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Abstract

Mid-IR Fiber-Optic Sensors †

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During the last 60 years, there has been continuous research and development in the field of middle infrared (mid-IR) in the wavelength range 3–30 µm. New devices have been developed, including: (1) broadband sources, such as thermal emitters and LEDs; (2) narrow band emitters, including gaseous and solid-state lasers and quantum cascade lasers (QCLs); (3) photoconductive and photovoltaic detectors; and (4) Fourier transform infrared (FTIR) spectrometers and tunable laser spectrometers.

Such devices and subsystems are incorporated in full mid-IR systems including optics, mechanics, electronics and computer control. For example, an array of detectors form the basis of a full thermal imaging system, and a broad-band mid-IR source, a mid-IR detector and an FTIR interferometer form a full mid-IR spectroscopy system. The latest achievement in this field is the development of integrated mid-IR photonics, such as a full spectroscopic system on a Si chip. This may lead to low-cost and high-performance mid-IR optoelectronic systems.

All these devices and systems have already proven themselves in many fields, such as defense, security, astronomy, biological and chemical studies, medicine, etc. Many of these applications and new ones will require the guiding of mid-IR radiation within systems, or connecting systems to the outside in ways lenses and mirrors cannot. Towards this goal, it would be highly beneficial to incorporate mid-IR transmitting optical fibers in these mid-IR systems. In particular, considering sensor systems, mid-IR fibers will make it possible to carry out sensing measurements that could not have been performed without such fibers.

Fibers made of silica are opaque in mid-IR. However, there are several families of other types of fibers: (1) chalcogenide glass fibers, made of sulfides (e.g., As_2S_3) or selenides (As_2Se_3); (2) fluoride glass fiber made, for example, from ZBLAN (SrF_4-BaF_2-$LaFe_3$-AlF_3-NaF); (3) polycrystalline fibers made of silver halides (e.g., AgCl, AgBr or AgClBr) or thallium halides (e.g., TlF or TlBr); (4) hollow core fibers (i.e., tubes) that act like fibers in guiding mid-IR radiation. All these fibers are flexible, fairly rugged and are highly transparent in mid-IR. Incorporating such fibers or fiber bundles in mid-IR systems will make it possible to use these systems in new ways.

These developments may be illustrated by one important example: a mid-IR fiber-optic spectroscopic system. This is based on one or two mid-IR fibers connecting an FTIR spectrometer to the outside world. The system can be used for measurements in a remote location, and in real time. This would be useful for process control, for studies of biological tissues and cells, and for the medical diagnosis of tissues on the outside or the inside of the body, at the patient's bed. It would also be useful for food analysis, for water quality and air quality, and for general pure and applied scientific research.

It is expected that mid-IR fiber-optic sensor systems will have a great impact on standard applications and will pave the way for totally new applications in the future.

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