

LASER ANEMOMETER OPTIMIZATION

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The purpose of this section of the project is to design, construct, and test laser anemometer configurations for Hot Section velocity measurements. Optimizing the laser anemometer system necessarily included the data processing algorithms used. It is felt that the requirements here are too demanding for standard laser anemometer systems.

Relevant Hot Section Properties

- 1) High temperature with possibility of a large background radiation
- 2) Difficult optical access
- 3) Large flow velocity variation - especially in the rotating sections
- 4) Presence of solid surfaces that generate spurious reflections
- 5) Low seed particle density

The laser anemometer works by detecting light scattered by small particles entrained in a flow as they pass through a well-defined region of space. This region is illuminated by a pattern of light (see Figures 1 and 2). The measurement problem is to detect the "signature" of a particle as it appears and to extract the velocity from that signature. Any detected light that is not coming from a particle within the desired region, interferes with the measurement. The desire to make measurements near walls makes it essential to design a system that is particularly effective at rejecting light coming from outside the wanted region (see Figure 3). The optical system must be designed so that all expected flow angle fluctuations generate a recognizable, measurable signature. The rest of the detector system must be robust enough to deal with the wide range of velocities encountered in rotating systems.

In the past few years, the laser scattering group at Risø, Denmark, under the direction of Lars Lading, and the laser scattering group at Case Western Reserve University under Robert V. Edwards, have worked together to develop procedures for the optimal design of laser anemometry systems. The principles derived are being used to design the system for Hot Section measurements.

The system decided on is a so-called time-of-flight anemometer with elliptical spots (see Figures 4 and 5). In terms of laser light utilization, this optical pattern gives the biggest "bang for the buck". The version of the time-of-flight designed for this project contains two new features:
1) Elliptical spots - This gives the wide flow angle acceptance characteristics of a "fringe" anemometer combined with the superior spatial resolution or a time-of-flight anemometer. 2) Part of the normal time-of-flight signal

processing is performed optically - The velocity information in a time-of-flight is obtained by timing the interval between the pulses from the two spots. In a light-scattering experiment the received pulses always contain noise. Therefore, the position of the peak of the pulse cannot be obtained by differentiation of the signal. The derivative of the noise will overwhelm the signal. It can be shown that the optimal method of detecting the pulse position in the presence of noise involves transforming the received pulse into a "sideways S" pulse as shown in Figure 6.

The prototype for the Hot Section measurements uses a unique optical coding to transform the pulse into the optimal form for pulse position sensing (See Figures 7 and 8). Heretofore, this required rather complex and inflexible electronic circuitry. This optical processor is intrinsically free from some of the errors to which the electronic circuits were prone.

The optical prototype has been constructed and is in the initial phase of testing. In the next year, the full system will be built and tested for accuracy, robustness and spatial discrimination. The theory from which the system was derived is being written up for publication and should appear in the next year.

Recent Publications

1. Edwards, R. V.: A New Look at Particle Statistics in Laser Anemometer Measurements, J. Fld. Mech. Vol. 105, pp. 317-325, 1981.
2. Edwards, R. V., Lading, L. and Jensen, A. S.: Optimizing and Comparing Laser Anemometers, International Symposium on Applications of Laser-Doppler Anemometry to Fluid Mechanics, Lisbon, Portugal, July 1982.
3. Edwards, R. V. and Jensen, A. S.: Output Statistics of Laser Anemometers in Sparsely Seeded Flows, International Symposium on Applications of Laser-Doppler Anemometry to Fluid Mechanics, Lisbon, Portugal, July 1982.

