Physical Sciences

True Shear Parallel Plate Viscometer

This instrument is designed to measure the viscosity of non-Newtonian liquids.

Marshall Space Flight Center, Alabama

This viscometer (which can also be used as a rheometer) is designed for use with liquids over a large temperature range. The device consists of horizontally disposed, similarly sized, parallel plates with a precisely known gap. The lower plate is driven laterally with a motor to apply shear to the liquid in the gap. The upper plate is freely suspended from a double-arm pendulum with a sufficiently long radius to reduce height variations during the swing to negligible levels. A sensitive load cell measures the shear force applied by the liquid to the upper plate. Viscosity is measured by taking the ratio of shear stress to shear rate.

The bearing points of the suspended plate and the upper arms of the pendulum ensure any motion is constrained to one axis, and no friction or resistance from the apparatus contributes to the load. Unlike other viscometers, e.g., those using rotating cylinders or disks, this design follows the simplest mechanical model to measure viscosity. By using large vitreous quartz plates and small gaps, liquids with very low viscosities at low temperatures can be measured with the same tooling as viscous liquids, like glass at elevated temperatures. By maintaining a constant gap and driving the lower plate with a linear driver motor, the liquid between the plates undergoes a uniform amount, and therefore rate, of shear over its volume.

When using the vitreous quartz plates to contain the liquid, high-temperature operation up to 800 °C, or more, can be considered. The transparency of the plates permits a precise measure of the liquid area of contact on the plate with a camera or similar method. One can recover the gap dimension from knowledge of the liquid area and the amount of liquid volume used; alternatively, one can set the gap and measure the area of spread to determine the liquid volume if it is an arbitrary amount. Another advantage of this method is the ability to quickly adjust the gap, and to determine what it is precisely (from the liquid spread area) between measurements of viscosity.

Although not implemented in the prototype, the plates can be temperature-controlled to ensure the liquid in contact with them is at proper temperatures. By building heaters and temperature sensors into the plates, one can be certain the liquid in contact will have the proper temperature. The thickly spread liquid will respond to the substrate (heater plate) temperature very rapidly. The thermal lag will be confined to the heater plates themselves, but not to support structures or fixtures.

The pendulum mounting of the upper plate offers noise elimination because only the lateral shear force is read on the load cell. The fixture and sample mass do not interfere with the load measurement. Furthermore, particularly worthwhile with viscous glasses, only small displacements away from the rest position of the pendulum are required to make a measurement. This reduces instrument error to a minimum.

This work was done by Edwin Ethridge of Marshall Space Flight Center and William Kaukler of the University of Alabama, Huntsville. For more information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at sammy.a.nabors@nasa.gov. Refer to MFS-32558-1.

Focusing Diffraction Grating Element With Aberration Control

The device has application in spectrometers, optical processors, and remote sensors.

Goddard Space Flight Center, Greenbelt, Maryland

Diffraction gratings are optical components with regular patterns of grooves, which angularly disperse incoming light by wavelength in a single plane, called dispersion plane. Traditional gratings on flat substrates do not perform wavefront transformation in the plane perpendicular to the dispersion plane. The device proposed here exhibits regular diffraction grating behavior, dispersing light. In addition, it performs wavelength transformation (focusing or defocusing) of diffracted light in a direction perpendicular to the dispersion plane (called sagittal plane).

The device is composed of a diffraction grating with the grooves in the form of equidistant arcs. It may be formed by defining a single arc or an arc approximation, then translating it along a certain direction by a distance equal to a multiple of a fixed distance ("grating period") to obtain other groove positions. Such groove layout is nearly impossible to obtain using traditional ruling methods, such as mechanical ruling or holographic scribing, but is trivial for lithographically scribed gratings. Lithographic scribing is the newly developed method first commercially introduced by LightSmyth Technologies, which produces gratings with the highest performance and arbitrary groove shape/spacing for advanced aberration control. Unlike other types of focusing gratings, the grating is formed on a flat substrate. In a plane perpendicular to the substrate and parallel to the translation direction, the period of the grating and, therefore, the projection of its k-vector onto the plane is the same for any location on the grating surface. In that plane, no waveform transformation by the grating k-vector occurs, except of simple redirection.

