A time-space synchronization of coherent Doppler scanning lidars for 3D measurements of wind fields

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This thesis consists of the results of a Ph.D. study that was focused on the development of the system of three time-space synchronized pulsed coherent Doppler scanning lidars, which are coordinated by a remote 'master computer'. This system has the unique capability to measure a complete three-dimensional flow field by emitting the laser beams from the three spatially separated lidars, directing them to intersect, and moving the beam intersection over an area of interest. Each individual lidar was engineered to be powered by two real servo motors, and one virtual stepper motor. The stepper motor initiates the laser pulse emission and acquisition of the backscattered light, while the two servo motors conduct the scanner head rotation that provides means to direct the laser pulses into the atmosphere. By controlling the rotation of the three motors from the motion controller the strict synchronization and time control of the emission, steering and acquisition were achieved, resulting that the complete lidar measurement process is controlled from the single hardware component.

The system was formed using a novel approach, in which the master computer simultaneously coordinates the remote lidars through a UDP/IP and TCP/IP network by exchange of network packets. Since the size of the packets is roughly 1 kB, this approach allows an uninterrupted and fast coordination of the lidars, even in the case of mobile networks such as GSM. With this approach a maximum lag of 10 ms was observed in terms of the scanner heads’ rotation and the measurements among the lidars in the system. The laser beam pointing accuracy of each lidar was estimated to ±0.5° for the laser beam direction, and roughly ±5 m for the sensing distance. A set of procedures were proposed that can improve the pointing accuracy by a factor of 20. Subsequently, two experiments were carried out in which the developed multiple lidars system was used to synchronously measure wind velocity fields in multiple points in the atmosphere.