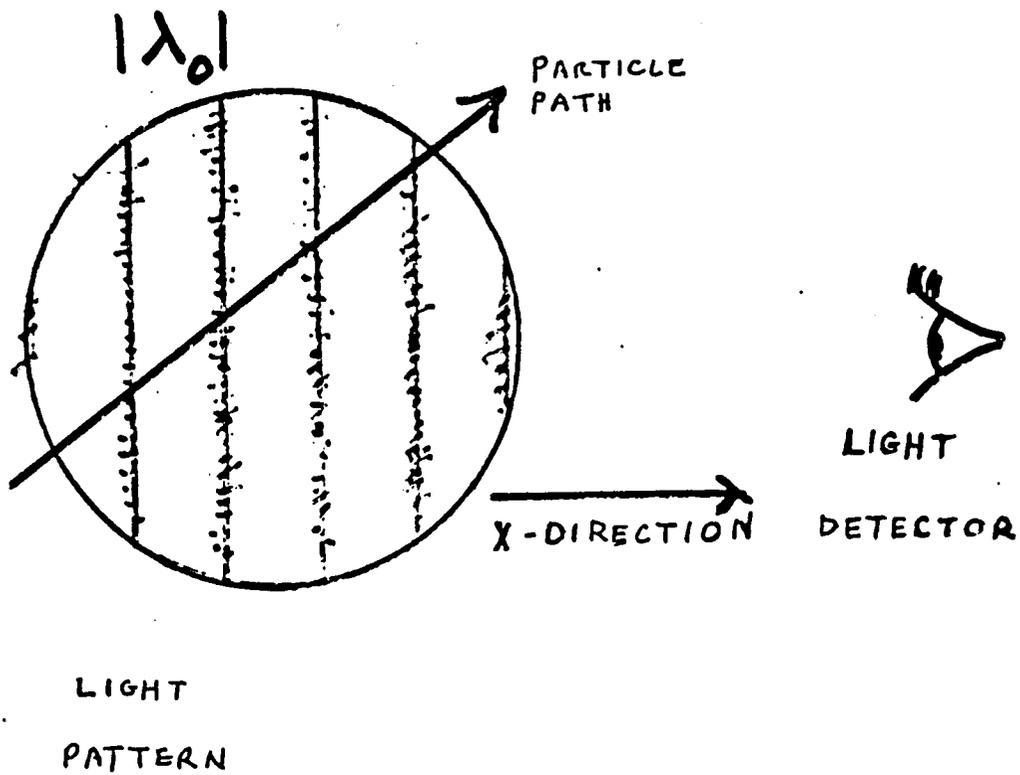
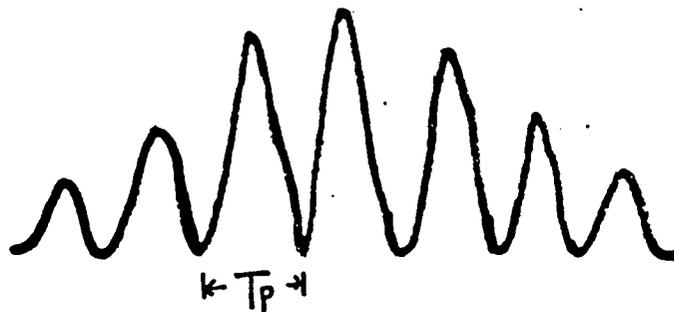


Figure 1

PARTICLE "SIGNATURE"



IN X DIRECTION , $V_{Px} T_p = \lambda_0$.

λ_0 IS KNOWN , SO MEASURING T_p
GIVES X - COMPONENT OF PARTICLE VELOCITY.

