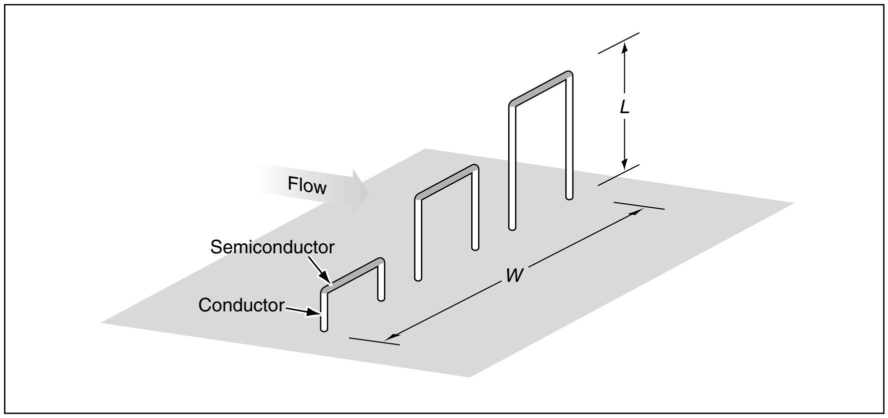
Nanoscale Hot-Wire Probes for Boundary-Layer Flows

Flow parameters near walls would be measured with unprecedented resolution.

Langley Research Center, Hampton, Virginia

Hot-wire probes having dimensions of the order of nanometers have been proposed for measuring temperatures (and possibly velocities) in boundary-layer flows at spatial resolutions much finer and distances from walls much smaller than have been possible heretofore. The achievable resolutions and minimum distances are expected to be of the order of tens of nanometers — much less than a typical mean free path of a molecule and much less than the thickness of a typical flow boundary layer in air at standard temperature and pressure. An additional benefit of the small scale of these probes is that they would perturb the measured flows less than do larger probes.

The hot-wire components of the probes would likely be made from semiconducting carbon nanotubes or ropes of such nanotubes. According to one design concept, a probe would comprise a single nanotube or rope of nanotubes laid out on the surface of an insulating substrate between two metallic wires. According to another design concept, a nanotube or rope of nanotubes would be electrically connected and held a short distance away from the substrate surface by stringing it between two metal electrodes. According to a third concept, a semiconducting nanotube or rope of nanotubes would be strung between the tips of two protruding electrodes made of fully conducting nanotubes or ropes of nanotubes. The figure depicts an array of such probes that could be used to gather data at several distances from a wall.



Nanoscale Hot-Wire Probes would be used to characterize a flow at several distances from a surface, typically ranging from tens of nanometers to a few micrometers. The lateral dimension, *W*, of the array of probes would be made much less than the expected characteristic dimension of lateral nonuniformity of the flow. The distance from the surface (*L*) of the most distant probe would be made much less than the expected thickness of the boundary layer of the flow.

It will be necessary to develop techniques for fabricating the probes. It will also be necessary to determine whether the probes will be strong enough to withstand the aerodynamic forces and impacts of micron-sized particles entrained in typical flows of interest.

The proposed probes may or may not be based on the same principles as those of larger hot-wire anemometer and thermometer probes. The potential for unexpected effects (e.g., quantized current or heat flow) in the nanometer size range makes it necessary to perform research on the basic physics of these probes in order to be able to calibrate them, operate them under conditions (e.g., constant current, or constant temperature) that will yield useful data, and interpret their thermal and electrical responses in terms of flow parameters.

This work was done by Ken T. Tedjojuwono and Gregory C. Herring of **Langley Research Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com***.

LAR-16223

Theodolite With CCD Camera for Safe Measurement of Laser-Beam Pointing

The risk of looking directly at the laser beam is eliminated.

Goddard Space Flight Center, Greenbelt, Maryland

The simple addition of a charge-coupled-device (CCD) camera to a theodolite makes it safe to measure the pointing direction of a laser beam. The present state of the art requires this to be a custom addition because theodolites are manufactured without CCD cameras as standard or even optional equipment.

A theodolite is an alignment telescope equipped with mechanisms to measure the azimuth and elevation angles to the sub-arc-second level. When measuring the angular pointing direction of a Class II laser with a theodolite, one could place a calculated amount of neutral density (ND) filters in front of the theodolite's telescope. One could then safely view and measure the laser's boresight looking through the theodolite's telescope without great risk to one's eyes. This method for a Class II visible wavelength laser is not acceptable to even consider tempting for a Class IV laser and not applicable for an infrared (IR) laser. If one chooses insufficient attenuation or forgets to use the filters, then looking at the laser beam through the theodolite could cause instant blindness.

The CCD camera is already commercially available. It is a small, inexpensive, black-and-white CCD circuit-board-level camera. An interface adaptor was designed and fabricated to mount the camera onto the eyepiece of the specific theodolite's viewing telescope.

Other equipment needed for operation of the camera are power supplies, cables, and a black-and-white television monitor. The picture displayed on the monitor is equivalent to what one would see when looking directly through the theodolite. Again, the additional advantage afforded by a cheap black-and-white CCD camera is that it is sensitive to infrared as well as to visible light. Hence, one can use the camera coupled to a theodolite to measure the pointing of an infrared as well as a visible laser.

Just as it is necessary to use filters to protect the eye when looking directly through the theodolite, it is necessary to use filters to protect the CCD camera and the theodolite's internal optics against damage by the laser beam. One should be aware of the metrology accuracy requirements and use high-quality filters for tighter accuracy metrology requirements. The main benefits of using the CCD camera are being able to view the IR laser and for high-powered lasers, that in the event that one chooses insufficient attenuation or forgets to use the filters, the equipment may be damaged, but there is no injury to the human eye.