Therefore, diffracted light experiences no wavelength transformation in the dispersion plane. It is redirected in much the same way as with a flat mirror. However, in the sagittal plane light gets redirected in a manner similar to a cylindrical mirror. It exhibits focusing with the focal length only defined by the curvature of the grooves, the incident wavelength, and the grating period.

Because of this, one single diffraction grating can exhibit two dispersal patterns. It disperses light just like a regular flat diffraction grating, while at the same time focusing (or de-focusing) diffracted light onto a perpendicular plane. This focusing generates less aberrations than a mirror would. Non-trivial property of this device is that its focal length for a fixed wavelength does not depend on the incident angle, even if the angle is extremely non-paraxial.

This work was done by Dmitri Iazikov, Thomas W. Mossberg, and Christoph M. Greiner of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15680-1

Universal Millimeter-Wave Radar Front End

NASA's Jet Propulsion Laboratory, Pasadena, California

A quasi-optical front end allows any arbitrary polarization to be transmitted by controlling the timing, amplitude, and phase of the two input ports. The front end consists of two indepen-dent channels — horizontal and vertical. Each channel has two ports — transmit and receive. The transmit signal is linearly polarized so as to pass through a periodic wire grid. It is then propagated through a ferrite Faraday rotator, which rotates the polarization state 45°. The received signal is propagated through the Faraday rotator in the opposite direction, undergoing a further 45° of polarization rotation due to the non-reciprocal action of the ferrite under magnetic bias. The received signal is now polarized at 90° relative to the transmit signal. This signal is now reflected from the wire grid and propagated to the receive port.

The horizontal and vertical channels are propagated through, or reflected from, another wire grid. This design is an improvement on the state of the art in that any transmit signal polarization can be chosen in whatever sequence desired. Prior systems require switching of the transmit signal from the amplifier, either mechanically or by using high-power millimeter-wave switches. This design can have higher reliability, lower mass, and more flexibility than mechanical switching systems, as well as higher reliability and lower losses than systems using high-power millimeter-wave switches.

This work was done by Raul M. Perez of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-46654

Mode Selection for a Single-Frequency Fiber Laser

NASA's Goddard Space Flight Center, Greenbelt, Maryland

A superstructured fiber-grating-based mode selection filter for a single-frequency fiber laser eliminates all free-space components, and makes the laser truly all-fiber. A ring cavity provides for stable operations in both frequency and power. There is no alignment or realignment required. After the fibers and components are spliced together and packaged, there is no need for specially trained technicians for operation or maintenance. It can be integrated with other modules, such as telescope systems, without extra optical alignment due to the flexibility of the optical fiber.

The filter features a narrow line width of 1 kHz and side mode suppression ratio of 65 dB. It provides a high-quality laser for lidar in terms of coherence length and signal-to-noise ratio, which is 20 dB higher than solid-state or microchip lasers.

This concept is useful in material processing, medical equipment, biomedical instrumentation, and optical communications. The pulse-shaping fiber laser can be directly used in space, airborne, and satellite applications including lidar, remote sensing, illuminators, and phase-array antenna systems.

This work was done by Jian Liu of Goddard Space Flight Center. For further information, contact the Goddard Innovative Partnerships Office at (301) 286-5810. GSC-15600-1

Qualification and Selection of Flight Diode Lasers for Space Applications

NASA's Jet Propulsion Laboratory, Pasadena, California

The reliability and lifetime of laser diodes is critical to space missions. The Nuclear Spectroscopic Telescope Array (NuSTAR) mission includes a metrology system that is based upon laser diodes. An operational test facility has been developed to qualify and select, by mission standards, laser diodes that will survive the intended space environment and mission lifetime. The facility is situated in an electrostatic discharge (ESD) certified cleanroom and consist of an enclosed temperature-controlled stage that can accommodate up to 20 laser diodes. The facility is designed to characterize a single laser diode, in addition to conducting laser lifetime testing on up to 20 laser diodes simultaneously.