Figure 2

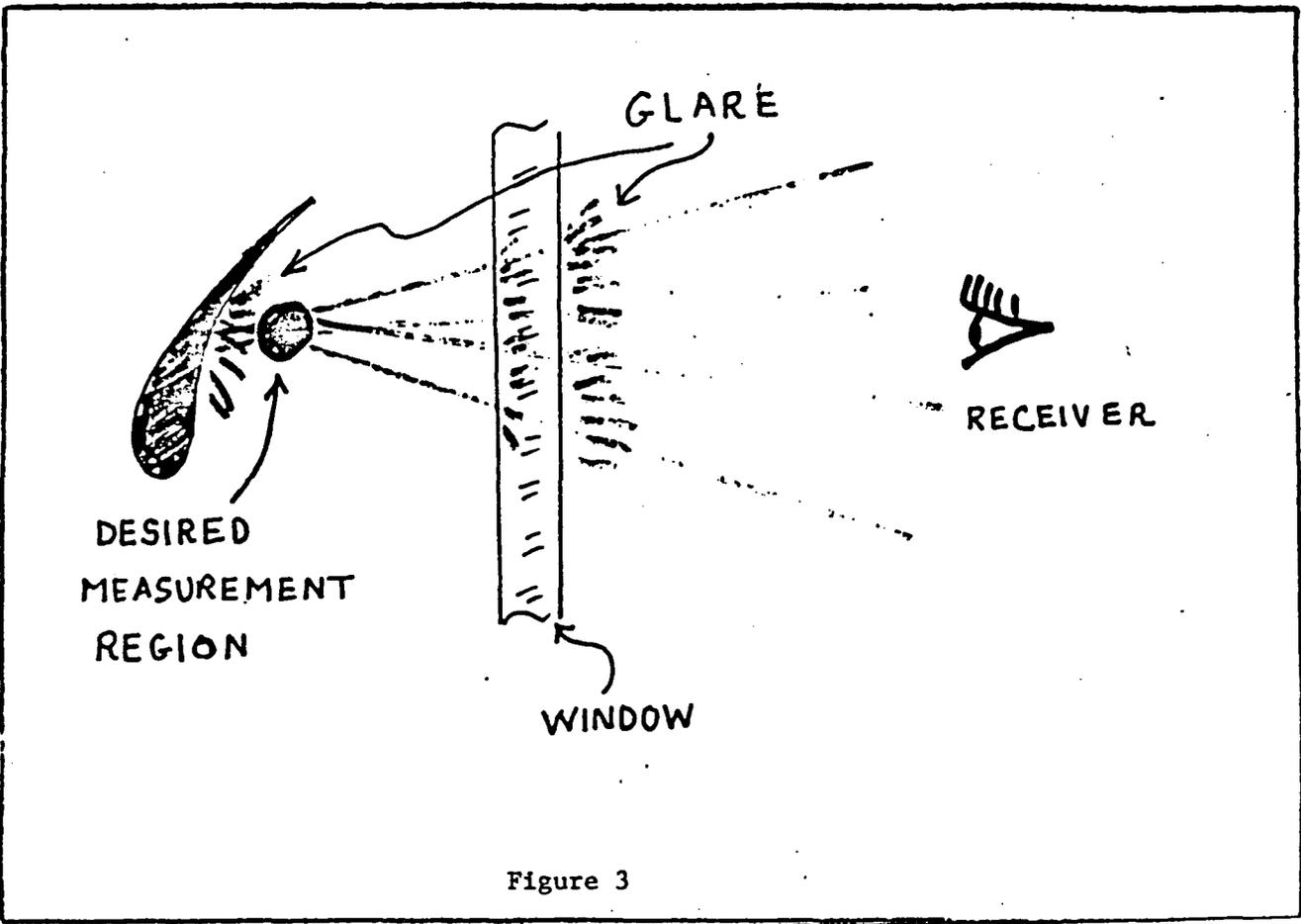


Figure 3

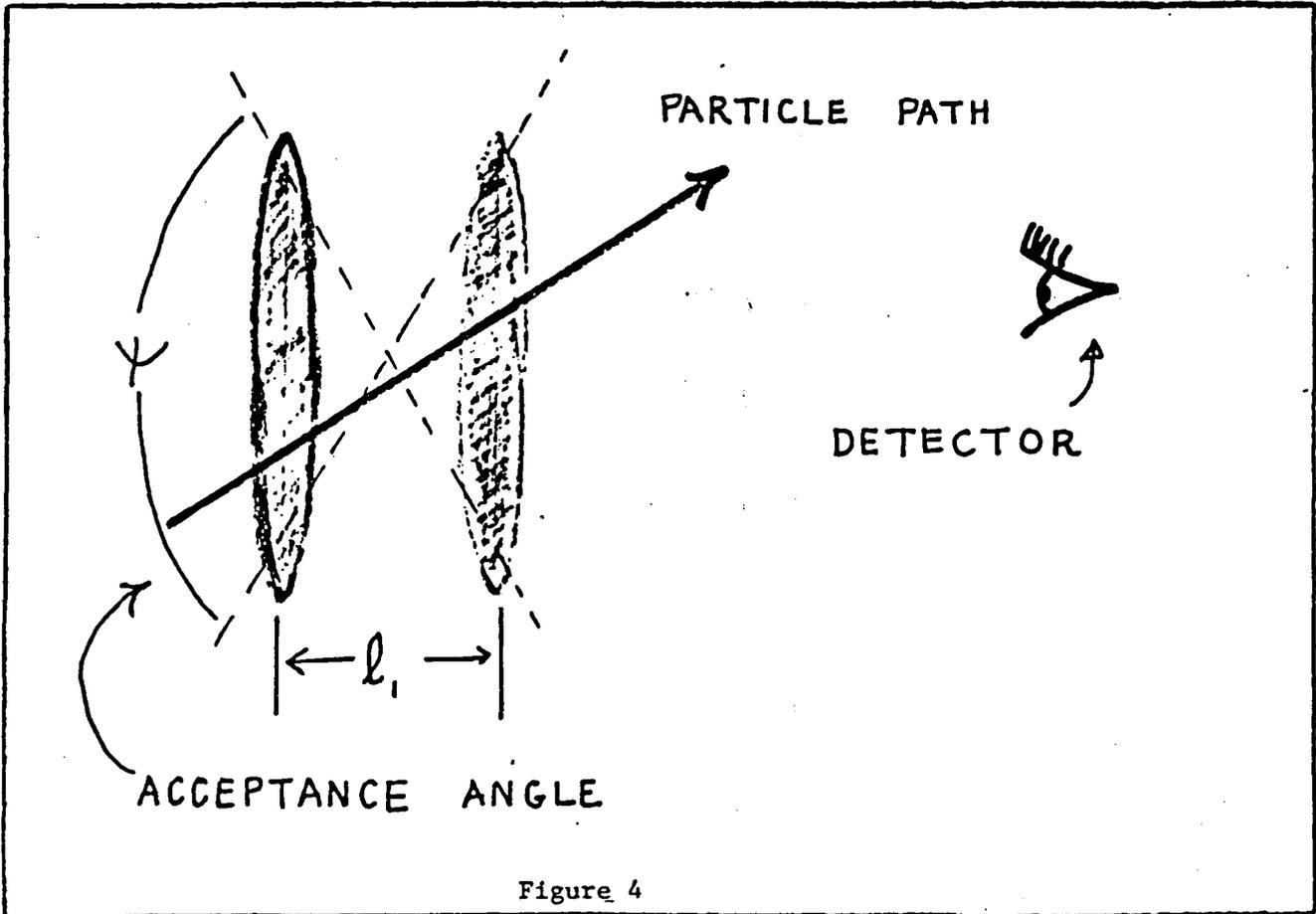
