Preface

This book is the result of two decades of research work which started with an accidental observation. One of my students, Dipl. phys. Volkmar Lenz, noticed that the speckle pattern of laser light scattered by a cuvette containing diluted milk performed a strange motion every time he came near the cuvette with his thumb. After thinking about this effect we came to the conclusion that this motion can only be caused by scattering particles with different velocities, as in the case of the diffraction pattern of an optical grating: A linear motion of the grating does not change the pattern whereas a rotation of the grating does. The observed speckle motion could then be explained qualitatively as produced by the inhomogeneous velocity of the convection within the cuvette which was produced by the heat of the thumb.

The theoretical treatment of this effect revealed that the velocity gradient of the light scattering medium is responsible for the speckle motion. The idea to use this effect for developing measurement techniques for velocity gradients arose almost immediately. For that purpose we had to develop not only experimental set-ups to measure the pattern velocity but also the theory which describes the connection between this velocity and the velocity gradient. The result of this work together with the description of a method developed by another group forms the contents of this book.

I am indebted to the students who worked in my laboratory and developed the measurement techniques. These were, in temporal order, Dr. Christoph Keveloh, Dr. Ulrich Schmidt, Dr. Holger Breyer, Dr. Hartmut Kriegs, and Dipl. phys. Rainer Schulz. They also read the manuscript and made lots of helpful comments which I gratefully accepted. I gratefully acknowledge the help of Dr. Matthias Renken in the production of many of the figures in the first part of the book. I furthermore thank Mr. Barry Rankin and my daughter Susanne Staude who helped substantially in the translation of the German manuscript. The final form of the manuscript was carefully read by Prof. Wilhelm Behrens whom I thank very much.

Finally, I would like to see that this book raises interest in the field of velocity gradient measurements and causes researchers to apply and develop measurements methods along the lines described here and to obtain new and interesting results.

Bremen, August 2001 *Wilfried Staude*

Symbols

$\boldsymbol{x}$	vector
$\hat{X}$	tensor
$\hat{X}^T$	transpose of a tensor
$< x >$	ensemble average
$\overline{x}$	time average
x^+	dimensionless quantity
$\boldsymbol{\nabla}$	nabla operator : $\boldsymbol{\nabla} = (\frac{\partial}{\partial x}, \frac{\partial}{\partial y}, \frac{\partial}{\partial z})$
b_i	image width of lens i
c_S	normalized correlation function of stochastic process S
d_S	diameter of scattering area or scattering volume
d_C	diameter of coherence area
d_s	diameter of a volume specified by s
$\boldsymbol{e}$	unit-vector
$\boldsymbol{e}_P$	unit-vector in the direction in which the pattern velocity is measured
$\boldsymbol{e}_i$	unit-vector in the direction of the illuminating light wave
$\boldsymbol{e}_o$	unit-vector denoting the considered component of the scattered light wave
f	focal length of a lens
f_W	weight function
g_i	object width of lens i
i	imaginary unit
	index
j, k, l, m, n	indices
n_x	refractive index of medium x
$\boldsymbol{k}$	wave vector
$\boldsymbol{k}_i$	wave vector of illuminating light wave
$\boldsymbol{k}_o$	wave vector of a component of the scattered light wave
$\boldsymbol{q}$	scattering vector
$\boldsymbol{r}$	location vector

t	time variable
$\boldsymbol{u}$	velocity of the fluid
$\boldsymbol{v}$	velocity of the pattern of the scattered light
$w(z), w_o$	radius of a Gaussian beam
u, v, w	x-, y-, and z-components of the fluid velocity
x, y, z	orthogonal components of the location vector
A	area
C_S	correlation function of stochastic process S
D	diffusion coefficient
D_T	thermal diffusion constant
$\hat{E}$	unit matrix
$\boldsymbol{E}$	electric field
G	spatial aperture function
I	light intensity
K	turbulent energy
L	distance
N	number
$\hat{O}$	orthogonal rotation matrix
$Q(I, n)$	photon count probaility
P^1	probability density of first order
P^2	joint probability density
P_c	conditional probability density
$R(z)$	radius of curvature of a light wave
R_e	Reynolds number
S	stochastic process
T	time interval
Y	expression in the DSS technique
Z	expression in the DSS technique
α	angle, phase
β	angle, phase
	parameter describing detector sensitivity
γ_W	wall gradient
δ	distance of two detectors
η	quantum efficiency
η_S	shear viscosity
η_t	turbulent viscosity
λ	wavelength
$\boldsymbol{\kappa}$	wave vector
ν	index
ν_S	kinematic viscosity
ν_{12}	ratio of refractive indices of two media
ϕ	angle, phase
ψ	angle, phase
σ	scattering factor
$\hat{\sigma}$	stress tensor

τ	time variable
τ_c	correlation time
τ_S	sample time
τ_D	time interval
$\boldsymbol{\rho}$	location vector
ω	frequency
$\boldsymbol{\omega}$	vorticity
$\boldsymbol{\omega}_P$	angular velocity of the scattered light wave
$\hat{\Gamma}$	velocity gradient tensor