Technology Focus: Sensors

Single-Photon-Sensitive HgCdTe Avalanche Photodiode Detector

Goddard Space Flight Center, Greenbelt, Maryland

The purpose of this program was to develop single-photon-sensitive short-wavelength infrared (SWIR) and mid-wavelength infrared (MWIR) avalanche photodiode (APD) sensors, and to detect sequential pulse returns from multiple objects that are closely spaced in range. Linear-mode APDs can also measure photon number, which Geiger APDs cannot, adding an extra dimension to lidar scene data for multi-photon returns. High-gain APDs with low multiplication noise are required for efficient single-photon detection of single photons because of APD gain statistics — a low-excess-noise APD will generate detectible current pulses from single photon input at a much higher rate of occurrence than will a noisy APD operated at the same average gain. MWIR and LWIR electron-avalanche HgCdTe APDs have been shown to operate in linear mode at high average avalanche gain (M > 1000) without excess multiplication noise (F = 1), and are therefore very good candidates for linear-mode photon counting. However, detectors must have a lower thermal noise requirement for SWIR HgCdTe APDs than Geiger APDs. In addition to the improvement of APD response, APD response were both obtained, but the maximum avalanche gain that could be achieved with SWIR-cutoff material was deemed too low to enable single-photon detection. Comparison of Voxel’s maximum gain measurements suggests that this is an inherent material limitation of the SWIR alloy. Room-temperature responsivity of about 5 kV/W and noise-equivalent power (NEP) of 33.3 nW were measured at 1550 nm when the APD operated at a gain of M=6.6.

Completion of development of CdTe surface passivation for MWIR HgCdTe APDs presents the best opportunity to further improve detector performance, it will enable operation at much higher avalanche gain with reduced dark current. This innovation can find use with quantum information (encryption and basic science), semiconductor inspection, and molecular spectroscopy.

This work was done by Andrew Huntington of Voxel, Inc. for Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16140-1

Surface-Enhanced Raman Scattering Using Silica Whispering-Gallery Mode Resonators

NASA’s Jet Propulsion Laboratory, Pasadena, California

The motivation of this work was to develop robust spectroscopic sensors for sensitive detection and chemical analysis of organic and molecular compounds. The solution is to use silica sphere optical resonators to provide surface-enhanced spectroscopic signal. Whispering-gallery mode (WGM) resonators made from silica microspheres were used for surface-enhanced Raman scattering (SERS) without coupling to a plasmonic mechanism. Large Raman signal enhancement is observed by exclusively using 5.08-micron silica spheres with 785-nm laser excitation. The advantage of this non-plasmonic approach is that the active substrate is chemically inert silica, thermally stable, and relatively simple to fabricate. The Raman signal enhancement in both approaches is approximately 73% at 1,550 nm by partial reflection from the non-coated optical entrance surface; quantum efficiency near 94% is expected for these devices if an anti-reflection coating is used. Excellent yield of operable APD pixels and uniformity of APD response were both obtained, but the maximum avalanche gain that could be achieved with SWIR-cutoff material was deemed too low to enable single-photon detection. Comparison of Voxel’s maximum gain measurements suggests that this is an inherent material limitation of the SWIR alloy. Room-temperature responsivity of about 5 kV/W and noise-equivalent power (NEP) of 33.3 nW were measured at 1550 nm when the APD operated at a gain of M=6.6.

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