

# microS™

## A Micro-Optical Sublayer Profilometer and Shear Stress Sensor

The microS is the world's first optical sensor for the direct measurement of the boundary sublayer velocity gradient and wall shear stress. Made possible by patented technology, it is capable of performing measurements just 75  $\mu\text{m}$  or 135  $\mu\text{m}$  from its face (in air) within a probe volume of only 30 by 30 by 15 microns. Designed to be flush-mounted to the surface in question, it is absolutely nonintrusive, has no moving parts, and can measure flow direction along with the gradient. The probe itself (the face) is only 0.375" (9.5 mm) in diameter and 1.18" (30 mm) long so it can be installed in even the tightest of spaces. Sensor electronics can be stowed safely away from the experiment, and since all the sensitive optics are fixed within the probe, no user alignment is necessary.

The microS is based on technology developed at the California Institute of Technology and NASA's Jet Propulsion Laboratories. Today there are customers around the world in academic, industrial, and research settings enjoying the reliability and ease of use of MSE's microS.

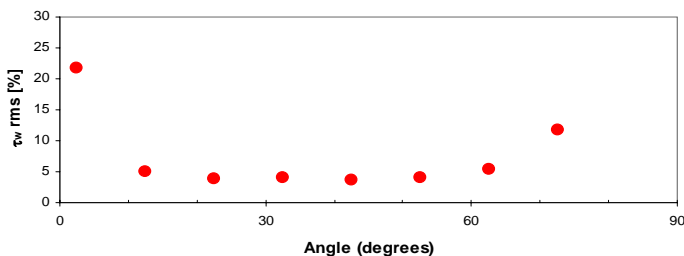
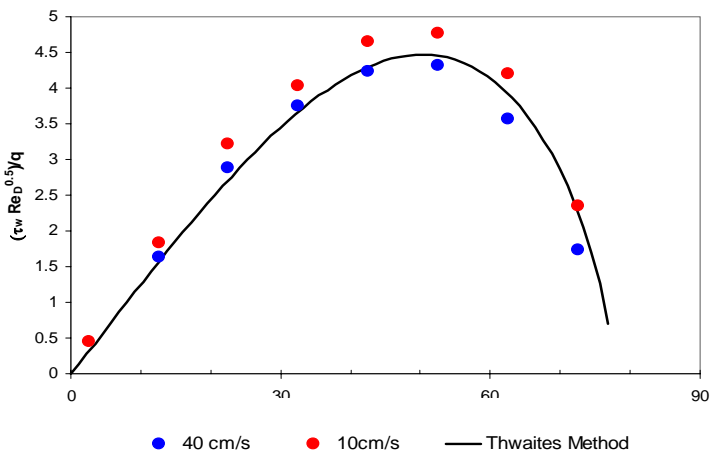


### The microS System

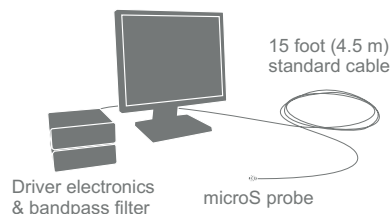
The microS System consists of a transceiver probe, driver electronics, bandpass filter, and *BP-microS Burst Processor* acquisition hardware and software. Optionally, the system can be ordered with a computer with the hardware and software installed and tested by MSE technicians.

The microS System is a standalone system – no other lasers or optics are required. Simply place the electronics at a convenient distance to the acquisition computer and install your probe at the desired location. A 15-foot (4.5 m) cable is standard (longer lengths are optional). The Burst Processor software collects data and presents flow statistics.

The microS System is at home either in the lab or at the field; its robust construction makes it perfect for harsh environments.



Above, top: shear stress on the surface of a cylinder in a water channel flow as a function of angle along the cylinder (comparison of microS measurements and theory). Bottom: the RMS of the shear stress in the 10cm/sec case, showing a rise at the stagnation and separation points.



