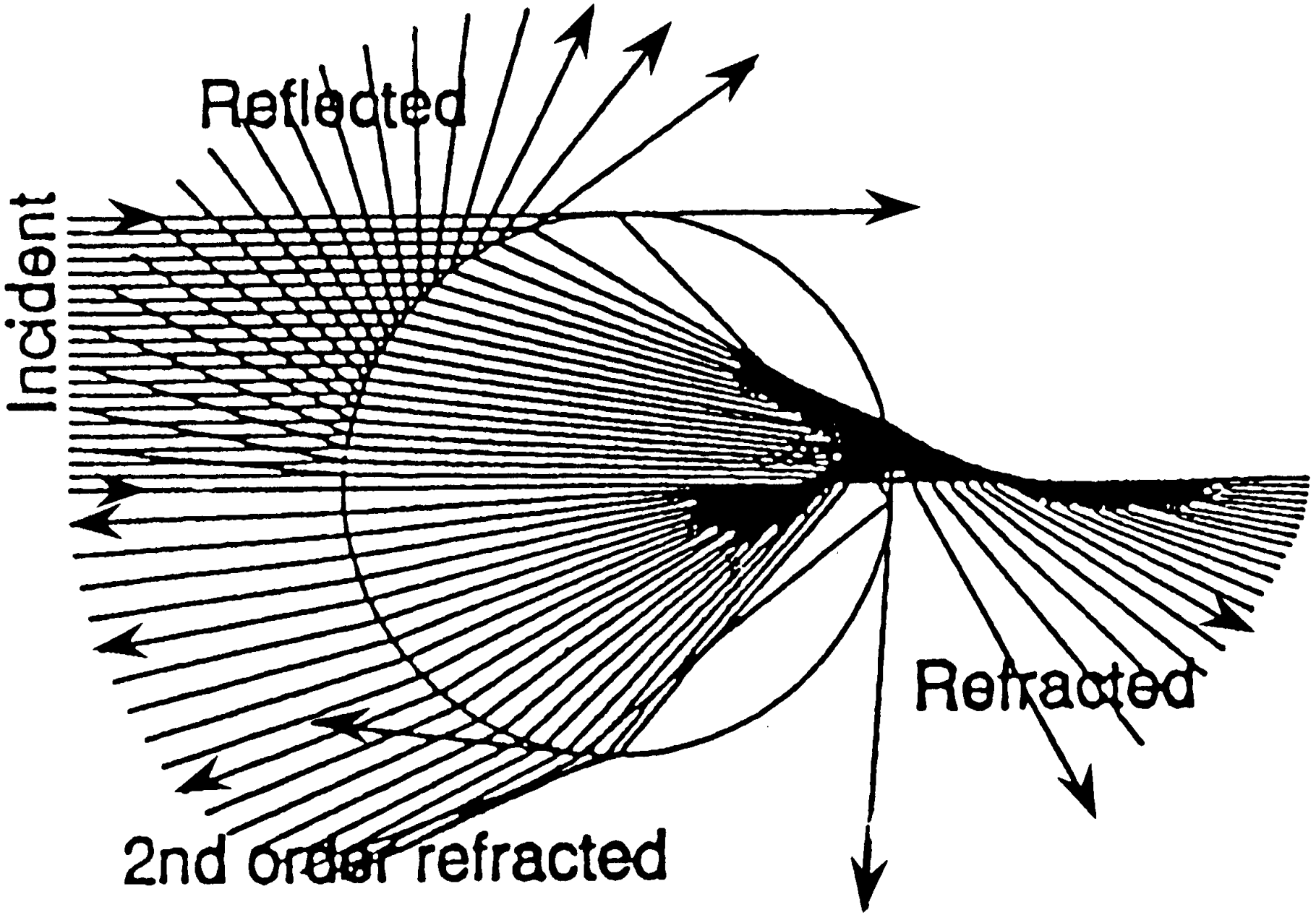
Setup of PDA system



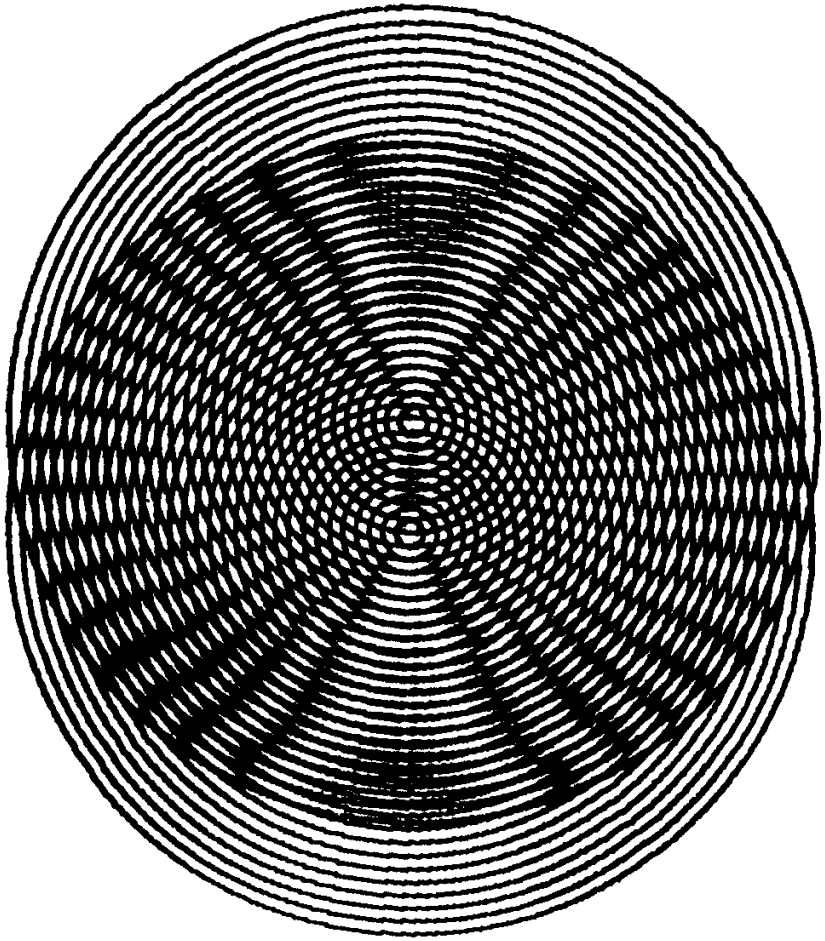