This work was done by Julie A. Crooke of **Goddard Space Flight Center**. *For further information, access the Technical Support Package (TSP)* ***free on-line at www.nasatech.com***.

GSC-14469

Efficient Coupling of Lasers to Telescopes With Obscuration

Two proposed techniques offer advantages over two prior techniques.

NASA's Jet Propulsion Laboratory, Pasadena, California

Two techniques have been proposed to increase the efficiency of coupling of light from lasers to Cassegrain telescopes and, in general, telescopes with secondary or tertiary mirror obscuration. The need to increase the efficiency of coupling arises in laser transmitters of lidar and free-space optical communication systems that utilize Cassegrain telescopes. The vignetting caused by the secondary reflector and baffle in such a telescope reduces the transmitted power by a large fraction because (1) the obscured area is central and is a significant fraction of the telescope aperture and (2) the cross-sectional intensity profile of a typical laser beam is Gaussian, so that intensity is greatest in the obscured central area.

In a technique proposed previously for increasing the efficiency of coupling, an optical assembly comprising an axicon device and a folding mirror that would render the solid laser beam annular — in effect, turning the laser beam inside out — so that the laser light would be concentrated into an annular cross section that would not be obscured by the secondary reflector and baffle. Hence, most or all of the light would be coupled into the output beam.

Another prior efficiency-enhancing technique is denoted subaperture illumination. In this technique, the laser beam is displaced laterally with respect to the optical axis of the secondary reflector, such that the beam impinges on an off-axis subaperture of the primary reflector that is not obscured by the secondary reflector and baffle.

The disadvantages of the axicon approach are that it is difficult to fabricate an axicon device and that a small misalignment can strongly degrade its functionality. The disadvantage of the subaperture-illumination approach is that the beam transmitted by the telescope diverges more than it would if the entire aperture were illuminated.

In the first of the techniques now proposed, one would use a folding mirror in combination with a prism beam slicer that would function partly similarly to an axicon. Like an axicon device, the prism slicer would be an afocal refractive and reflective optical element. Like an axicon, the prism beam slicer would utilize both transmitting and reflecting optical surfaces. In the meridional cross-sectional detail in Figure 1, the prism slicer would look exactly like the axicon device.

Unlike the axicon device, the prism beam slicer would not have any curved optical surfaces: this would make it easier to fabricate and would make its functionality less sensitive to misalignment. The prism beam slicer

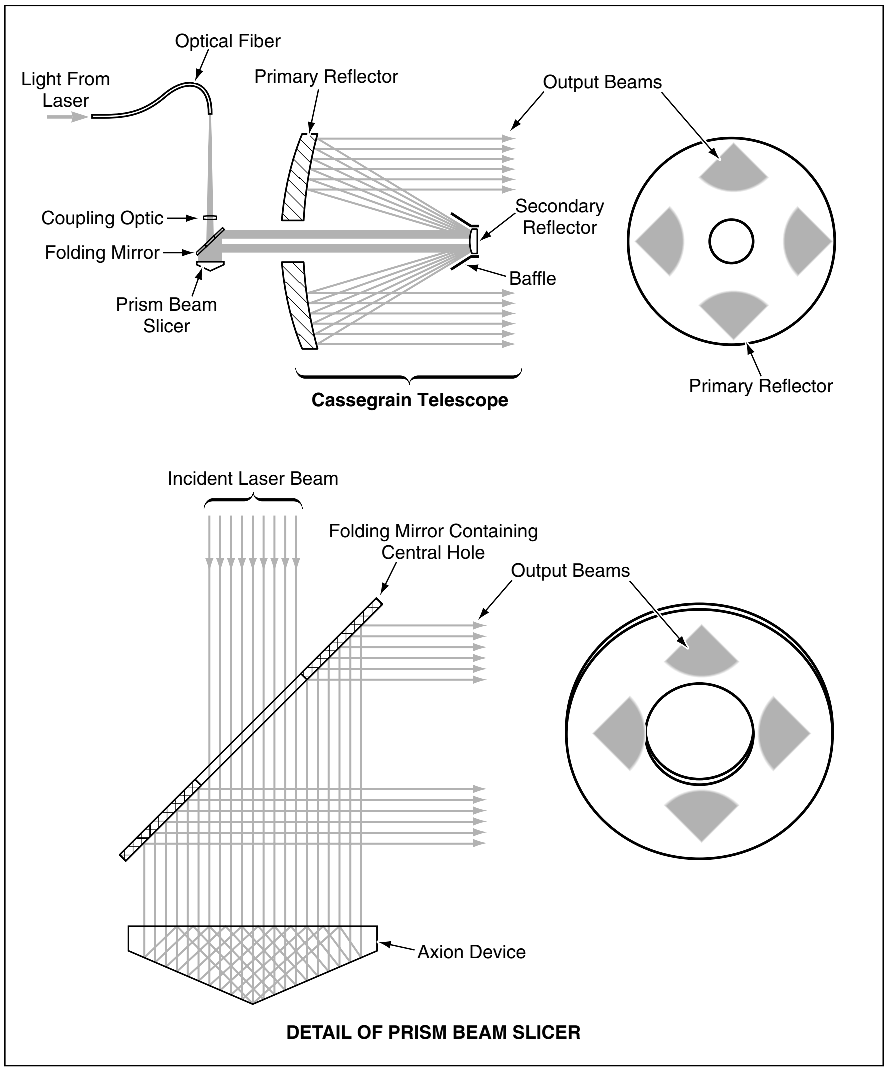


Figure 1. The **Prism Beam Slicer and Folding Mirror** in a laser transmitter would concentrate most of the laser light into off-axis sector-of-circle cross sections that would not be obscured by the secondary reflector and baffle.