Phase-Array Approach to Optical Whispering Gallery Modulators

NASA’s Jet Propulsion Laboratory, Pasadena, California

This technology leverages the well-defined orbital number of a whispering gallery modulator (WGM) to expand the range of applications for such resonators. This property rigidly connects the phase variation of the field in this mode with the azimuthal angle between the coupling locations.

A WGM with orbital momentum L has exactly L instant nodes around the circumference of the WGM resonator supporting such a mode. Therefore, in two locations separated by the arc α, the phase difference of such a field will be equal to φ = αL. Coupling the field out of such locations, and into a balanced interferometer, one can observe a complete constructive or destructive interference (or have any situation in between) depending on the angle α. Similarly, a mode L + ΔL will pick up the phase φ + αΔL.

In all applications of a WGM resonator as a modulator, the orbital numbers for the carrier and sidebands are different, and their differences ΔL are known (usually, but not necessarily, ΔL = 1). Therefore, the choice of the angle α, and of the interferometer arms difference, allows one to control the relative phase between different modes and to perform the conversion, separation, and filtering tasks necessary.

This work was done by Dmitry Strékalov of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18539-1.

Infrared Camera System for Visualization of IR-Absorbing Gas Leaks

This system is applicable in HVAC, methane production plants, and oil refineries.

John F. Kennedy Space Center, Florida

Leak detection and location remain a common problem in NASA and industry, where gas leaks can create hazardous conditions if not quickly detected and corrected. In order to help rectify this problem, this design equips an infrared (IR) camera with the means to make gas leaks of IR-absorbing gases more visible for leak detection and location.

By comparing the output of two IR cameras (or two pictures from the same camera under essentially identical conditions and very closely spaced in time) on a pixel-by-pixel basis, one can cancel out all but the desired variations that correspond to the IR absorption of the gas of interest. This can be simply done by absorbing the IR lines that correspond to the gas of interest from the radiation received by one of the cameras by the intervention of a filter that removes the particular wavelength of interest from the “reference” picture. This can be done most sensitively with a gas filter (filled with the gas of interest) placed in front of the IR detector array, or (less sensitively) by use of a suitable line filter in the same location.

This arrangement would then be balanced against the unfiltered “measurement” picture, which will have variations from IR absorption of the gas of interest. By suitable processing of the signals from each pixel in the two IR pictures, the user can display only the differences in the signals. Either a difference or a ratio output of the two signals is feasible. From a gas concentration viewpoint, the ratio could be processed to show the column depth of the gas leak. If a variation in the background IR light intensity is present in the field of view, then large changes in the difference signal will occur for the same gas column concentration between the background and the camera. By ratioing the outputs, the
same signal ratio is obtained for both high- and low-background signals, even though the low-signal areas may have greater noise content due to their smaller signal strength. Thus, one embodiment would use a ratioed output signal to better represent the gas column concentration.

An alternative approach uses a simpler multiplication of the filtered signal to make the filtered signal equal to the unfiltered signal at most locations, followed by a subtraction to remove all but the wavelength-specific absorption in the unfiltered sample. This signal processing can also reveal the net difference signal representing the leaking gas absorption, and allow rapid leak location, but signal intensity would not relate solely to gas absorption, as raw signal intensity would also affect the displayed signal.

A second design choice is whether to use one camera with two images closely spaced in time, or two cameras with essentially the same view and time. The figure shows the two-camera version. This choice involves many tradeoffs that are not apparent until some detailed testing is done. In short, the tradeoffs involve the temporal changes in the field picture versus the pixel sensitivity curves and frame alignment differences with two cameras, and which system would lead to the smaller variations from the uncontrolled variables.

This work was done by Robert Youngquist and Dale Lueck of Kennedy Space Center and Christopher Immer and Robert Cox of ASRC Aerospace Corporation. Further information is contained in a TSP (see page 1).

**Submonolayer Quantum Dot Infrared Photodetector**

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

A method has been developed for inserting submonolayer (SML) quantum dots (QDs) or SML QD stacks, instead of conventional Stranski-Krastanov (SK) QDs, into the active region of intersubband photodetectors. A typical configuration would be InAs SML QDs embedded in thin layers of GaAs, surrounded by AlGaAs barriers. Here, the GaAs and the AlGaAs have nearly the same lattice constant, while InAs has a larger lattice constant.

In QD infrared photodetector, the important quantization directions are in the plane perpendicular to the normal incidence radiation. In-plane quantization is what enables the absorption of normal incidence radiation. The height of the SK QD controls the positions of the quantized energy levels, but is not critically important to the desired normal incidence absorption properties. The SML QD or SML QD stack configurations give more control of the structure grown, retains normal incidence absorption properties, and decreases the strain buildup to allow thicker active layers for higher quantum efficiency.

This work was done by David Z. Ting, Sumith V. Bandara, and Sarath D. Gnapala of Caltech and Yia-Chung Chang of the University of Illinois for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

**Mode Tracker for Mode-Hop-Free Operation of a Laser**

**Lyndon B. Johnson Space Center, Houston, Texas**

A mode-tracking system that includes a mode-controlling subsystem has been incorporated into an external-cavity (EC) quantum cascade laser that operates in a mid-infrared wavelength range. The mode-tracking system makes it possible to perform mode-hop-free wavelength scans, as needed for high-resolution spectroscopy and detection of trace gases. The laser includes a gain chip, a beam-collimating lens, and a diffraction grating. The grating is mounted on a platform, the position of which can be varied to effect independent control of the EC length and the grating angle.