

Factsheet 03: Mid-Infrared (MIR) Laser Technology

Overview: Mid-infrared (MIR) laser technology refers to laser systems emitting light in the mid-infrared spectrum, typically ranging from 2.5 to 25 micrometres (μm). This segment of the electromagnetic spectrum is crucial for various applications due to its unique interaction with molecular vibrations, making it particularly suitable for spectroscopy, chemical sensing, and other advanced applications.

Key Characteristics

MIR lasers operate in a wavelength range of 2.5 to 25 μm , a region where many molecules exhibit strong absorption features. These features are valuable for identifying and analysing chemical compounds. Additionally, certain wavelengths within the mid-IR range fall within atmospheric windows where absorption by gases like water vapor and CO₂ is minimal. This property is beneficial for remote sensing and free-space communication.

Types of MIR Lasers

- Quantum Cascade Lasers (QCLs) are a prominent type of MIR laser that utilize intersub-band transitions within a semiconductor structure. These lasers are highly tunable, covering specific wavelengths in the MIR range and are extensively used in chemical sensing, spectroscopy, and environmental monitoring.
- Optical Parametric Oscillators (OPOs) employ nonlinear optical crystals to convert a pump laser wavelength into the mid-IR range, offering broad tunability and applications in medical diagnostics and scientific research.
- Lead-salt diode lasers, constructed from lead-salt semiconductors, are typically used for spectroscopy and gas sensing in industrial and environmental monitoring contexts.
- Fiber lasers, doped with elements like erbium or holmium, emit in the MIR range and are noted for their compact and efficient design, making them useful in telecommunications and medical treatments.
- Gas lasers, such as CO₂ lasers, operate at wavelengths around 10.6 μm and are widely employed in industrial processing tasks like cutting, welding, and marking materials.

Current Applications

MIR lasers have diverse applications across nu-

merous fields. In spectroscopy and chemical sensing, they are instrumental in identifying and quantifying chemical compounds through techniques like absorption spectroscopy and photo-acoustic spectroscopy, benefiting industries such as environmental monitoring, pharmaceuticals, and food safety. Environmental monitoring relies on MIR lasers to detect trace gases and pollutants, aiding in air quality control and greenhouse gas monitoring. In the medical field, MIR lasers are used for diagnostic purposes, analysing tissues and body fluids, and for therapeutic applications, including laser surgery. Their ability to precisely target biological tissues makes them valuable for cancer detection and ophthalmic procedures. Industrial processing sees the extensive use of CO₂ lasers for tasks requiring high precision and efficiency, such as cutting, welding, and marking materials, particularly in the automotive, aerospace, and electronics industries. Military and security applications include infrared countermeasures, target designation, free-space optical communications, and explosive detection, making MIR lasers vital for defence and homeland security. Scientific research also benefits from MIR lasers, which are used to study molecular dynamics and chemical reactions, providing essential tools for fundamental research in physics, chemistry, and materials science.

Current Challenges

While the high cost of advanced lasers, such as QCLs and OPOs, poses a challenge, it also presents a significant opportunity for innovation and cost reduction. The necessity of efficient cooling systems to manage heat dissipation and ensure stable operation highlights the potential for advancements in thermal management technologies, which can improve overall system performance and reliability. Material limitations, while currently constraining performance and efficiency, drive ongoing research and development in

semiconductor materials and nonlinear crystals. Progress in this area promises to enhance the capabilities of MIR lasers, making them more versatile and efficient. Additionally, the current lack of market awareness and acceptance offers a unique opportunity for education and outreach. By demonstrating the benefits and capabilities of MIR lasers, industry leaders can accelerate market adoption and unlock new applications. The MILADO project aims to make MIR laser technology more accessible and practical for a wide range of applications. Addressing these costs can lead to more widespread adoption, particularly among small and medium-sized enterprises, fulfilling one of MILADO's primary goals. Furthermore, the MILADO project is dedicated to raising awareness and understanding of MIR laser technologies, showcasing their advantages and driving broader market acceptance.

Future Prospects: The future of MIR laser technology is promising, with ongoing research focused on improving efficiency, reducing costs, and developing better materials. As technology advances, new applications are expected to emerge in areas like biotechnology, environmental science, and telecommunications. The market for MIR lasers is poised for growth, driven by increasing demand for precise sensing and diagnostic tools, with significant potential in emerging economies. MILADO will provide a robust and universal technology platform for low-cost and large volume fabrication of mid infrared QCL lasers. The goal of the MILADO project is the development of a mid-infrared QCL laser source technology that revolutionizes the infrared optical sensing by moving from an expensive and complex craft production to high volume manufacturing.