AFRL PATENTED TECHNOLOGY EXPANDS FUNCTIONALITY OF MID-INFRARED FILTERS

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WRIGHT-PATTERSON AFB – A team of Air Force Research Laboratory (AFRL) inventors have worked to shed new light on a challenge which has earned them a patent that could help both the Department of Defense (DoD) and the public at large.

It was a few years back when Shivashankar Vangala, Ph.D., with the AFRL Sensors Directorate (RY), took responsibility for the project when the former lead researcher, Justin Cleary, Ph. D, transitioned to deputy branch chief. Vangala, whose previous experience included working in the field of semiconductor physics and devices at the University of Massachusetts-Lowell, as well as working with midinfrared photodetectors, and had coauthored over 60 peer-reviewed journal publications, took charge as the lead researcher on a new project.

“We were working with the Air Force Office of Scientific Research (AFOSR) on light manipulation, generation, and detection under the portfolio of projects in the AFOSR’s program managed by Dr. Gernot Pomrenke. We were trying to come up with new ideas to expand capabilities of infrared devices and imaging systems,” Vangala said. “We had a lot of discussion and came up with this particular idea of arranging dense micro-resonators together and fabricating the device in the AFRL/RY clean room. We eventually tested them out and demonstrated their use.”

Dr. Vangala, Dr. Cleary, and team members Ricky Gibson, Jr., Ph.D., Joshua Hendrickson, Ph. D., and Evan Smith, Ph.D. of AFRL/RY, and Ivan Avrutsky, Ph.D., an associate professor of electrical and computer engineering at Wayne State University in Detroit, MI, produced the Angle- and Polarization-Insensitive Narrow-Band Optical Filters Using Resonant Cavities (#11,543,571) patent. Avrutsky’s work at Wright-Patterson AFRL was supported by multiple awards from the AFOSR Summer Faculty Fellowship Program. He has a long history of collaborative research with all the team members.

In 2019, after completing a few cycles of design, fabrication, and testing, the team reported in a peer-reviewed publication that their filter employs a dense array of dielectric resonant cavities in a metal film, where the transmission of each cavity depends upon localized rather than travelling electromagnetic fields, making the filter fundamentally angle-independent. The patent covering the technology was issued in January of 2023.

Operation of the proposed device relies upon a peculiar transmission property of a microcavity in a conductive, and thus highly reflective, screen. In theory, the tiniest, vanishing small cavity, can show a narrowband transmission with an effective cross section of transmission at the resonance that is comparable to the wavelength-squared of the incident light. Maximal transmission at the resonance reaches unity in case of lossless metals. The challenge is to design the system with required transmission characteristics using real rather than idealized

materials, as well as to fabricate macroscopically large filter structures with sub-micrometric precision. Another micro-fabrication challenge is to maintain smooth interfaces between different parts of each cavity as interface roughness may contribute to undesirable scattering of light.

“This is a narrowband infrared filter, which has a rather unique property of a transmission spectrum that is independent of the angle of incidence as well as polarization of incident light to a great degree,” Avrutsky said. “These types of properties are important in a number of applications, including infrared countermeasures and thermal imaging, but more specifically multi-spectral imaging and other various technologies where optical filtering is required.”

The team used micro-resonators, which act as individual filters. When placed in a dense array, these resonators act as a larger filter with enhanced transmission. “It’s a unique way to filter the light and/or improve the sensing or detecting capabilities of the infrared detectors when integrated with such detectors,” Vangala said.

Of course, the potential uses for such technology by the Air Force, and DoD in general, is immense.

“(O)ur current research efforts are focused on the integration part, so we can realize the focal plane array imagers suitable for multispectral imaging, surveillance, and target detection and other Air and Space Force applications,” according to Vangala.

“We think first of multi-spectral imaging. This is if you want to make infrared imaging with colors. Of course, these are all infrared wavelengths, but within the range from eight to 12 micrometers we would have up to five or so spectral bands with each band producing its own image. (The warfighter) would have some additional information on how to identify objects,” Avrutsky added. “Thermal emissivity spectra of materials are different one from another, and thus the contrast of imaging can be improved by dynamically selecting a proper wavelength. Also, infrared light scattered or reflected by flat surfaces tends to be polarized, which helps distinguishing manmade objects from the background of natural origin. Our invention will help improve working characteristics of such imaging systems.”

Outside the military, such a tool could be beneficial in finding survivors in collapsed buildings following an earthquake by sensing different temperatures or making out the details of sea wreckage among other uses.

Avrutsky, a native of Ukraine, also feels that contributing towards technological developments from the AFRL has a very special and deeply symbolic importance to combat any aggression from our adversaries that represent a viable threat to the entire world.

Though both inventors have patents to their names prior to this collaboration, this is the first patent for the team. Avrutsky believes it’s crucial to keep academia in the picture when working towards innovation. “I think it’s important to add that collaboration between academic institutions and the AFRL is a very good thing. The more opportunities to bring these people together, the better it is for both groups.”

Vangala concurred adding, “Collaboration is another key element to focus on to successfully demonstrate new technologies and we can use such opportunities available for us at AFRL. I’m sure there are similar opportunities across other DoD agencies and academia for any other inventors and technology enthusiasts.”

United States Patent Office: #11,543,571

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