Photograph of experiment



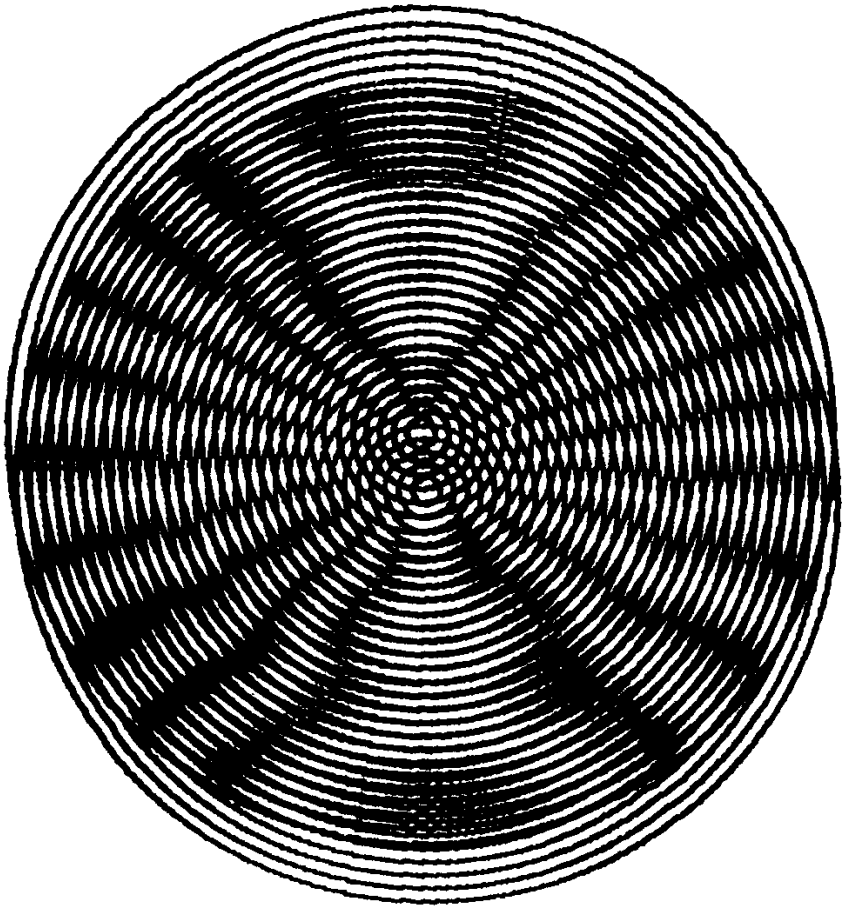
Laser light scattering of a transparent particle



