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

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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 siganl 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 10mW. 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:
1. N. Takeuchi, N. Sugimoto, H. Baba, and K. Sakurai,"Random modulation cw lidar," Applied Optics 22, 1382 (1983).
2. N. Takeuchi, H. Baba, K. Sakurai, and T. Ueno,"Diode-laser random-modulation cw lidar," Applied Optics 25, 63 (1986).
3. J. B. Abshire, J. A. R. Rall, and S. Manizade."Altimetry and Lidar Using AlGaAs Lasers Modulated with Pseudo-Random Codes," 16th International Laser Radar Conference, (1992).
4. J. A. R. Rall and P. L. Spadin, "Optomechanical Design of the Grating Laser Beam Combiner (GLBC) Laser Diode Header," SPIE Vol 1044, Optomechanical Design of Laser Transmitters and Receivers, p89 (1989).

Table 1 - Prototype AlGaAs Lidar Characteristics

Laser Type	AlGaAs Laser Diode, Mitsubishi ML5415N
Laser Modulator	Negative Drive
Collimating Lens	3 element, NA=0.5
PN Code	255 bit, 1 MHz bit time
Range Resolution	1 µsec ≈ 150 meters
Telescope	20 cm diameter, f6.3
Interference filter	820 nm, 10 nm bandpass
Detector	Photon Counting Si APD
Discriminator	Tennelec TC 453 Constant Fraction

Figure 1. AlGaAs Lidar and Altimeter System Diagram

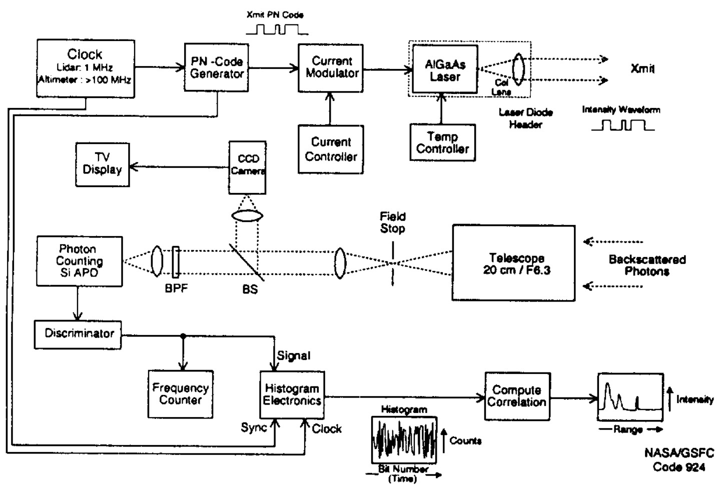

Figure 2. AlGaAs Altimetry Measurements

4/29/92	NASA/GSFC	Filename:	429255e.1.hst.corr
Transmit power:	6.4 mW avg	Integr. time:	240 sec
Bit rate:	1.0 MHz	Pointing angle:	Horizontal
Range resol.:	150 m/bit	Count rates:	
Smoothing:	none	Signal + back:	3.4 KHz
Receiver FOV:	1.27 mrad	Back. only:	1.2 KHz

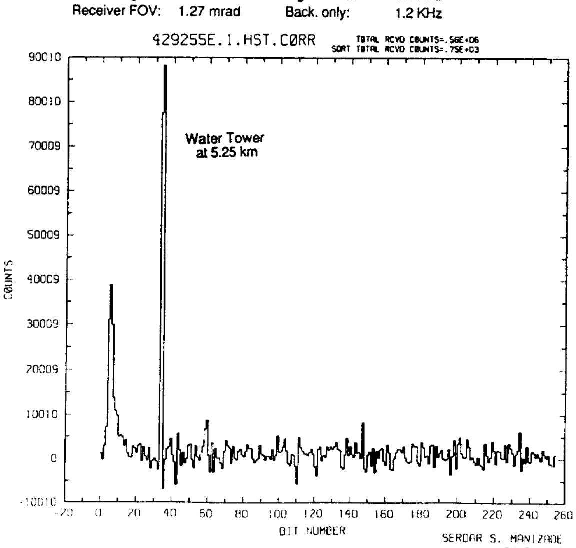

Figure 3. AlGaAs Lidar Measurements

5/1/92	NASA/GSFC	Filename:	51255N.1.hst.corr
Transmit power:	10 mW	Integr. time:	300 sec
Bit rate:	1.0 MHz	Pointing angle:	50 deg. (elev.)
Range resol.:	150 m/bit	Count rates:	
Smoothing:	4 bits	Signal + back:	2.0 KHz
Receiver FOV:	645 urad	Back. only:	1.4 KHz