Improved Apparatus for Measuring Distance Between Axles

Accuracy is double that of the previous version.

John F. Kennedy Space Center, Florida

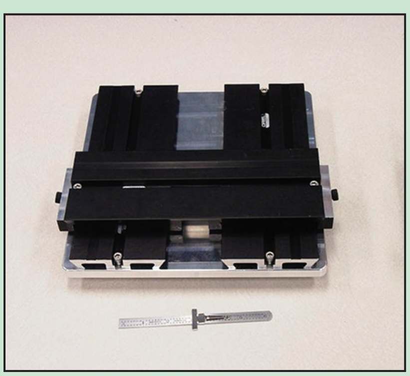
An improved version of an optoelectronic apparatus for measuring distances of the order of tens of feet with an error no larger than a small fraction of an inch (a few millimeters) has been built. Like the previous version, the present improved version of the apparatus is designed to measure the distance ≈66 ft (≈20 m) between the axes of rotation of the front and rear tires of the space shuttle orbiter as it rests in a ground-based processing facility. Like the previous version, the present version could also be adapted for similar purposes in other settings: Examples include measuring perpendicular distance from a wall in a building, placement of architectural foundations, and general alignment and measurement operations.

The previous version was described in "Apparatus and Technique for Measuring Distance Between Axles" (KSC-11980), *NASA Tech Briefs*, Vol. 25, No. 3 (March 2000), page 76. To recapitulate: The major components of the apparatus were (1) a laser range finder and (2) laser line projectors that included two battery-powered laser-diode modules with collimating optics. Each laser-diode module generated a continuous-wave beam with a power of 3 mW at a wavelength of 670 nm. The modules were aimed to point the beams downward, and the beams were made to pass through cylindrical diverging lenses to spread the beams into fans oriented in a nominally vertical plane. The modules were aligned to project coincident vertical lines as viewed from the side and collinear horizontal lines as viewed from the top.

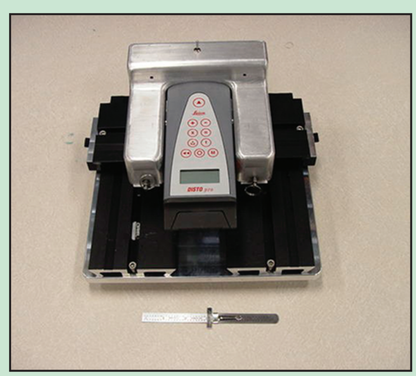
The range finder was aligned precisely with respect to the laser-diode modules and the diverging lenses so that the line of sight of the range finder was perpendicular to the plane defined by the beams from the laser-diode modules. This line of sight was thus nominally horizontal. The apparatus was mounted on a tripod (between the rear tires, in the case of a space shuttle) with the range finder at approximately the height of the distant object of interest (the front tire hub in the case of the space shuttle). Exact matching of heights was not necessary in this application because the geometry was such that even at a height difference as large as a few inches, the difference between the horizontal distance and the measured distance was less than the allowable error of 1/8 in (≈3.2 mm). A target was mounted on the distant object of interest (the front tire hub). The position and orientation of the apparatus were adjusted until the bright lines projected by the fan beams struck the near objects of interest (the hubs of both rear tires in the space-shuttle application) and the beam from the range finder struck the center of the target. Then the distance was measured by use of the range finder, which produced a digital readout. The measurement range was from <1 ft (<0.3 m) to about 300 ft (≈91 m).

The differences between the previous and present versions are the following:

- In the previous version, an optical assembly containing the laser fan-beam generators and the laser range finder was aligned by sliding it on top of a platform attached to a tripod. Because this alignment process proved awkward in practice, rails were added so that the optical assembly could be aligned more precisely and then locked in position. As shown in the left part of the figure, there are two pairs of parallel rails for left/right motion of the assembly and a single rail for forward/backward motion of the assembly.
- The original range finder was replaced with a newer and more accurate one, reducing the measurement error to within a tolerance of 1/16 in. (≈1.6 mm).
- Rechargeable batteries that were used in the original version were found to last only a couple of years. They were replaced by batteries of common nonrechargeable AA-size cells.
- The original tripod was replaced with a more rugged one.
- Hinged plates with simple pull pins


Base Plate With Rails


Optical Assembly


Optical Assembly Mounted on Rails

Parts of the Improved Distance-Measuring Apparatus are shown here, variously, by themselves and assembled with other parts. [A ruler in each photo is approximately 6 in. (15 cm) long.]

were installed to afford access, for replacing batteries without need to use tools.