Projected fringe pattern of a particle

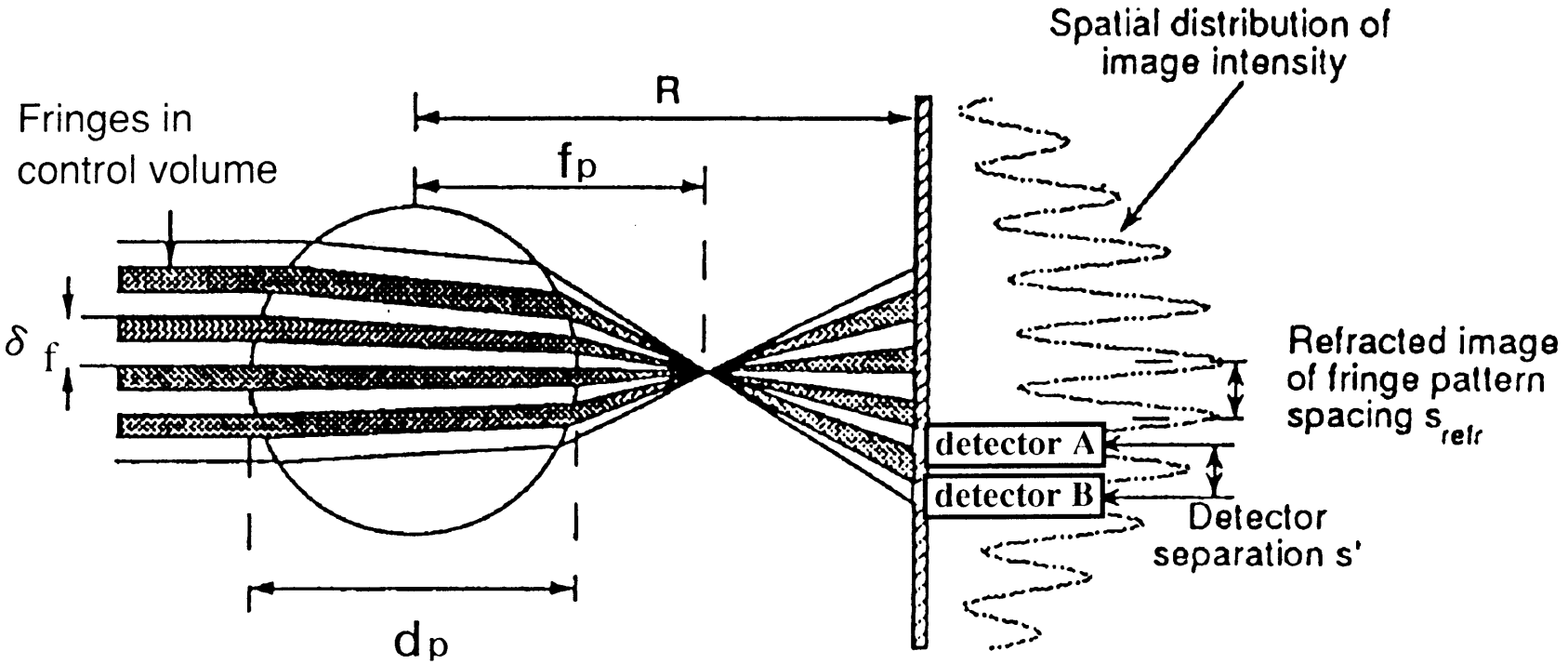


Large droplet



Small droplet

Principle of diameter measurement

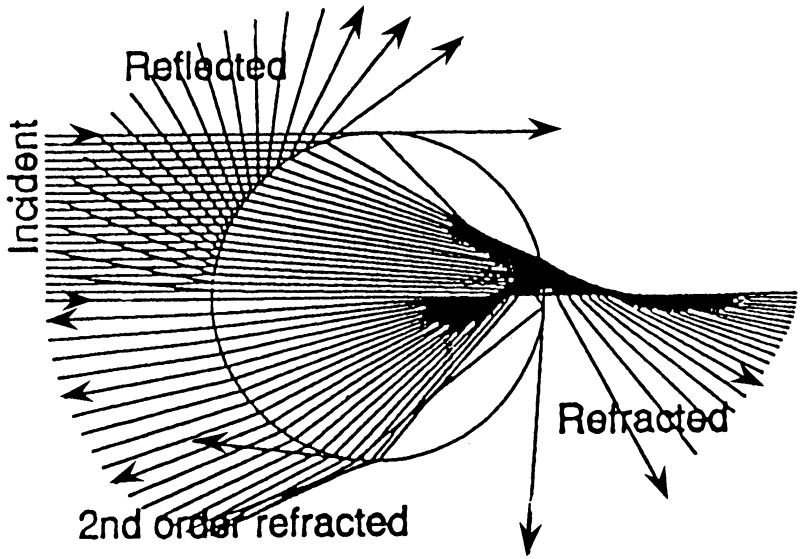


$$V = \delta_f \cdot f_d \qquad f_p = \frac{n}{n-1} \cdot \frac{d_p}{4}$$

$$S_{refr} \cong (R - f_p)\frac{\delta_f}{f_p} \cong R\frac{\delta_f}{f_p}$$

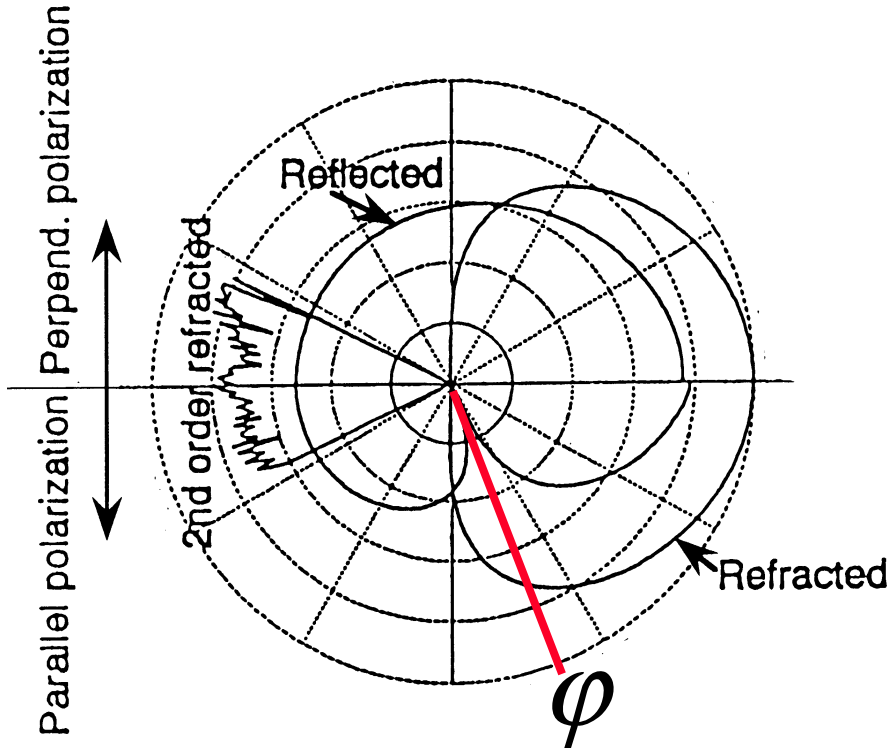
$$\Phi = 2\pi \frac{S'}{S_{refr}} = 2\pi S' \frac{n}{n-1}\frac{d_p}{4}\frac{1}{R\delta_f}$$