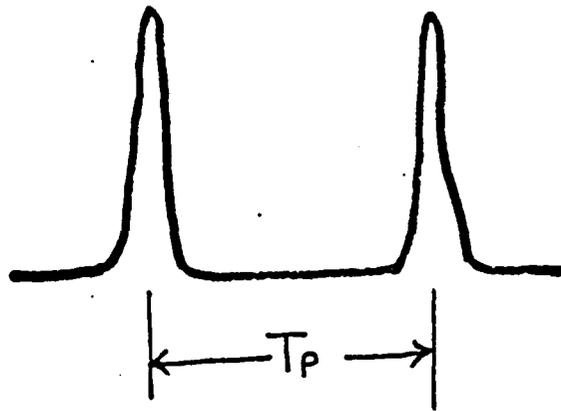


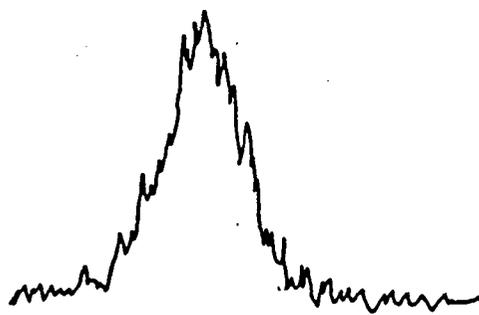
Figure 4

"SIGNATURE"

