Foreword

Laser is another discovery of great significance by humans after semiconductor and nuclear energy. By using the excellent properties of laser, including high coherence and narrow beam, people have applied the laser to active acquisition of target information, thus developing the laser detection technology, which has been widely applied to many fields. These include science research, deep space exploration, environmental monitoring, ocean exploration, forest survey, topographic mapping, and military domain. For example, it has been applied to the atmosphere, land, and ocean exploration in the geoscience field; to satellite-earth remote sensing, inter-satellite ranging, fragment detection, and space rendezvous and docking in the aerospace field; to detection of particulate matter, polluting components, visibility, and quietness in the environment and meteorology field; to the establishment of digital elevation models, topographic mapping, and forest stock investigation in the mapping and resource field; and reconnaissance and imaging, space surveillance, target measurement, obstacle avoidance, underwater target detection, and chemical/biological warfare agent detection in the military application domain.

According to the detection style, laser detection can be divided into direct detection and coherent detection. Direct detection directly transforms laser signal intensity into electrical signals, where the amplitude of the output from photoelectric detectors is directly proportional to the received optical power. Target information is contained in the signal amplitude and travel time. Coherent detection coherently mixes laser echo and local-oscillator (LO) signals on the detector and outputs intermediate frequency (IF) signals, in which target information is modulated. Relevant information on targets can be obtained by processing IF signals. Due to the introduction of LO signals, coherent detection improves the detection sensitivity and reduces the minimum detectable power. It can also acquire the phase and frequency variation of laser echoes, so laser coherent detection outperforms direct detection in terms of measurement accuracy. With advantages including high sensitivity, abundant detectable information characteristics, and high conversion gain,

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it can achieve high-accuracy target detection and recognition. Given this, laser coherent detection has gotten more and more attention and become one of the research focuses all over the world. However, laser coherent detection systems feature complex structures and set a high requirement for the coherence of light sources. Additionally, the detection platform, the atmosphere in the transmission channel, and the target itself heavily affect the coherence of laser echoes and it is also difficult to extract target-modulated optical frequencies from weak signals. As a result, coherent detection has not been widely applied.

The author has been engaged in the research of target laser detection for a long time and has conducted a number of national and military research projects. Starting with airborne laser ranging, the author has studied laser direct detection, developed the first remote-sensing laser system for space use, that is, the laser altimeter on the lunar probe satellite Chang 'e-1, and then developed a 3D target laser imaging system. Meanwhile, the author leads a team to carry out in-depth research on laser coherent detection, accumulate abundant first-hand data, publish a series of papers, apply for a batch of patents, and develop experimental or application systems. This monograph was written by summarizing years of research achievements of the team in laser coherent detection, aiming to systematically expound theoretical methods of laser coherent detection oriented to target detection.

The monograph includes five chapters, laying emphases on discussing the theoretical methods and research achievements of laser coherent detection in atmospheric disturbance detection, ranging and velocity measurement, micro-Doppler-based detection, and synthetic aperture detection. Chapter 1 provides the theoretical foundation of laser coherent detection and mainly introduces the fundamentals, principles, main technology indexes and their characteristics, application situation, and typical systems of laser coherent detection. Chapter 2 introduces laser coherent detection of atmospheric disturbances and describes two aspects (atmospheric CO_2 and wind-field disturbances induced by moving targets) following the idea of detection principle, detection system, and experimental verification. Chapter 3 describes the chirped amplitude-modulated (AM) laser coherent detection of range and velocity and mainly introduces the principles, methods, and systems for ranging and velocity measurement of chirped AM lidars. Chapter 4 introduces laser coherent detection based on the micro-Doppler effect, and expounds its modeling as well as rapid extraction of micro-motion characteristics based on time–frequency analysis (TFA) and micro-motion parameter estimation based on the signal model. Focusing on synthetic-aperture laser coherent detection, chapter 5 describes laser coherent detection of synthetic aperture lidars (SALs) and introduces the detection principle, imaging algorithm, phase compensation algorithm, and experimental systems, and verification of SALs.

Research in the monograph was conducted by the author's team in the College of Electronic Countermeasures, National University of Defense Technology (former Electronic Engineering Institute of PLA) and Shanghai Institute of Technical Physics, Chinese Academy of Sciences (CSA). In the process, the research team was carefully guided and vigorously supported by experts including academicians Yongqi Xue, Guangcan Guo, Wei Huang, Lijun Wang, Wei Wang, Wenqing Liu,

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The monograph only represents the tip of a giant iceberg in the research of laser coherent detection and some problems remain to be further deeply studied. Due to the limited knowledge of the author, there might be inevitably some mistakes and flaws in the monograph. Comments from experts and readers are welcomed.

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