Selection of receiving angle

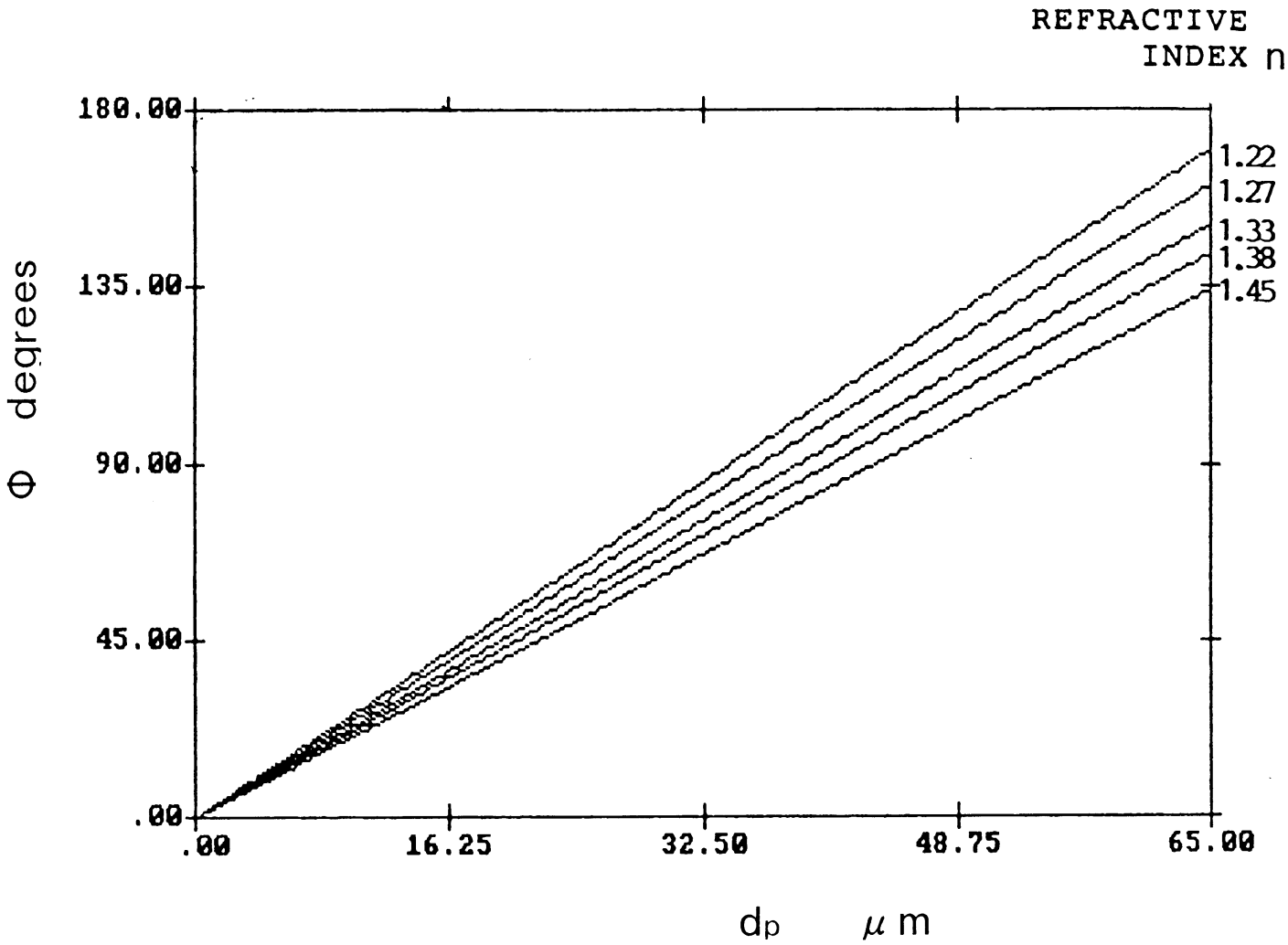


$$\varphi = 180° - 2\varphi_B$$

$$\varphi_B = \tan^{-1} n$$



Phase-diameter relationship of different refractive index particle



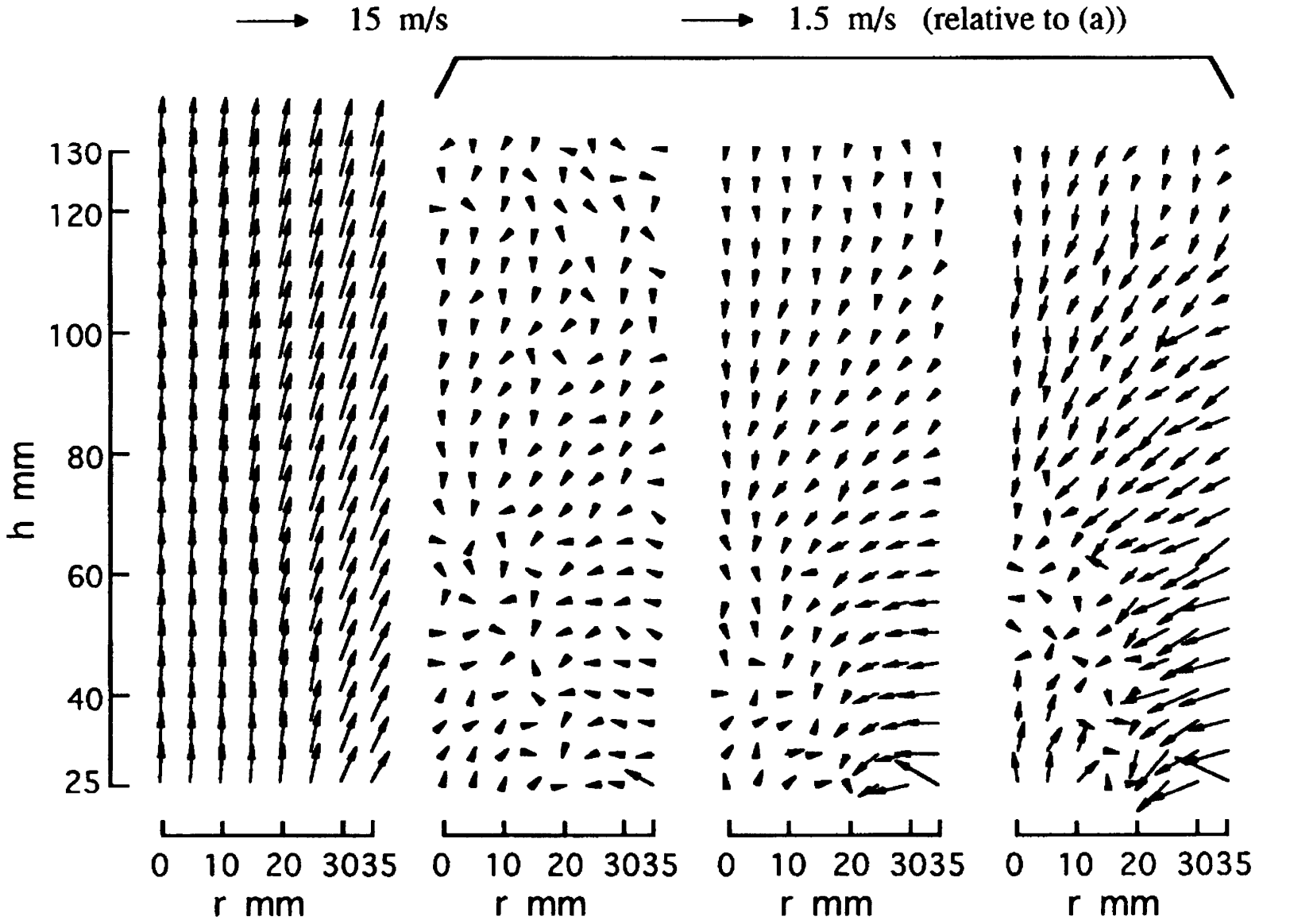
Eykman Equation

$$\frac{n^2-1}{n+0.4}=C\cdot\rho$$

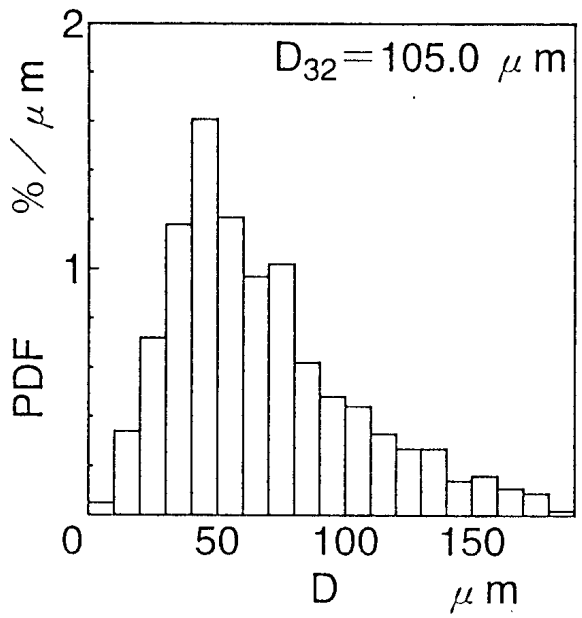
Specification of PDA

Probe:	**Focal length**	**310**	**mm**
	Spot diameter	**145**	**μm**