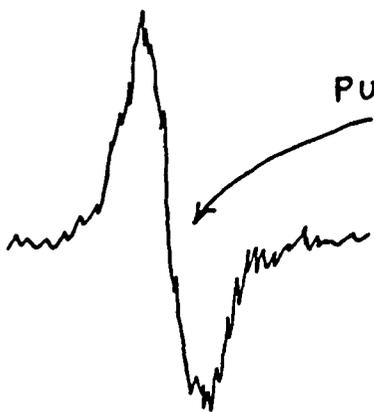


$$V_{Px} = \frac{l_1}{T_P}$$

Figure 5



NOISY PULSE



PULSE POSITION

TRANSFORMED
PULSE

Figure 6

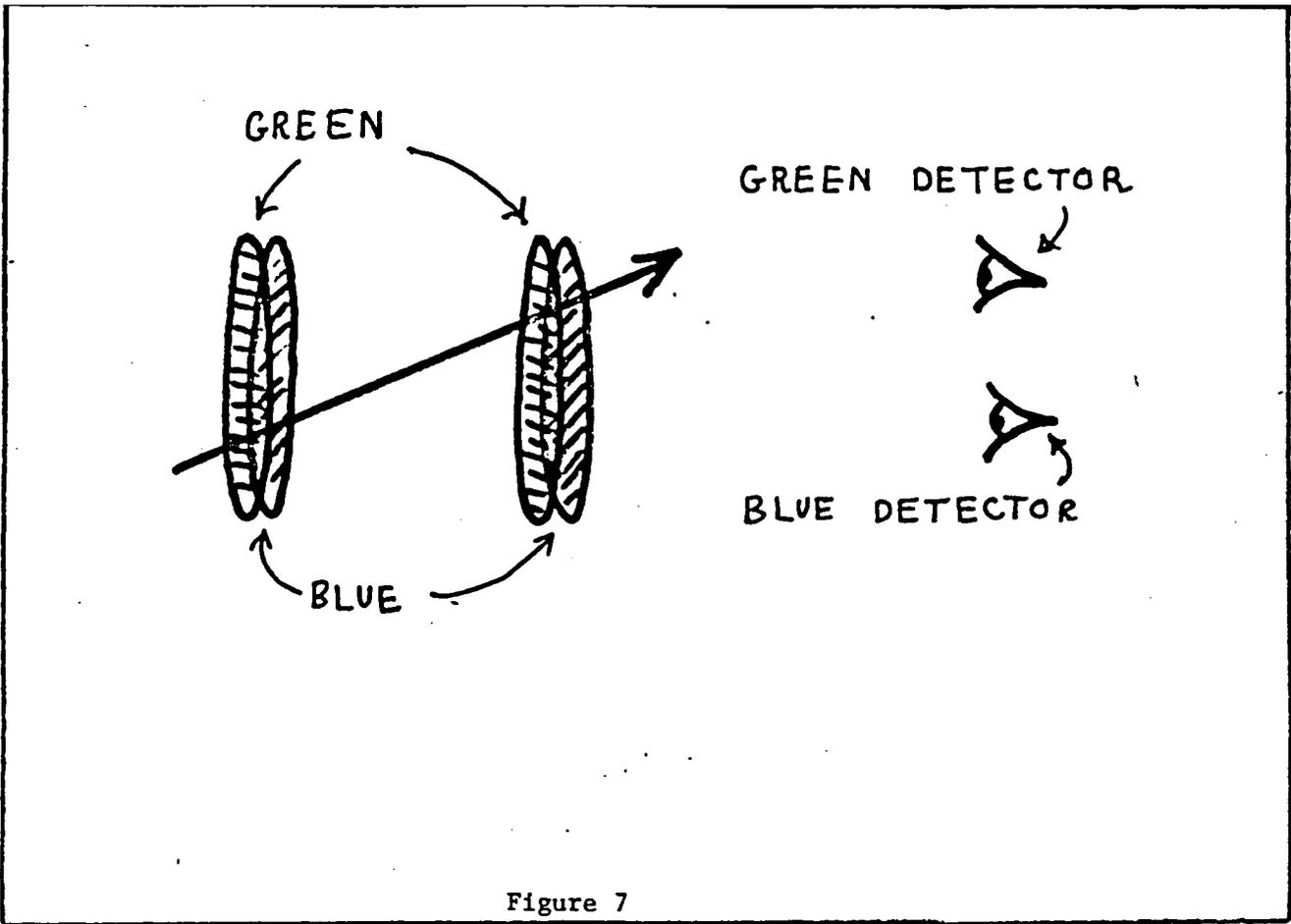


Figure 7

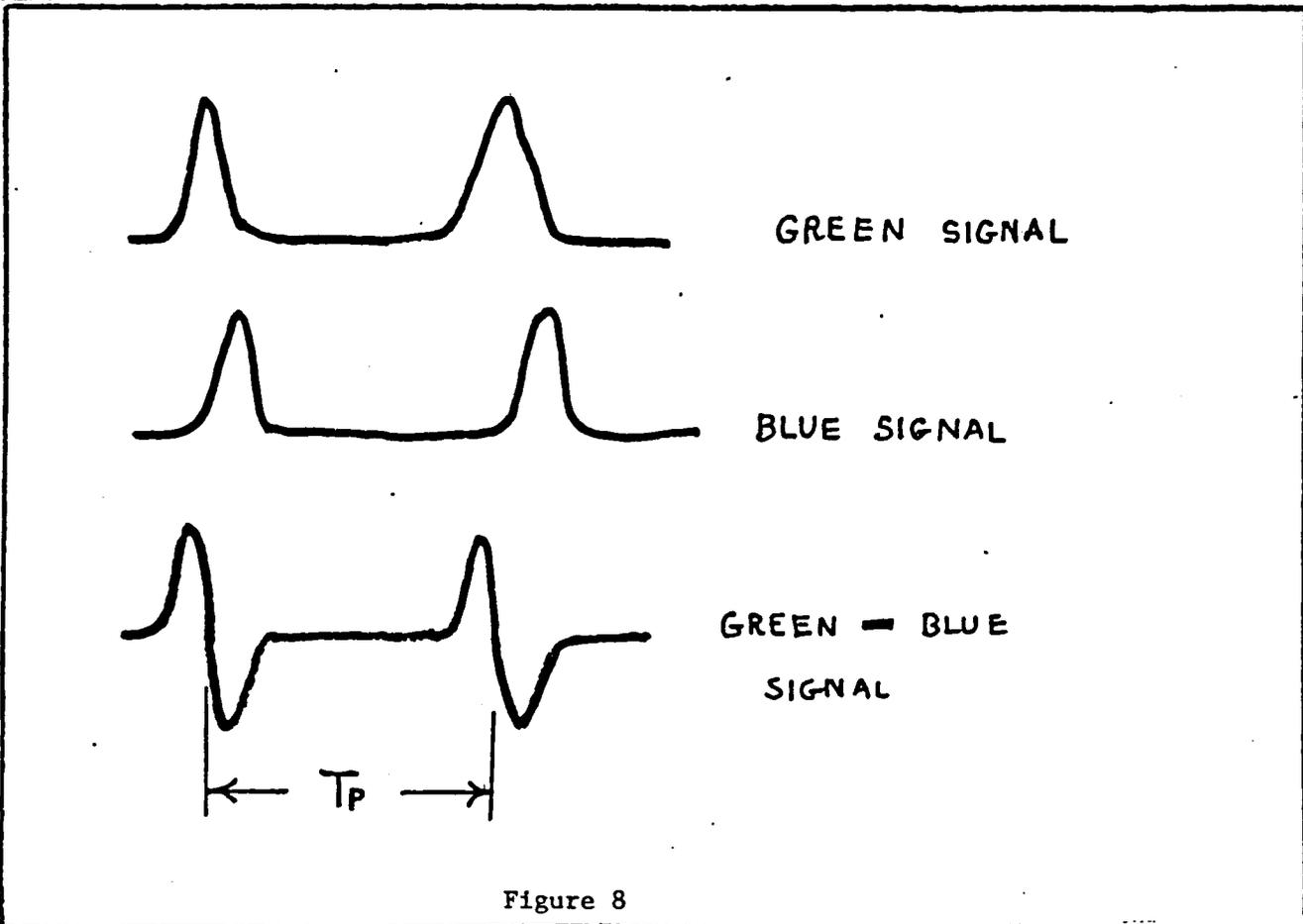


Figure 8