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New laser technology prepares to revolutionize communications

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As fiber optic technology continues to advance, it faces challenges from both its physical properties and its use of infrastructure. One emerging high-speed solution being developed at Stevens Institute of Technology uses lasers to transmit data through readily available open space, with the potential of expanding past the limitation of fibers into a system known as optical free space communications. Dr. Rainer Martini has overcome a number of free space challenges to develop a high-speed communications technology that is not limited by a physical conductor. With an optical system that is stable enough, satellites may one day convert to laser technology, resulting in a more mobile military and super-sensitive scanners, as well as faster Internet for the masses.

A paper explaining the work, "Optically induced fast wavelength modulation in a quantum cascade laser," was recently published in Applied Physics Letters. The paper was later featured in the research highlights of Nature Photonics. In addition, Laser Focus World Magazine created a feature news story on the results for its November issue.

Director of Stevens Ultrafast Laser Spectroscopy and Communication Laboratory and Associate Professor of Physics and Engineering Physics, Dr. Martini hopes to extend the reach into the terahertz spectrum. But first he and his team faced a fundamental problem: optically-induced modulation of lasers.

A laser's beam must be optically modulated in order to transmit large amounts of data. Optically-induced amplitude modulation (AM) of mid-infrared lasers was realized by researchers at Stevens a few years ago, but AM signals are at the mercy of dust and fog. Now, Stevens researchers led by Dr. Martini have developed a technique to optically modulate the frequency of the beam as well (frequency modulation; FM) – resulting in a signal that is disrupted significantly less by environmental factors. The new research stands to revolutionize communications, rendering environmental barriers meaningless and allowing mobile units not tied to fiber optic cable to communicate in the range of 100 GHz and beyond, the equivalent of 100 gigabytes of data per second.

Electronic modulation of middle infrared quantum cascade laser is limited to 10 GHz, and optical modulation of frequency and amplitude offers a viable alternative. Last year, Martini and his team at Stevens, The Innovation University™, developed a method to optically induce fast amplitude modulation in a quantum cascade laser - a process that allows them to control the laser's intensity. Their amplitude modulation system employed a second laser to modulate the amplitude of the middle infrared laser – in essence using light to control light. But the team still faced the problem of reliability, so they turned to optical frequency modulation. "FM transmitted data is not affected by the environmental elements that affect AM data," Martini says. The recent success allows modulating specifically the emission frequency of the laser – allowing a much more reliable transmission. "But," Martini qualifies, "This was much more difficult to achieve and to prove."

Their optical approach has a number of applications, including frequency modulation in a middle infrared free space communications system, wavelength conversion that will transform a near infrared signal directly into a middle infrared signal, and frequency modulation spectroscopy.

"Dr. Martini's creativity and persistence have yielded great advances in laser optics," says Dr. Michael Bruno, Dean of the Charles V. Schaefer, Jr. School of Engineering and Science. "As the first person to explore amplitude and frequency modulation, he opened the doors to faster, clearer, free space communications. Today, he continues to advance a field he created."

As pioneers into the evolving world of free-space optical communications, Dr. Martini and his team continue to search for new solutions in translating research into every-day reality. One area of focus could take the lasers below ground by integrating the system into existing fiber optics networks, enabling high speed laser communications both above and below ground. The team is also developing a phase control detector to complement their recently-created phase control emitter, which will create an entirely phase-controlled system, and enable researchers to manage every aspect of the system. Such a control is well know from radar and radio systems – yet unprecedented in optical systems. This could open a whole new world of possibilities including enhanced chemical and biological detection by up to 1,000,000 times, and facilitate integration into products.

For Dr. Martini, it is all a matter of perseverance as he explores this new frontier. "There is proof of concept that we can do it," Martini says. "The question now is what limitations are there?"

Provided by Stevens Institute of Technology