	Fringe spacing	**5.0**	**μm**
	Fringe number	**29**	
Range:	**Maximum diameter**	**96.5**	**μm**
	Maximum velocity	**15.0**	**m/s**
	Minimum velocity	**-5.0**	**m/s**
Focal length of receiving optics		**310**	**mm**
Wavelength of laser beam		**514.5**	**nm**
Bandwidth of signal processor		**4**	**MHz**
Frequency shift		**40**	**MHz**

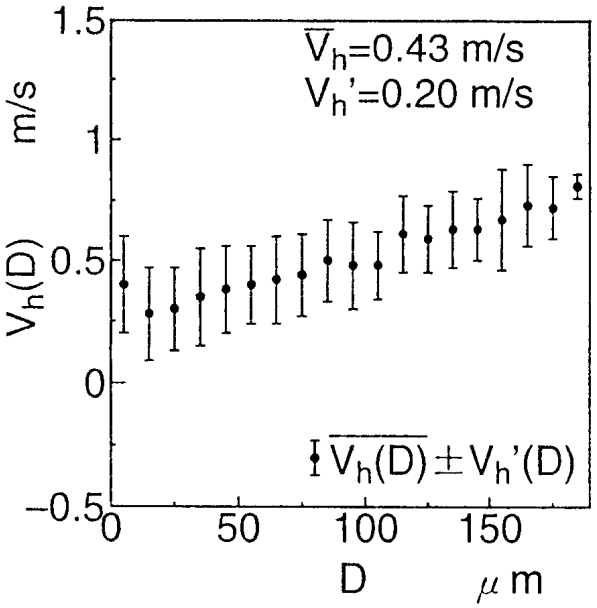
Size-classified droplet velocity vectors in flame



