TERAHERTZ STAND-OFF VIDEO RATE IMAGING THROUGH HOT CARBON AEROSOL (SMOKE)

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Terahertz (THz) imaging is a powerful technique that exploits a nonionizing (i.e., safe) portion of the electromagnetic spectrum located between microwaves and the IR. Directed toward an appropriate sample, such as wood or ceramics, THz light passes through and is detected by a camera. Because of its nondestructive nature, THz imaging is applicable to many areas. For example, it has advantages over x-rays for diagnosis of skin cancer and can detect sketches underlying paintings. The technique is also potentially advantageous in conditions of hot carbon aerosol (hot black smoke), where conventional imaging is unsuitable. Even ordinary smoke is difficult to see through at visible wavelengths, and hot, black smoke saturates and scatters IR radiation. THz wavelengths are absorbed by hot smoke less strongly and transmitted more readily through it, compared with the IR. However, although wellplaced for (bio)materials analysis, THz imaging was until recently considered ill-adapted for hot conditions, limiting its utility in search and rescue missions.

We report a THz video rate imaging system consisting of a quantum-cascade laser light source, and a microbolometer focal-plane array (an IR detector common in thermal cameras). The camera is based on one we previously designed, but with improved power and sensitivity. We describe two applications of our imaging system: stand-off imaging for search and rescue in a fire disaster, and label-free biomaterial detection.

With these technical improvements in place, we performed stand-off (~5m distance) THz-imaging experiments under simulated fire conditions. We were able to obtain images in hot, black smoke (with an SNR of ~140 versus ~6000 with no smoke) that blocked visible light and and induced signal saturation in the long-wavelength IR (LWIR) region. These results clearly show an advantage of THz compared with LWIR or visible imaging. Our camera is particularly adapted to search and rescuemissions due to its 60Hz (real-time) image acquisition rate.

In pharmaceutical drug discovery, molecular interactions are commonly tracked using chemical ‘labels’ that are costly and prone to error. We applied our THz camera to label-free detection of small-molecule reactions with proteins. The THz waves are readily absorbed and enable sensing of very small changes in biomaterials. The detection sensitivity of a label-free biotin-streptavidin reaction (routinely used in biotechnology), for example, was nearly the same as that of conventional methods, and the THz system has the advantage of high throughput and low cost.We note that for real life-science applications, our detection system requires a very large biomaterial spectral database in the THz range.

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