\*17" LCD monitor for scale



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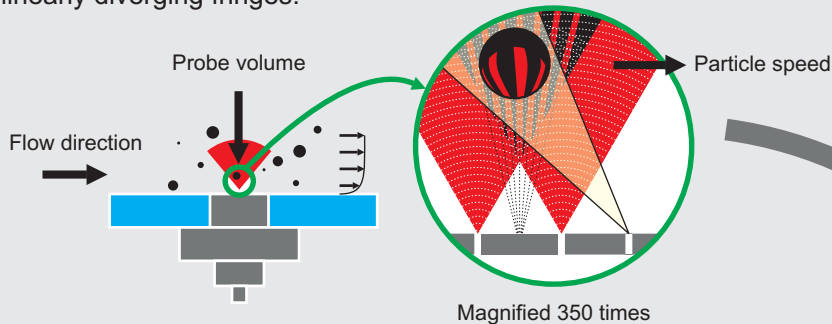
## A Micro-Optical Sublayer Profilometer and Shear Stress Sensor

### The microS Concept

MSE's microS probe is similar to a standard LDV in that it uses the interference pattern of two coherent beams as the illumination. Unlike an LDV, where aberrations are kept to a minimum to make the fringes as straight as possible, microS measurements are made possible by the interference pattern of two *cylindrical* waves which form a diverging fringe pattern, first demonstrated in [1]. Since the probe volume is only 30  $\mu\text{m}$  tall, the velocity profile in the region can be assumed to be linear. If  $y$  is the distance from the wall, then  $u = Cy$  where  $C$  is the slope,  $\partial u/\partial y$ , of the [linear] velocity profile. The spacing between fringes at a particular height  $y$  can be written as  $\delta = ky$  where  $k$  is the constant obtained from calibration of the probe. A particle passing through the probe volume at a particular height  $y$  will reflect the fringes such that the receiver sees a sinusoid intensity variation with frequency  $f = u(y)/d(y) = C/k$ . Since  $k$  is known from calibration of the probe,  $C$  can be determined, and since the probe volume is microscopically small and close to the wall, *the microS directly measures the derivative of the velocity profile at the wall*. Shear stress can then be calculated by multiplying the measurement by the dynamic viscosity of the fluid. Additionally, the microS's fringes are tilted relative to the normal so that flow direction can also be detected.

1. Naqwi, A. A. & W. C. Reynolds (1987), "Dual cylindrical wave laser-Doppler method for measurement of skin friction in fluid flow", NASA STI/Recon Technical Report N 87

The interference pattern of two coherent cylindrical waves is used to create a set of linearly diverging fringes.

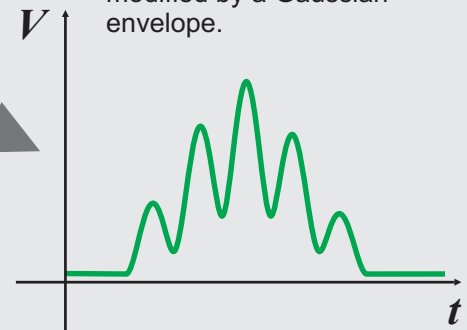


The probe volume is defined by the field of view of the receiver (shown in yellow). As a particle travels through it, the receiver records the reflection of each fringe off the particle

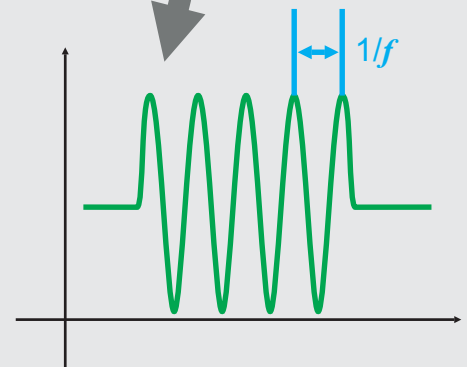
The frequency of the sinusoid is measured (usually by FFT). The fringe divergence is known (from calibration), thus the slope of the velocity profile at the wall can be calculated.

$$du/dy = \text{fringe divergence} \times f$$

As seen by the photodetector, the light signal is a sinusoid (corresponding to the regions of constructive interference) modified by a Gaussian envelope.



The sinusoid is isolated by a bandpass frequency filter.



U.S. Patents Nos. 6,717,172 and 6,956,230



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