

# **THE WRIGHT LABORATORY AVIONICS DIRECTORATE LASER COMMUNICATIONS LABORATORY, A FACILITY TO PERFORM FREE SPACE LASER COMMUNICATIONS SYSTEM TESTING**

by

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The Laser Communications Laboratory (LCL) of the Wright Laboratory Avionics Directorate, Wright Patterson Air Force Base is a facility located on the twelfth floor of Area, B's Building 620 tower. The LCL has a line-of-sight coverage to any point in the two hundred square kilometer area surrounding WPAFB, including an eight kilometer line-of-sight link to its off-base remote transmit station, Trebein Test Facility (TTF). This paper summarizes the capabilities and provides a physical description of the LCL and TTF which can be used by those needing line-of-sight ranges up to eight kilometers to experimentally evaluate optical communications systems performance. A brief synopsis of past projects, current programs and future projects are included in the paper.

The Wright Laboratory Laser Communications Laboratory (LCL) was founded in 1981 to establish a testbed for Air Force Free Space Laser Communications developmental systems. The nerve center of the LCL is the control/receiver facility located on the twelfth floor of the Wright Patterson Air Force Base (WPAFB), Area B, Building 620 tower three miles East of Dayton Ohio. The LCL Control/Receiver Facility (LCLCRF) contains 400 square feet of enclosed working space with 240 square feet of additional working space on each of the attached balconies. The balconies are located on the east and west sides of the LCLCRF and are separated from it by 240 square feet of glass in the windows and doors making the area surrounding building 620 visible on the east and west sides of the LCLCRF. From the LCLCRF and its balconies, connectivity is achievable to just about everywhere in the 200 square kilometer area

surrounding Building 620. Three of the most commonly used locations for communications testing include links between the LCL and the USAF Museum taxiway/runway, the WPAFB Area C runway and the LCL Transmit Facility (LCLTF) located at the off base Trebein Test Site.

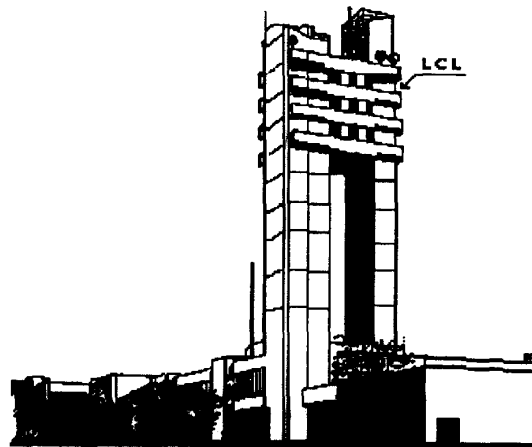


Figure 1. WPAFB, Area B, Building 620 Laser Communications Laboratory

The link between the LCL west balcony and the museum provides short range distances from 1 to 2 miles for short-to-medium range optical communications testing requirements. For testing requiring shorter ranges and isolation, the one mile runway of the museum with its restricted access can be used exclusively.

The proximity of the Area C flight line to the LCL provides a three mile line-of-sight link for preflight

testing of optical communications equipment, ready for flight testing, before takeoff. Connectivity between the LCLCRF and the aircraft can be established by locating an optical transceiver, compatible with the ones to be tested on the plane, on the east balcony of the LCLCRF and aligning them. After takeoff, additional preflight tests can be achieved by having the aircraft fly an oval or race track pattern in the vicinity of the LCLCRF.

For tests requiring longer distances and a more permanent setup, the LCL includes an area of land with buildings which is located eight kilometers to the east of the LCLCRF known as the Trebein Test Facility (TTF). Trebein contains 95 acres of fenced-in land with five buildings. One of the buildings, No. 356, is elevated 10 feet above ground level and functions as the LCL Transmit Facility (LCLTF). The link between the LCLCRF and the LCLTF is line-of-sight and the atmospheric turbulence in the channel is monitored through real time measurements of the diffraction limited aperture of the atmosphere,  $r_0$  [5]. Meteorological measurements of temperature, humidity, and atmospheric pressure are also monitored at the LCL to provide additional data for the analysis of the received communications signal.

Besides the strategic location of the test site, and its abundance of land isolating it from sources of electromagnetic interference and the surrounding community, Trebein has a 3200 square foot building which is ideal for the research, development, and testing of laser communications equipment. The building is partially underground with two access doors and no windows making it completely dark when the lights are off and the doors are shut. It is 125 feet long and 40 feet wide and contains four rooms, two vaults, and two radio frequency enclosures. The largest room is 125 feet long and 20 feet wide. It is ideal for aligning optical transmitter and receiver equipment and for checking the divergence and wavefront characteristics of transmitted laser beams.

In addition to the meteorological and atmospheric turbulence profiling mentioned earlier, the capability exists in the LCL to accomplish a large assortment of

additional diagnostic tests from profiling the output of the transmitter to system level tests involving the characterization of the received signal thorough bit error rate testing and signal-to-noise ratio analysis.

