



### **Aligning Astronomical Telescopes via Identification of Stars**

**The alignment process would be completely automatic.**

*Marshall Space Flight Center, Alabama*

A proposed method of automated, precise alignment of a ground-based astronomical telescope would eliminate the need for initial manual alignment. The method, based on automated identification of known stars and other celestial objects in the telescope field of view, would also eliminate the need for an initial estimate of the aiming direction. The method does not require any equipment other than a digital imaging device such as a charge-coupled-device digital imaging camera and control computers of the telescope and camera, all of which are standard components in professional astronomical telescope systems and in high-end amateur astronomical telescope systems. The method could be implemented in software running in the telescope or camera control computer or in an external computer communicating with the telescope pointing mount and camera control computers.

The image in the telescope field of view would be captured by the digital imaging device and digitized and then, according to the method, would be processed by a variant of any of several previously published star-identification

algorithms. In simplified terms, such an algorithm determines criteria such as brightnesses and relative angles or distances between stars in the digital image and matches those criteria with stars in a database. Once such a match was found, the celestial coordinates of the identified objects in the image and the pixel coordinates of the object would be used to precisely determine the line of sight of the telescope in celestial coordinates.

Although the method does not require an initial estimate of the aiming direction, such an estimate (or ancillary information from which such an estimate can be calculated) could be used to accelerate the automated precise alignment process by limiting the search space to a small portion of the celestial-object database. Even if all that is known are the geographic coordinates of the telescope and the time, portions of the sky known not to be visible from that location at that time could be excluded from the search.

Once the celestial coordinates of two different lines of sight have been determined precisely as outlined above, the telescope would be automatically initial-

ized and aligned for subsequent automated pointing and tracking. Thereafter, during tracking, the alignment process as described thus far could be repeated as often as desired to update the alignment: At each update, the celestial coordinates of the current line of sight would be communicated to the telescope control computer to maintain or restore the precise alignment of the telescope drive axes. Because the line-of-sight directions determined by this method would be based on direct observation of celestial objects having known coordinates, they would be more accurate than are the line-of-sight directions determined by prior methods that involve intermediate measurements (e.g., drive-shaft-angle measurements), which introduce drive-train and axis-misalignment errors.

*This work was done by Mark Whorton of Marshall Space Flight Center.*

*This invention is owned by NASA, and a patent application has been filed. For further information, contact Sammy Nabors, MSFC Commercialization Assistance Lead, at [sammy.a.nabors@nasa.gov](mailto:sammy.a.nabors@nasa.gov). Refer to MFS-31968-1.*

### **Generation of Optical Combs in a WGM Resonator From a Bichromatic Pump**

**A different approach to nonlinear oscillation excitation avoids undesired effects that previously limited optical comb quality.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Optical combs generated by a monolithic resonator with Kerr-medium can be used in a number of applications, including orbital clocks and frequency standards of extremely high accuracy, such as astronomy, molecular spectroscopy, and the like. The main difficulty of this approach is the relatively high pump power that has to be used in such devices, causing undesired thermorefractive effects, as well as stimulated Raman

scattering, and limiting the optical comb quality and utility.

In order to overcome this problem, this innovation uses a different approach to excitation of the nonlinear oscillations in a Kerr-nonlinear whispering gallery mode (WGM) resonator and generation of the optical comb. By coupling to the resonator two optical pump frequencies instead of just one, the efficiency of the comb source can be increased considerably. It therefore can operate in a lower-

power regime where the undesirable effects are not present. This process does not have a power threshold; therefore, the new optical component can easily be made strong enough to generate further components, making the optical comb spread in a cascade fashion. Additionally, the comb spacing can be made in an arbitrary number of the resonator free spectral ranges (FSR).

The experimental setup for this innovation used a fluorite resonator with

$\Omega = 13.56$  GHz. This material has very low dispersion at the wavelength of 1.5 microns, so the resonator spectrum around this wavelength is highly equidistant. Light was coupled in and out of the resonator using two optical fibers polished at the optimal coupling angle. The gap between the resonator and the fibers, affecting the light coupling and the resonator loading, was controlled by piezo positioners. The light from the input fiber that did not go into the resonator reflected off of its rim, and was collected by a photodetector. This enabled observation and

measurement of the (absorption) spectrum of the resonator.