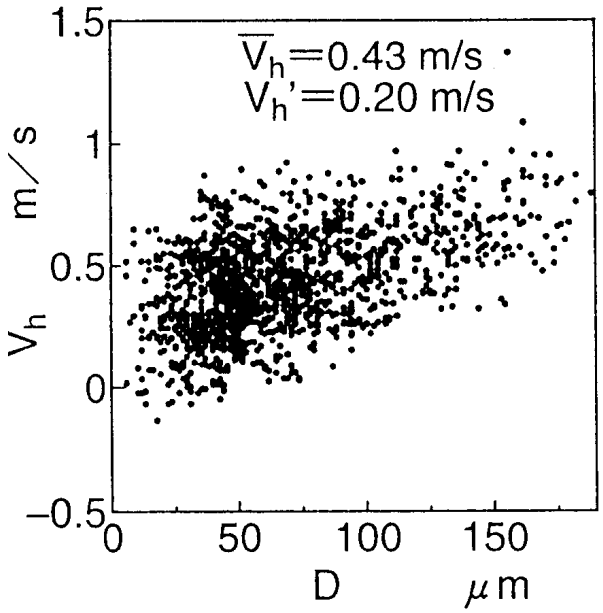
Examples of PDA Results



Droplet Size Distribution

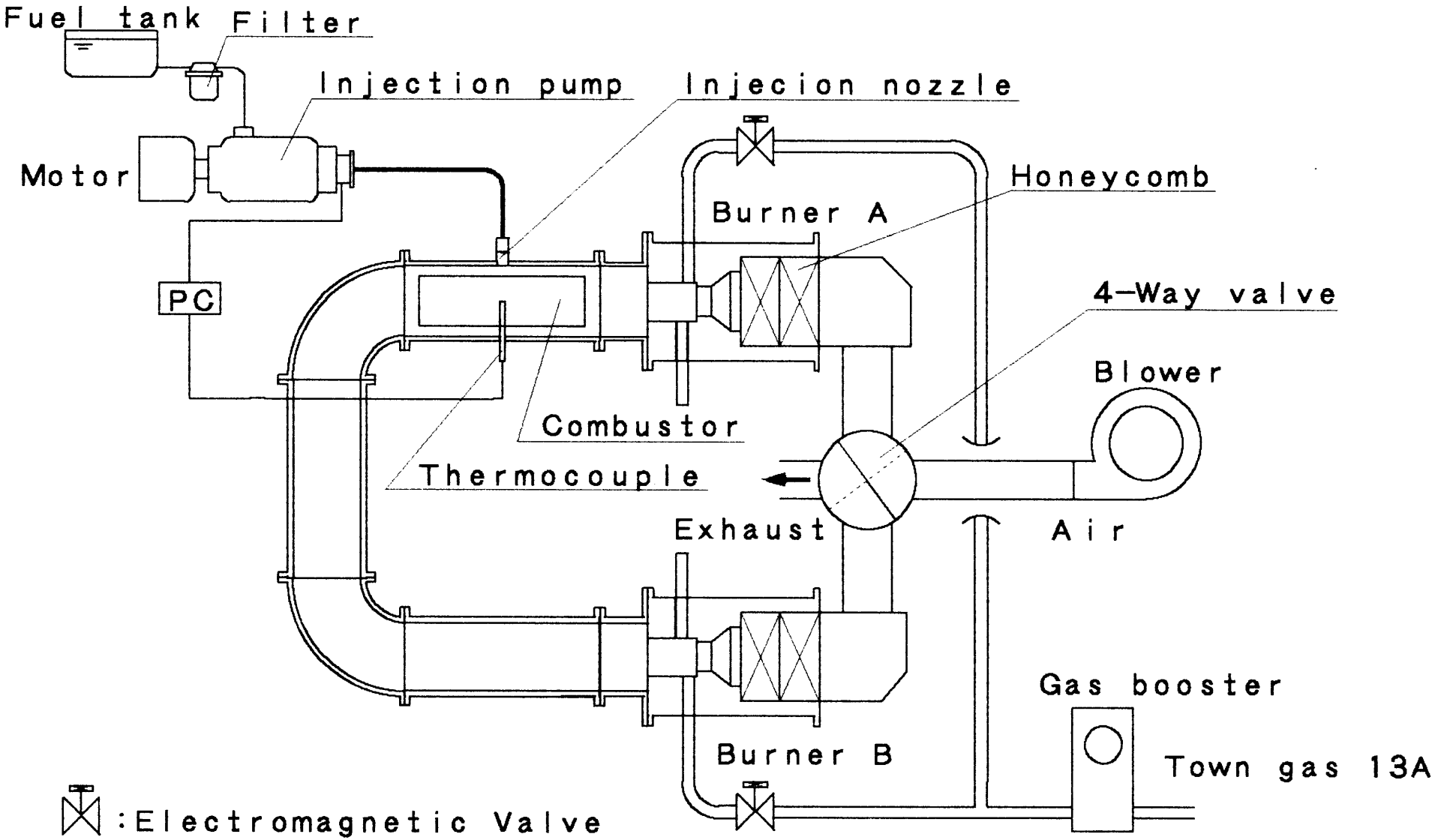


