Technology Development of Miniaturized Far-Infrared Sources for Biomolecular Spectroscopy

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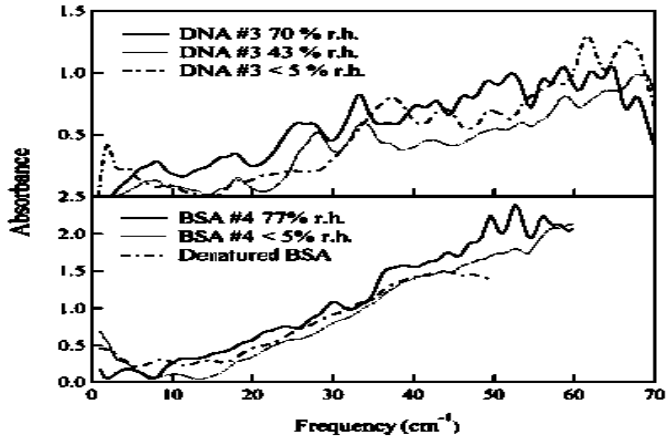

Absorbance hydration dependence for different DNA samples showing the spectral features within 2 THz frequency range (from Markelz et al, Ref.[2])

Description

The objective of this proposal is to develop a purely solid-state based, thus miniaturized, far-infrared (FIR) (also known as terahertz (THz)) wave source using III-V semiconductor nanostructures for biomolecular detection and sensing. Many biomolecules, such as DNA and proteins, have distinct spectroscopic features in the FIR wavelength range as a result of vibration-rotation-tunneling motions and various inter- and intra molecule collective motions [1-4]. Spectroscopic characterization of such molecules requires narrow linewidth, sufficiently high power, tunable (in wavelength), and coherent FIR sources. Unfortunately, the FIR frequency is one of the least technologically developed ranges in the electromagnetic spectrum. Current available FIR sources based on non-solid state technology are bulky, inefficient, and very often incoherent. We propose to use antimonide based semiconductor nanostructures as the active medium to generate FIR radiation. The final goal of this project is to demonstrate a semiconductor THz source integrated with a pumping diode laser module to achieve a compact system for biomolecular applications.

Innovative Claims/NASA Significance

There are a few innovative features in our proposed approach. The small band offsets of the material systems used in typical optically pumped FIR emitters preclude the use of compact semiconductor lasers. A bulky CO2 pump laser inevitably makes the whole system bulky, even though the core FIR-generating semiconductor element is on the nanometer scale. Our innovative approach is based on a design first explored during a just completed DDF project using antimonide-based quantum well structures. As indicated in Fig.1, this unique quantum well structure has large enough conduction band offset for a commercially available near-infrared diode laser to be used as a pumping source. Our approach therefore reduces the pumping laser from the size of a CO2 laser measured in meters to that of a diode laser of millimeters. An additional innovative aspect is that both the pumping laser and the FIR generating cell can be integrated, potentially monolithically, leading to miniaturized, portable FIR spectroscopic systems for biomolecular detection or biomedical diagnostics. Furthermore, an external electric field can be used to tune the FIR wavelength. Such FIR sources will fill an important spectral gap in biomolecular and biomedical detections that are currently dominated by the UV and near infrared wavelength ranges. Such technology will provide an important arsenal to reveal both functional and structural information of many biologically important large molecules, such as DNA and proteins.

Plans

Task 1. Design and Modeling (Dr. Ning with one postdoc at NASA Ames)

Task 2. Fabrication and Characterization (Dr. Kono with 1 Graduate Student)

Task 3. Growth of ABCS Coupled QWs (Dr. Inoue with 1 Postdoc)