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Increasing the Effectiveness of Steered Agile Beams

DARPA's Steered Agile Beam Program is developing components to steer laser beams for wide application in Defense Department programs, dramatically increasing the effectiveness and reducing the complexity of laser beam steering systems now in use.

Good afternoon. I'm John Carrano, with the Microsystems Technology Office at DARPA. Today I am going to speak about one of my photonics programs, the Steered Agile Beam (STAB) Program.

Current generations of U.S. weapons and communication systems use lenses, mirrors, and gimbals to steer laser beams. The goal of the STAB Program is to eliminate the slow, heavy gimbals and replace them with compact electronically controlled laser beam steering components.

The STAB Program will develop components that can be used in soldier transportable tactical laser communications and conformal, compact infrared countermeasures (IRCM). The payoff of STAB technology will be reduction in system size and weight by more than a factor of 30 and an increase in data throughput by more than a factor of 10.

For the IRCM application, the only way to steer a beam is with large gimbals and mirrors that are external to the aircraft skin. For laser communications, there are no systems with on-the-move point-and-track and none that are easily soldier transportable.

The existing ground-based optical communication systems are large and permit only fixed point-to-point communications. The payoff to our military of increasing laser beam agility is two-fold.

First, we will enable on-the-move, high-data rate, optical communications. A conceptual laser communications network in support of a typical military operation might consist of multiple platforms, such as armored vehicles, dismounted soldiers, UAVs, command posts, logistic points, and aircraft. We see STAB technologies deployed on each of these platforms to allow for high-data rate, line-of-sight communications as a complement to the existing RF communications network.

STAB's second payoff to our military is to reduce the complexity and fragility of current IRCM systems. The STAB payoff for IRCM will be demonstrated in actual missile tests using STAB components.

Here we see the basic sequence of events in defeating an incoming missile. The aircraft under attack must detect a missile launch, direct a laser beam to the missile, and cause the missile guidance system to malfunction—all in the few seconds before impact.

STAB technology will allow IRCM beam steering without using large gimbals. The STAB beam steering component could be conformal to the aircraft skin and could fit in the same aperture as the threat warning system.

We have a plan for demonstrating STAB technology as part of a live missile test in which we will evaluate our agile beam steering modules under a realistic IRCM scenario. This effort is cofunded by DARPA Program Manager Greg Vansuch as part of the MEDUSA Program in DARPA's Special Projects Office.

To achieve these goals, we are pursuing several candidate component technologies in the STAB Program. For example, we have multiple efforts using micro-electro- mechanical systems (MEMS) structures. In one of the MEMS projects, we are developing an array of actuators that translates a microlens array in both orthogonal lateral directions.

This building block structure is then repeated as a large, two-dimensional lenslet array where each pixel element can be independently controlled. This results in beam steering to any point in the desired 90 degree field of regard.

Another electrostatically driven actuator approach being pursued consists of micromirrors with novel "twin-crank" actuators that efficiently convert lateral motion into rotational motion in two dimensions. These are electrostatically driven actuators with very little power consumption. The small size of these MEMS mirrors makes them less susceptible to G-loading than conventional gimbal mirrors.

In the steered agile laser transceiver (SALT) cube, we see the true heterogeneous integration of MEMS, photonics, and electronics at the chipscale. This is an example of innovative component technology in action.

A key component of the SALT cube is the twin-crank MEMS mirror that will steer the IR diode laser beam. Semiconductor laser diodes at the four top corners of the cube illuminate a MEMS mirror that steers in both azimuth and elevation. A photoreceiver array accepts incoming beams from the collecting lens, processes this information to obtain the transmitted data, and establishes the exact location of the transmitting node. Based on this positional data, electronics control the MEMS mirror to point the transmit beam in the correct direction. A MEMS inertial measurement unit is used to determine orientation of the SALT cube platform with respect to other receivers or transmitters in the data link.

We recently completed a major increase in scope to the SALT Cube project that will culminate in a demonstration of laser communications between small UAV platforms. This increase in scope is cofunded by Program Manager George Duchak under the THOR Program in DARPA's Advanced Technology Office.