- In the previous version, it was necessary to cut cylindrical lenses and glue them to the laser diodes. During the last few intervening years, much better laser devices arrived on the market. Therefore, the original laser diodes were replaced by laser-diode assemblies that include built-in adjustable focus devices so that the projected lines can be made narrow, increasing the accuracy of apparatus.

This work was done by Douglas E. Willard of **Kennedy Space Center** *and Ivan I. Townsend III of Dynacs, Inc. For further information, contact the Kennedy Technology Programs and Commercialization Office at (321) 867-8130.*
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Six Classes of Diffraction-Based Optoelectronic Instruments

These instruments can play diverse roles in scientific instrumentation.

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Six classes of diffraction-based optoelectronic instruments have been invented as means for wavelength-based processing of light. One family of anticipated applications lies in scientific instrumentation for studying chemical and physical reactions that affect and/or are affected differently by light of different wavelengths or different combinations of wavelengths. Another family of anticipated applications lies in optoelectronic communication systems.

An instrument of the first class is basically a spectrometer that can serve as a building block for the instruments of the other classes. In this instrument, a beam of light emitted from the site of a chemical or physical reaction strikes a diffraction grating, which causes each of its wavelength components to propagate in a direction that depends on its wavelength. Photodetectors are positioned to receive light diffracted to different angular intervals that, by virtue of the aforementioned diffraction, correspond to different wavelength bands. Hence, the photodetector outputs are indicative of the time-dependent intensities of light emitted by the chemical or physical reaction in the selected wavelength bands.

In an instrument of the second class, the input light comprises two beams. In one of two possible modes of operation, the purpose served by the instrument is to help determine whether the beams are correlated sufficiently to be considered as having originated from the same source. In the other mode of operation, one of the beams is a reference beam and the instrument is used to compare the other beam with the reference beam. The two incoming beams impinge from different directions on a diffraction grating. As in the first instrument, the diffracted light from each beam impinges on photodetectors corresponding to various wavelength bands. In this case, there are two sets of photodetectors — one for each incoming beam. The outputs of the photodetectors as functions of time are sampled and the samples used to compute correlations between the time-dependent spectra of the two beams. The correlation values are taken to be indications of the relatedness or unrelatedness of the incoming beams.

In an instrument of the third class, a beam of light is split into two beams, which are then diffracted into wavelength components. One set of wavelength-component beams passes through a chamber containing a medium (hereafter denoted the altered medium) that could be undergoing a reaction that one seeks to study. The other set of wavelength-component beams passes through an otherwise identical chamber that contains a reference medium. After passage through the chambers, the two sets of wavelength-component beams impinge on photodetectors that are arranged in one or two sets, depending on the number and arrangement of diffraction gratings. The outputs of the photodetectors are sampled and processed to analyze differences between the effects of the altered and reference media on the light propagating through them.

The instruments of the fourth class can exist in diverse forms. Common to all forms is the use of diffraction gratings to split beams of light from multiple sources into wavelength components, which are then made to impinge on reaction sites to determine whether light at those wavelengths does or does not promote the reactions in question. In some cases reactions may be promoted by light of different wavelengths impinging in specified sequences within short intervals of time; the instruments of this class can be designed to generate the required sequences and measure their effects.

An instrument of the fifth class includes two coaxial cylinders. The outer surface of the inner cylinder is covered with a diffraction grating. The outer cylinder holds an array of photodetectors that intercept light diffracted by the grating. The cylinders can be translated axially and/or rotated, relative to each other, to change the wavelength range of the monitored light.

An instrument of the sixth class is a beam-steering device for data communication. A light beam modulated to convey symbols impinges successively on two diffraction gratings. The direction(s) of diffraction depend(s) on the wavelength(s) present in the beam. Hence, diffraction can be used to steer the beam, according to its wavelength, to one or more desired photodetector(s) in an array.

This work was done by Stevan Spremo of **Ames Research Center***, Peter Fuhr of San Jose State University Foundation, and John Schipper, Law Offices of John Schipper. Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14650.