The input fiber combined light from two lasers centered at around 1,560 nanometers. Both laser frequencies were simultaneously scanned around the selected WGMs of the same family. However, they were separated by one, two, three, or ten FSRs. This was achieved by fine-tuning each laser frequency offset until the selected resonances overlap on the oscilloscope screen. The resonator quality factor  $Q = 7 \times 10^7$  was relatively low to increase the linewidth and, therefore, the duty cycle

of both lasers simultaneously coupled into their WGMs. The optical spectrum analyzer (OSA) connected to the output fiber was continuously acquiring data, asynchronously with the laser scan. The instrument was set to retain the peak power values; therefore, a trace recorded for a sufficiently long period of time reflected the situation with both lasers maximally coupled to the WGMs.

*This work was done by Dmitry V. Strelakov and Nan Yu of Caltech and Andrey B. Matsko of OEWaves for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-46253*

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## Large-Format AlGaIn PIN Photodiode Arrays for UV Images

**This UV detector can be used for measuring airborne particulates and for biological agent detection.**

*NASA's Goddard Space Flight Center, Greenbelt, Maryland*

A large-format hybridized AlGaIn photodiode array with an adjustable bandwidth features stray-light control, ultra-low dark-current noise to reduce cooling requirements, and much higher radiation tolerance than previous technologies. This technology reduces the size, mass, power, and cost of future ultraviolet (UV) detection instruments by using lightweight, low-voltage AlGaIn detectors in a hybrid detector/multiplexer configuration. The solar-blind feature eliminates the need for additional visible light rejection and reduces the sensitivity of the system to stray light that can contaminate observations.

The AlGaIn UV detector operating at 325 nm gives a 1,000 $\times$  better extraterrestrial solar radiation rejection than silicon. This reduced need for blocking filters increases the quantum efficiency

(QE) and simplifies the optical systems. The wide direct bandgap reduces the thermally generated dark current to levels that allow many observations at room temperature. Because of this, the AlGaIn UV photodiode array doesn't require the extensive cooling (and the associated cooling cost, complexity, and weight) that silicon does, significantly reducing system cost. Wide direct bandgap materials are naturally more radiation tolerant, which is crucial for instruments located outside of Earth's atmosphere.

The device is most sensitive to UV radiation when operated in the photovoltaic mode at or near zero-reverse bias voltage. The effect of the bandgap is seen at the long wavelength cutoff of 365 nm, and shows a contrast ratio before and after the cutoff edge of better than  $10^3$ . Between 355 and 365 nm, the QE is

fairly flat, with a high of 50 percent at 360 nm at  $-0.5$  V bias. The QE falls rapidly with decreasing wavelength reaching a minimum of 3 percent at 345 nm. The detector's current responsivity at 360 nm and 0 V bias is 0.13 A/W. The spectral detectivity is  $2.6 \times 10^{15}$  cm Hz $^{1/2}$ W $^{-1}$ , corresponding to a detector noise equivalent power of  $4.1 \times 10^{-18}$  W/Hz $^{1/2}$ .

While the benefits for space-based UV detection are readily apparent, there are Earth-based applications that can benefit as well. These include plume measurements, flame sensing, UV lidar, biological agent detection, and measuring airborne particulate size and velocity.

*This work was done by Shahid Aslam and David Franz of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15673-1*

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## Fiber-Coupled Planar Light-Wave Circuit for Seed Laser Control in High Spectral Resolution Lidar Systems

**The compact, efficient, and reliable design enables use on small aircraft and satellites.**

*Langley Research Center, Hampton, Virginia*

Precise laser remote sensing of aerosol extinction and backscatter in the atmosphere requires a high-power, pulsed, frequency doubled Nd:YAG laser that is wavelength-stabilized to a narrow absorption line such as found in iodine vapor. One method for precise wavelength control is to injection seed the Nd:YAG laser with a

low-power CW laser that is stabilized by frequency converting a fraction of the beam to 532 nm, and to actively frequency-lock it to an iodine vapor absorption line. While the feasibility of this approach has been demonstrated using bulk optics in NASA Langley's Airborne High Spectral Resolution Lidar (HSRL) program, an ideal,

lower cost solution is to develop an all-waveguide, frequency-locked seed laser in a compact, robust package that will withstand the temperature, shock, and vibration levels associated with airborne and space-based remote sensing platforms.

A key technology leading to this miniaturization is the integration of an efficient