Another technique for steering a beam is to use an optical phase array (or OPA). Liquid crystal OPAs can be fabricated such that the phase change introduced along the array can be electrically controlled. In this fashion, an incident beam sees a varying refractive index as it propagates along the array and is thereby steered.

In one approach, OPAs used for "fine" steering are combined with very high efficiency Bragg gratings for "coarse" steering. This approach allows precision beam steering over a wide field of regard. Describing this in the terms used by radar designers, we would say that the combination of high efficiency Bragg gratings and OPAs concentrate power into the main lobe and reduce power in the sidelobes, thereby enhancing the beam steering efficiency.

One such concept for all-electronic control is called the universal beam controller (or UBC). It involves the integration of several key component technologies including high-performance OPAs, adaptive optics, and photothermal refractive glass (PTRG). PTRG devices are fabricated by storing 3D phase perturbations in glass elements that are then selected using OPAs.

The STAB Program recently demonstrated components of the UBC, showing the ability to do both wide-angle (coarse) steering and zone-fill or fine-angle steering. OPA elements were used to select one of two PTRGs for wide-angle beam steering, followed by OPAs for zone fill. This was the first practical demonstration of the ability to steer a laser beam very precisely over wide angles using only electronic components.

The key performance metrics for the STAB Program include the overall beam steering efficiency (which we want to be greater than 80 percent), an aperture size of 2 cm, steering speed of less than 1 msec, a field of regard of plus or minus 45 degrees, and an operating wavelength of 1.5 to 5 micron. Recently, completed laboratory demonstrations by STAB contractors have shown that STAB components are meeting the performance metrics required for the successful transition of STAB technology into DoD systems.

The STAB Program now consists of major defense corporations such as Raytheon, BAE Systems, Hughes Research Lab, Rockwell Scientific Company, and Honeywell. We also have involvement from several universities including the University of California at Berkeley, Kent State University, UCLA, UCSD, and USC. Each group is working on complementary parts of the program.

We completed the system design and validation stage and have made excellent progress on developing and demonstrating several different component technologies. Most important, we have accomplished the world's first practical, all-electronic agile beam steering over wide angles.

Our future plans include STAB system demonstrations of real-time optical communication links between UAVs and the use of steered agile lasers to detect and defeat a ground-to-air missile before impact.

As I said earlier, we completed detailed plans for both an IRCM demonstration and an optical communications demonstration, and have increased the scope of those efforts within the program. These two critical tasks form the basis of the technology transitions that will occur from the successful completion of the STAB Program. The transitions directly involve two key Service component labs and research and development engineering centers as well as transitions within DARPA between our technology-based MTO and the system offices of ATO and SPO.

There are several transition opportunities that we are working hard to effect as the end state of the STAB Program. MEDUSA and THOR are two new DARPA system development programs for which STAB technology will play a key role. The goal of the MEDUSA Program is to defeat any electro-optics that look at a U.S. platform. This requires technology to steer midwave infrared lasers without wavelength dispersion. The THOR Program goal is to establish theater-level, free-space, optical communications between ground-based and airborne platforms.

Again, agile beam steering is required to allow for on-the-move point and track. We are working closely with the U.S. Army to transition STAB technologies into Army communications systems. Specifically, one of the STAB participants is the Army Research Laboratory's Atmospheric Laser Optical Testbed. The ARL testbed will be used to evaluate STAB beam-steering technologies under realistic, but controlled and well-characterized, conditions. Thus, we will have a direct path for transistioning STAB Program outcomes as they are developed.

The U.S. Air Force Research Laboratory and DARPA are working together to demonstrate the feasibility of STAB technologies for IRCM by transitioning our components into demonstrations that will show DARPA technology being inserted into ongoing DoD programs to leverage advances in technology.

In summary, the STAB Program is developing components to steer laser beams for wide application in DoD programs, dramatically increasing the effectiveness and reducing the complexity of laser beam steering systems now in use. Technology developed by STAB will be used to reduce the weight and volume of IRCM beam-steering systems and will increase the data throughput of optical communication systems.

DARPA's Microsystem Technology Office is working closely with the Services to effect the transition and early insertion of STAB technologies into critical DoD systems.