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Sensitive Detection: Photoacoustics, Thermography and Optical Radiation Pressure

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Research Summary

Several research areas have been investigated during the granting period. The possibility of using the high sensitivity of the photoacoustic effect to act as an infrared pyrometer has been investigated. A new device based on the use of a cell constructed to view two surfaces, one having an unknown temperature and the other a reference temperature has been constructed and evaluated. It was show that the device can detect temperature differences as small as 50 mK. In the photoacoustic research carried out here, the effects of the large thermal gradient produced when a short pulse laser is directed at an absorbing surface on the character of photoacoustic waves have been determined. The sharp pressure transient predicted by a theory that includes heat diffusion has been confirmed in experiments carried out on thin, absorbing films. The transients found are a general feature of the photoacoustic effect with short pulse laser beams, but, surprisingly, have never been reported before. The photoacoustic effect for source moving in one dimension has been investigated. It was shown that for a source moving in one dimension at the sound speed, the photoacoustic effect, in the linear acoustics regime, increases linearly with time. This amplification effect appears to be unique to the photoacoustic effect, with no parallel in electromagnetic theory. Experiments have shown the advantage of using this effect for ultrasensitive trace gas detection. Experiments are in progress where an infrared grating moves at the sound speed to take advantage of this amplification property. The experiment uses a transducer with a high quality factor and a resonance at over 400 kHz. It is expected that the sensitivity of the device will range to the parts-per-quadrillion level. The photoacoustic effect in a structure where the acoustic properties are periodically modulated in a one-dimensional geometry have been found based on solutions to a Mathieu equation. The results show it is possible to excite photoacoustic waves in the band gaps of the structure to produce large amplitude acoustic waves—within the band gaps. The theory for self-oscillation in a photoacoustic cell using a continuous laser has been reported. The idea is based on the principle that in a compressive wave, the absorption increases as a result of the density increase leading to further absorption and hence an increased photoacoustic effect. It is predicted that self- oscillation can take place in a longitudinal resonator. The irradiation of a suspension of absorbing carbon particles with a high power laser has been shown to result in cavitation luminescence. Further work on the properties of the ultrasonic vibration potential are reported. In particular, the voltage generated by a spherical colloidal object has been determined. A minor effort on X-ray imaging using a grating to generate a spatially heterodyned image has been made. The properties of X-ray images taken with a grating placed before the object and the resulting image Fourier transformed and filtered has been determined. The method dubbed X-ray spatial frequency heterodyne imaging is currently under investigation by another group at this institution. The dynamics of a separation method known as thermal diffusion, also known as the Soret effect, has been investigated. By exploring the mathematics of the effect, it was found that the underlying mechanism of separation implies the existence of shock waves. Previous experiments have confirmed the predictions of theory.

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16. "Generation of the sedimentation potential by rapid deceleration of a fluid jet", Ziyao Tang, Han Jung Park, and Gerald J. Diebold, *J. Appl. Phys.* **116**, 104908/1/3 (2014) DOI: 10.1063/1.4895488

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