Ultra-Compact, Superconducting Spectrometer-on-a-Chip at Submillimeter Wavelengths

These spectrometer modules can be used for future astrophysics missions that require compact cryogenic spectrometers.

NASA's Jet Propulsion Laboratory, Pasadena, California

Small size, wide spectral bandwidth, and highly multiplexed detector readout are required to develop powerful multi-beam spectrometers for high-redshift observations. Currently available spectrometers at these frequencies are large and bulky. The grating sizes for these spectrometers are prohibitive. This fundamental size issue is a key limitation for space-based spectrometers for astrophysics applications.

A novel, moderate-resolving-power (R-700), ultra-compact spectrograph-on-a-chip for millimeter and submillimeter wavelengths is the solution. Its very small size, wide spectral bandwidth, and highly multiplexed detector readout will enable construction of powerful multi-beam spectrometers for high-redshift observations. The octave-bandwidth, background-limited performance of this spectrometer is comparable to that of a diffraction grating, but in a photolithographically developed thin-film package. This novel photolithographic on-chip spectrometer camera is compact, delivering 200 to 500 km/s spectral resolution over an octave bandwidth for hundreds of pixels in the telescope's field of view.

The spectrometer employs a filter bank consisting of planar, lithographed, superconducting transmission line resonators. Each millimeter-wave resonator is weakly coupled to both the feedline and to the inductive portion of a lumped-element microwave kinetic inductance detector (MKID). Incoming millimeter-wave radiation breaks Cooper pairs in the MKID, modifying its kinetic inductance and resonant frequency, allowing for frequency-multiplexed readout. This is realized using thin-film lithographic structures on a silicon wafer, with titanium nitride MKID resonators.

The ultra-compact superconducting spectrometer approach offers the potential for hundreds of individual spectrometers integrated into a 2D focal plane for future ground- and space-based astrophysics instruments.

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UV Resonant Raman Spectrometer With Multi-Line Laser Excitation

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A Raman spectrometer employs two or more UV (ultraviolet) laser wavelengths to generate UV resonant Raman (UVRR) spectra in organic samples. Resonant Raman scattering results when the laser excitation is near an electronic transition of a molecule, and the enhancement of Raman signals can be several orders of magnitude. In addition, the Raman cross-section is inversely proportional to the fourth power of the wavelength, so the UV Raman emission is increased by another factor of 16, or greater, over visible Raman emissions. The Raman-scattered light is collected using a high-resolution broadband spectrograph. Further suppression of the Rayleigh-scattered laser light is provided by custom UV notch filters.

The complete Raman instrument is compact and robust, and suitable for *in-situ* chemical analysis. By employing multiple UV lasers at a suitable wavelength spacing, a matrix of resonant Raman bands can be generated for organic compounds in the UV that are distinct and easily resolvable from the fluorescence emission in the visible-wavelength region. The multiple excitation laser wavelengths produce a repeated series of Raman bands, each with the same frequency shifts from the corresponding excitation laser. UV laser excitation, in addition, allows a resonant enhancement of the Raman scattering in organic compounds such as aromatic hydrocarbons, nucleic acids, and proteins. The multiple excitation wavelengths can be generated from a single UV laser by using stimulated Raman scattering in a hydrogen gas cell. This coherent, multi-wavelength light source has the ideal frequency spacing to maximize spectral coverage and to avoid overlap of adjacent Raman spectra.

This work was done by James L. Lambert, James M. Kohel, James P. Kirby, John Michael Morookian, and Michael J. Pelletier of Caltech for NASA's Jet Propulsion Laboratory. For more information, contact iaoffice@jpl.nasa.gov. NPO-47423