The LCLCRF has most of the measurement tasks completely automated. The meteorological and atmospheric turbulence data is collected by computer and saved in a format which is easily imported into data analysis software like SigmaPlot. Data analysis and data collection is accomplished in the LCL using a Digital Equipment Corporation GPX Workstation and a Toshiba T3200SXC Portable Computer. Both computers contain an IEEE-488 interface and frame grabber which work with any camera having a RS-170 output. The GPX workstation is used mainly for collection of atmospheric turbulence data, control of laboratory receiver telescopes, and as an interface to the Avionic Directorate local area network. The portable 386 Toshiba has one full size 16 bit accessory slot and one half size 8 bit slot which allows it to be configured as an asynchronous bit error machine using the HP 4957PC protocol analyzer card, an equipment controller using the National Instruments GPIB-PCII card and LabView software, and a beam profiler using a Scentech's video frame grabber with a CCD camera and GTFS's Beam Analysis IV software. Automated power and energy measurements are accomplished using a Coherent Corporation Labmaster power/energy meter connected to the RS-232 port of the Toshiba.

The LCL has made a profound impact on all laser communications projects which have been accomplished by the Wright Laboratory Avionics Directorate. The HAVE LACE (Laser Communications Experiment) program [1] in the mid 80's used the LCL to perform preflight testing of the laser communication equipment to be used in the air-to-air laser communications feasibility demonstration. Before take off, the laser communications equipment on the two C-135 aircraft on the runway in Area C were checked by establishing communication between the aircraft laser communication equipment and a like system stationed on the east balcony of the LCL. Once communications were established, and last

minute tweaking was accomplished, the two planes took off to accomplish their testing to evaluate/prove the feasibility of air-to-air laser communications.

Another program which benefited from the LCL was the Scattered-light Test Airborne Receiver (STAR) program [3]. The test was a cooperative effort between the Naval Ocean Systems Center (NOSC) and Wright Laboratory to demonstrate scattered-light communications in an airborne platform, scientifically evaluate the receiver, and to characterize the channel. Upon delivery, the STAR equipment was thoroughly tested in the LCL before integration into the aircraft where it was flight tested to examine the effects of beam spreading and pulse stretching when communicating through clouds. Upon conclusion of the flight test, the data was taken to the LCL for processing where it was found that previous methods of obtaining cloud probe data grossly under predicted the scattering losses and that when using radiometric derived cloud optical thickness, the Stotts equation overpredicted measured pulse widths by a factor of two to ten.

Testing of the Hand Held Laser Communicators (HHLC) [2] which we had developed for helicopter refueling missions was done extensively using all the LCL resources. Initially we tested them in the LCLCRF to determine their wavelength, output power, pulse repetition frequency, and modulation characteristics. We then took them out to the Air Force Museum for ground testing. We stationed one person in the LCLCRF and another person on the runway for distance checking and pointing ability. We were able to communicate the full two miles without tripod support so we decided to attempt communications from the LCLCRF at Area B to the LCLTF at the TTF. We were able to communicate over the five mile range with exceptional quality. However, acquisition and tracking requirements were a little more stringent and we had to stabilize the HHLCs. After the test in the LCL, the units were field tested on two helicopters. These tests were so successful that funding was approved to build 8 preproduction models. There were some design changes made to make the communicators lighter, smaller, and eyesafe.

Once these units were redesigned, fabricated and delivered, testing resumed in the LCL, checking the divergence and receive/transmitter alignment.

In order to be able to scientifically evaluate free space laser communications systems, it is necessary to have the ability to measure the degree of atmospheric turbulence present in the channel. Since equipment required to do this is not commercially available, we built our own diffraction limited aperture of the atmosphere measuring device. The device was built to provide  $r_0$  and laser beam angle-of-arrival data.

Another area of interest involves optical communications via ultra-violet (UV) scattering. We are presently using a mercury vapor lamp excited by a 915 MHz oscillator. The oscillator is TTL triggered by a NRZ (non return to zero) bit stream and modulates the UV radiation by exciting the bulb during positive pulses of the bit stream. Non-line-of-sight communications around the LCLCRF have been accomplished at baud rates up to 9600 bits per second and line-of-sight communications have been achieved out to one mile. The potential of Low Probability of Intercept (LPI) UV communications has us looking for new device sources such as UV laser diodes and better detectors for our future requirements.

As a consequence of a requirement for laser communications to be eyesafe, we are launching an effort to study the eyesafe region of the infrared spectrum to determine its susceptibility to atmospheric turbulence and atmospheric absorption. The wavelength being explored is the two micron region which according to LOWTRAN models is a window which can be exploited for long distance laser communications requirements. A two micron, one watt laser diode has been ordered from Spectra Diode Laboratory and a two micron camera has been purchased to operate with our beam profiling software and equipment. The building and testing of the communications equipment is expected to be completed in June 1994, at which time bit error and atmospheric turbulence data will be collected to characterize the channel and com-

pared with other communications systems which have been previously tested.

The existence of the LCL has been a tremendous asset in the research and development of past and present laser communications systems and will play an even more important role in the years to come as these developmental systems become operational. Since the LCL is an Air Force asset, it is available to test other products/laser communications systems developed by other DOD agencies and industry.

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