| award No. | award title | Start date | End date | Award amount | PI | co-PI | Agency |
|---|---|---|---|---|---|---|---|
| 1640576 | **PFI:AIR - TT: Advancement of Interband Cascade Lasers** | 2016-9-1 | 2018-2-28 | 200,000 | Yang | Santos | NSF |
| 1608224 | **Narrow Bandgap Multi-Stage Structures for Thermophotovoltaics** | 2016-7-1 | 2019-6-30 | 460,000 | Yang | Johnson | |
| 1346307 | STTR phase I<br>Efficeint MIR ICL | 2014-1-1 | 2014-12-31 | 225,000 | Namjou | Yang | NSF |
| 1002202 | Energy Efficient ICL | 2010-6-1 | 2013-5-31 | 400,000 | Yang | Santos, Johnson | NSF |
| 0838439 | SGER: Mid-Infrared IC Photodetectors | 2008-9-1 | 2010-2-28 | 75,029 | Yang | | NSF |
| 1229678 | Acquisition of a MBE Chamber for Quantum-Engineered Structures and Devices | 2012-9-1 | 2014-8-31 | 812,984 | Santos | Sheena, Johnson, Yang, Sellers | NSF |
| 1202318 | Quantum-Engineered Long-Wavelength Infrared Photodetectors | 2012-6-1 | 2015-5-31 | 239,085 or 360,000? | Yang | Santos, Johnson | NSF |
| 0520550 | MRSEC: Center for Semiconductor Physics in Nanostructures (CSPIN) | 2005-10-1 | 2013-9-30 | 7,961,960 | Johnson | Salamo | NSF |

http://www.nsf.gov/awardsearch/simpleSearchResult?queryText=%22interband+cascade%22
http://www.nsf.gov/awardsearch/showAward?AWD_ID=1346307&HistoricalAwards=false
http://www.nsf.gov/awardsearch/showAward?AWD_ID=0520550

1640576
This **PFI: AIR Technology Translation project focuses on translating mid-infrared (IR) interband cascade (IC) laser** technology to fill the need for instruments that identify and measure the concentration of specific molecules in a gas. Application areas for such instruments include chemical detection, greenhouse gas/pollution and pipeline monitoring, homeland security, industrial process control, and medical diagnostics. IC lasers are compact semiconductor light sources that are enabling components for sensor systems that correlate the absorption of mid-IR light with

the presence of particular molecular species. This project will result in the demonstration and development of efficient IC laser sources that cover a wide range of mid-IR wavelengths. These IC lasers have the advantage of low power consumption when compared to other mid-IR lasers in this market space. The availability of efficient mid-IR IC lasers will dramatically enhance chemical sensing capabilities and help to deploy the sensor network globally. This project addresses the technology gap related to mid-IR semiconductor IC lasers as the technology translates from research discovery toward commercial application. Efficient IC lasers have been developed primarily based on GaSb substrates in the wavelength region from 3 to 4 microns. This project will develop efficient IC lasers based on InAs substrates in the wavelength region of 4 to 10 microns that conventional interband lasers have not been able to reach. These InAs-based IC lasers will be able to operate continuously with low power consumption at room temperature. The project will match the laser wavelengths to fundamental absorption lines of target molecules in the region of 4 to 6 microns. Through further innovation of the device structure, the power consumption will be further reduced for operation in the continuous wave (cw) mode at room temperature. In parallel, the cw operating temperature will be increased for lasers operating at 6 to 10 microns. To reach these long wavelengths, InAs-based plasmon waveguides are required to significantly enhance optical confinement, improve thermal dissipation, and reduce strain. With a carefully designed strain-balanced structure and good control of growth parameters, high-quality epitaxial structures will be achieved for InAs-based IC lasers. This project engages AdTech Optics, one of the leading commercial companies in mid-IR laser manufacturing with expertise in quantum cascade lasers, to further advance InAs-based interband cascade lasers into the commercial marketplace. The involvement of AdTech Optics will be particularly useful for addressing issues of reliability, thermal management, packaging, and yield. Personnel involved in this project, including one postdoc, two graduate students, and at least three undergraduate students, will gain innovation, technology transfer, and entrepreneurship experiences through the entrepreneurship program in the university's business college, interactions with AdTech Optics, and participation in the research and market survey activities.

1608224
Non-technical Description: About two-thirds of the energy generated to power the world's machinery is lost as waste heat. The recovery of even a fraction of these large losses would have a significant environmental impact. This project explores semiconductor multilayer structures for converting this otherwise wasted heat into useful electricity. The objectives of the project are to achieve extensive and systematic understanding of the fundamental aspects of the multilayer semiconductor structures, and to advance the knowledge of how underlying physical processes affect their electrical and optical properties. This enables development of novel concepts for effective conversion of radiant energy from a heat source into electricity. The project offers graduate and undergraduate students at the University of Oklahoma unique opportunities to pursue education, training and research in multidisciplinary topics, such as materials science, quantum engineering, photonics, and device fabrication. This project also enhances Oklahoma's infrastructure for science and technology development and opens new opportunities for students from under-represented groups. Technical Description: Narrow bandgap materials are desirable for making efficient thermophotovoltaic (TPV) cells that convert the otherwise-wasted radiant energy from a heat source into useful electrical energy. The TPV devices take advantage of the type-II band alignment of InAs/GaSb interfaces to form multi-stage cascade structures. These multi-stage structures have many potential advantages including: significantly improved collection efficiency for photo-generated carriers, a wide range of infrared spectral coverage, high open-circuit voltage due to the cascade architecture, as well as the benefits of current matching through adjustments of the number of cascade stages and the thickness of individual absorber layers. Consequently, these narrow bandgap materials enable TPV cells that effectively absorb infrared radiant photons from a heat source and efficiently convert them into electricity. The power conversion efficiency is expected to approach 20%, which would be remarkably high for a TPV system operating at long wavelengths and with a modest light intensity from a low temperature source. The approach and tasks involve:

theory development and designs for multi-stage TPV structures, molecular beam epitaxial growth of the TPV structures, material characterization, and prototype device fabrication and characterization. The TPV cells enabled by multi-stage structures have important applications for waste-heat recovery, more efficient use of solar energy, space exploration, power beaming, as well as portable and quiet energy sources. This project not only advances the understanding of physical processes, it also generates new knowledge in the design of quantum-engineered structures and broadens their applications. The advancement of narrow bandgap multi-stage TPV structures in the mid-infrared wavelength region is a critical step toward harvesting energy from widely available heat sources.