Size-Classified Velocity

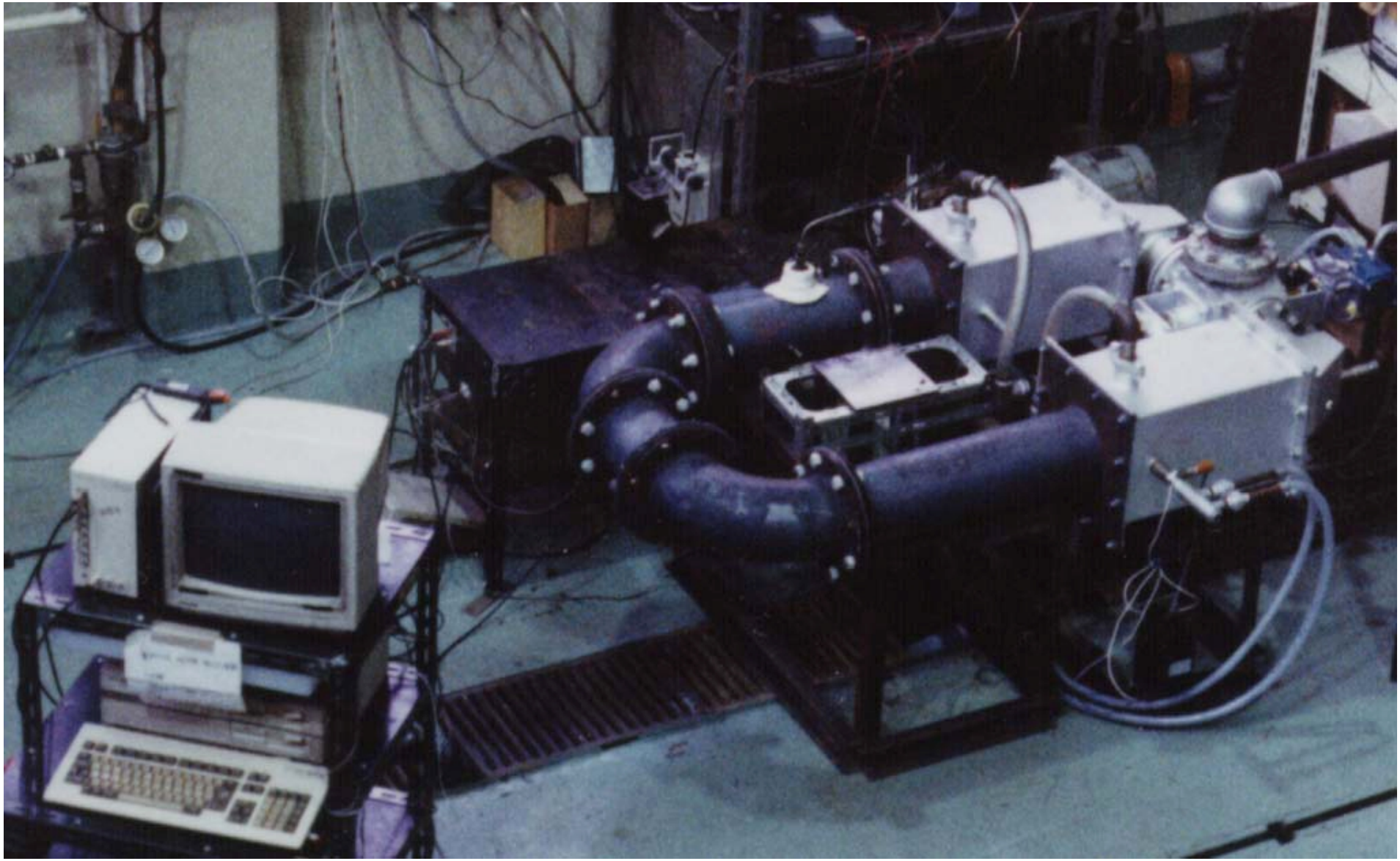


Correlation of D and V_h

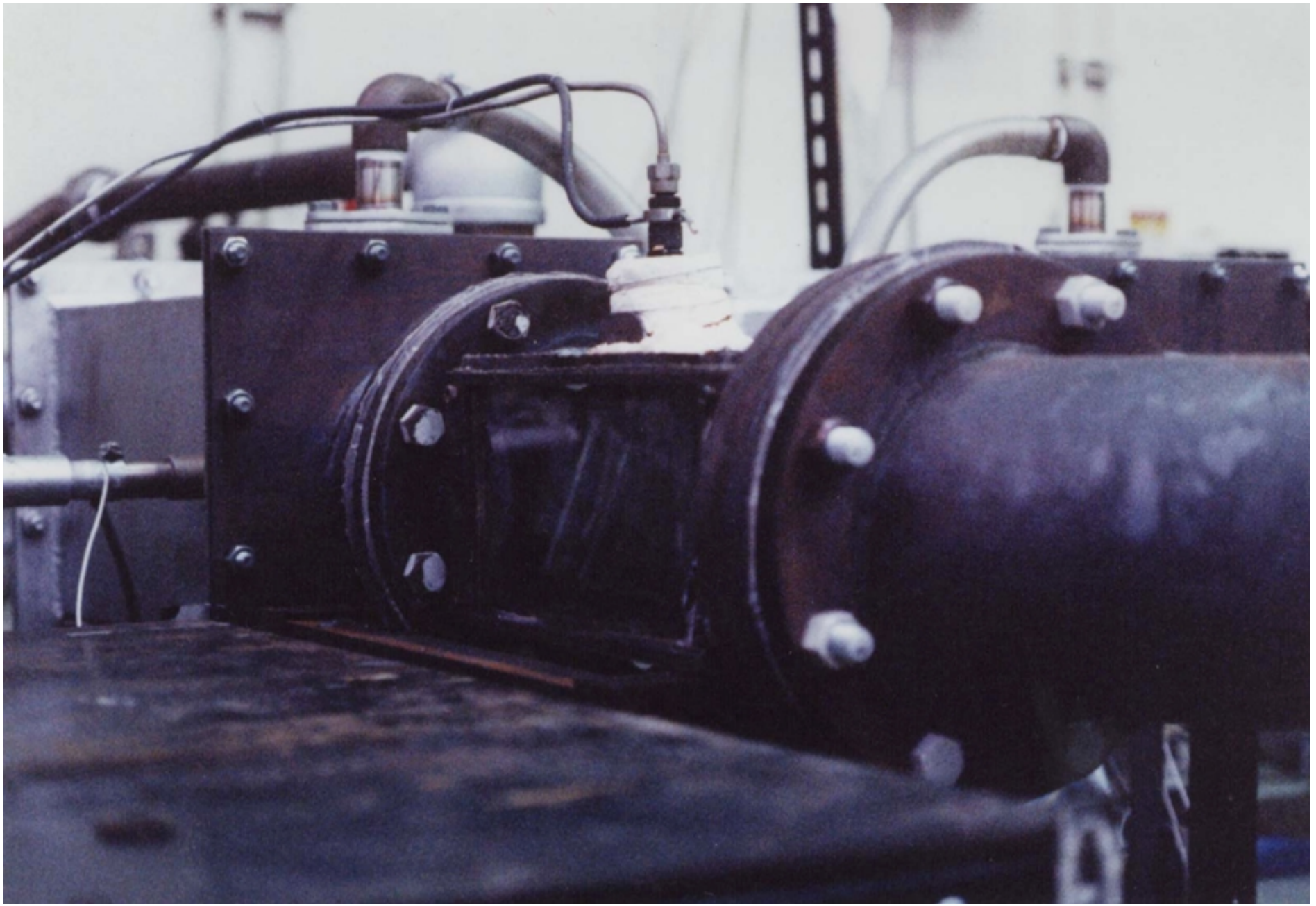
Ignition delay of spray



Photograph of experimental apparatus



Photograph of measurement section



Spray flame in stagnation flow