Lidar Measurements of Clouds and Aerosols Using AlGaAs Lasers Modulated with Pseudorandom Codes

Jonathan A. R. Rall
James B. Abshire
Serdar S. Manizade*
NASA Goddard Space Flight Center
Experimental Instrumentation Branch
Greenbelt MD 20771
*Science Systems and Applications, Inc.

June 22, 1992

AlGaAs lasers provide an optical source for lidar transmitters which is small, lightweight, and efficient. When compared to monopulse lidar transmitters, they are limited in peak power, but are capable of high average transmitted power. Atmospheric lidar profiles have been measured using a quasi-CW transmitted signal by means of pseudorandom-noise (PN) amplitude modulation [1,2]. A PN code modulated laser beam is transmitted through the atmosphere and a small fraction, less than one photon per bit, of the transmitted signal is backscattered to the receiver. The receiver detects these photons and accumulates a photoelectron count over many repetitions of the code. This accumulated count is a histogram of counts versus time delay (expressed as number of bits). On average, the histogram represents the convolution of the atmospheric backscatter function with the transmitted code. The correlation properties of the PN code permit recovery of the atmospheric response by correlation of the histogram with the transmitted bit sequence.

We developed, improved and tested a prototype PN code AlGaAs lidar and altimeter [3]. A system diagram is shown in Figure 1 and system characteristics are tabulated in Table 1. Significant features of the system include: a laser diode header integrating optics, thermal control, electrical driver and AlGaAs laser into a single unit [4]; variable PN code lengths up to 4095 bits; a photon counting Si APD detector; and a dedicated histogramming circuit. Modulation rates in excess of 200 MBit/sec are possible, in the altimetry mode, yielding range resolutions down to ~0.75 m/bit.

Figure 2 shows nighttime ranging measurements to a water tower over a horizontal path through the planetary boundary layer. A 255-bit code was transmitted at 1 MHz, providing resolution of 150 m/bit. The average transmit power was 6.4 mW and the integration time was 240 seconds. Features in the data include near-range aerosol backscatter out to 2 km with the water tower return at 5.3 km. The altimeter resolution may be improved by oversampling at the receiver or increasing the transmit PN code bit rate.

Figure 3 shows lidar measurements made on a clear night at a 50° elevation angle with a 300 second integration time. The average transmit power was 10 mW. No visible clouds were observed. Aerosol backscatter was detected up to 4.0 km altitude. At 8.6 km altitude a large lidar return shows a layer of subvisible cirrus clouds 1.7 km thick. The correlation data shown have been smoothed with a four bit running average.

In conclusion, we measured lidar signals using an AlGaAs laser with 10 mW average power to 11.3 km range. It appears that this technique could achieve longer ranges and shorter integration times by increasing the average laser power and decreasing the transmitter divergence.

References:
Table 1 - Prototype AlGaAs Lidar Characteristics

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laser Type</td>
<td>AlGaAs Laser Diode, Mitsubishi ML5415N</td>
</tr>
<tr>
<td>Laser Modulator</td>
<td>Negative Drive</td>
</tr>
<tr>
<td>Collimating Lens</td>
<td>3 element, NA=0.5</td>
</tr>
<tr>
<td>PN Code</td>
<td>255 bit, 1 MHz bit time</td>
</tr>
<tr>
<td>Range Resolution</td>
<td>1 μsec = 150 meters</td>
</tr>
<tr>
<td>Telescope</td>
<td>20 cm diameter, f/6.3</td>
</tr>
<tr>
<td>Interference filter</td>
<td>820 nm, 10 nm bandpass</td>
</tr>
<tr>
<td>Detector</td>
<td>Photon Counting Si APD</td>
</tr>
<tr>
<td>Discriminator</td>
<td>Tennelec TC 453 Constant Fraction</td>
</tr>
</tbody>
</table>

Figure 1. AlGaAs Lidar and Altimeter System Diagram

Figure 2. AlGaAs Altimetry Measurements
4/3/92 NASAGSF, 9/2/92 NASAGSF
Transmit power: 6.4 mW avg
Bit rate: 1.0 MHz
Pointing angle: Horizontal
Range resol.: 150 mbit
Count rates:
Smoothing:
Receiver FOV:
1.27 mrad
Back only: 1.2 kHz

Figure 3. AlGaAs Lidar Measurements
5/1/92 NASAGSF
Transmit power: 10 mW
Integ. time: 300 sec
Bit rate: 1.0 MHz
Pointing angle: 50 deg. (elev.)
Range resol.: 150 mbit
Count rates:
Smoothing: 4 bit
Receiver FOV: 645 urad
Signal + back: 2.0 kHz
Back only: 1.4 kHz

207