Instrument boosts analysis of small, extremely dark materials

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Researchers have developed a new instrument that can analyze light reflected from very small or extremely dark materials such as some meteorite samples and VANTABlack, the darkest manmade substance created. The instrument is already revealing new information about these and other difficult-to-analyze surfaces.

Using spectroscopy to measure how light reflects off a surface can provide information on the physical and chemical properties of a sample material. However, extremely dark or small samples such as those from meteorites make this type of analysis difficult because they reflect very little light.

In The Optical Society (OSA) journal *Applied Optics*, first author Sandra Potin and colleagues from Institut de Planétologie et Astrophysique de Grenoble (IPAG), University Grenoble Alpes in France, report that their new instrument, called SHADOWS, can be used for reflectance spectroscopy of samples measuring less than one millimeter cubed and that reflect less than 0.03 percent of light illuminating the sample.

The new instrument can be used to better understand the composition of meteorites and to identify the asteroid or comet from which they originated. It can also be used to analyze surfaces on spacecraft, where very dark coatings are used to reduce stray light or remove heat from instrumentation used in space.

Improving sensitivity

The spectroscopy instrument created by the researchers is known as a spectro-gonio radiometer, which works by shining light on a sample from a precise direction and then detecting light reflected back from a different direction. This approach is known as bi-directional reflectance spectroscopy because it calculates the reflectance of a material based on the direction of the illumination light and the direction from which that reflected light is detected. The spectra produced by this measurement are like a fingerprint that can be used to determine a sample's composition.

The researchers began with a radiometer they previously developed for large, bright samples and worked to improve its sensitivity by reducing the illumination to a diameter of around 5.2 mm. The illumination spot can be made even smaller to map heterogeneous surfaces such as a surface that contains multiple types of materials.

"The instrument has a very good signal-to-noise ratio because we used what we call synchronous detection," said Potin. "This means that rather than using continuous light, we illuminate the samples with pulses of light at a very precise frequency. By linking the radiometer's two detectors to this frequency, everything that is not light reflected from the sample can be removed from the measurement."

The new instrument uses multiple colors of light and moves the light source and the detector around the sample to measure light coming from and reflected to multiple directions. The information obtained from the various directions and colors of light is used to build a 3-D angular map of the sample's light reflection that can provide even more information about the sample.

Wide range of temperatures

Another aspect of the new instrument is that it can be used to analyze samples at -20 degrees C up to 250 degrees C, with plans to operate at even lower temperatures, down to -210 degrees C. This is important because the temperature of the sample can change the spectra obtained with the instrument.

"Some asteroids are very far from the sun and thus rather cold, but when a comet goes near the sun, it gets very hot," said Potin. "If we're trying to compare meteorite samples found on Earth with spectra obtained from asteroids in space, we need to take the measurements at a very wide range of temperatures."

The researchers used SHADOWS to take measurements of a VANTABlack sample, which is a chemical substance made of carbon nanotubes grown on aluminum foil. The spectra of this material obtained with the new instrument looked completely different from those acquired by other spectroscopy techniques because it included information taken from different directions.

"By customizing bi-directional spectral analysis for very dark surfaces, our new approach can reveal structural information that has not been observed with other types of measurements," said Potin.

The researchers say they are now working on making improvements to the instrument, including incorporating polarization measurements to provide even more information about samples analyzed. The instrument is available for use by researchers in Europe through the Trans National Access activity of the Europlanet 2020-RI program.

More information: Sandra Potin et al, SHADOWS: a spectro-gonio radiometer for bidirectional reflectance studies of dark meteorites and

terrestrial analogs: design, calibrations, and performances on challenging surfaces, *Applied Optics* (2018). DOI: 10.1364/AO.57.008279