Spectral analysis made by Mach–Zehnder interferometer for atmospheric backscattering

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Abstract: The ability to analyze the spectra of 532 nm/354.7 nm backscatter signal of atmosphere for Mach-Zehnder interferometer is demonstrated. The Mach-Zehnder interferometer accepts return signal. The phase difference and interference contrast are measured, which are formed by the interferometer’s double arm, polarization and quadro-channels, and Doppler frequency shift of atmosphere and backscatter ratio of aerosol backscatter to molecular backscatter are derived.

Unlike the previously developed high spectral resolution lidar (HSRL) by use of Fabry–Perot interferometers or iodine filters, the Mach–Zehnder interferometer (MZI) receiver does not separate the molecule and particle scatterings. We perform the backscatter ratio determination by deriving the interference contrast from the signal delivered by the different channels. In the same way, the Doppler shift is calculated by the difference in the interference state between the outgoing pulse and the backscattered signal. For both retrievals it is then unnecessary to lock the emitted frequency onto the receiver as required by most HSRL devices to reduce bias in the signal analysis. Only relative frequency stability is necessary during signal averaging, which is a more easily achievable requirement. Another characteristic of the MZI receiver is that it transmits all the incident photons in contrast to most of the HSRL devices that use only the signal that is transmitted through a highly selective filter, and Michelson interferometer receiver reflects half of all the incident photons. The MZI receiver allows larger signal to noise ratio (SNR) for the MZI compared with the HSRL devices, as long as the noise is not dominated by the background light contribution. It must also be noted that the measurements of the backscatter ratio and the wind velocity can be performed independently and do not require cross corrections.

We prove physics theory of an HSRL using a laser that oscillates in a multi-longitudinal mode. The instrument exploits the light backscattered by particles using an MZI with an optical path difference matched to the free spectral range of the laser longitudinal modes. Rayleigh and Mie scattering components are acquired using an MZI with the same free spectral range (FSR) as the transmitted laser. The transmitted laser light is measured as a reference signal with the same MZI. Using rectangular prism reflex light path built up double optical arms, one of the same class geometrical model of MZI is devised. With combination magnesium fluoride crystal and mountain crystal two crystals material, a quarter wave plate is devised, and then it makes MZI adapt to two types 532 nm/354.7 nm wavelength light echo synchronously. If MZI is employed as atmospheric backscatter signal’s frequency spectrum analyzer, this high spectral resolution lidar will become an atmosphere analysis instrument with excellent performance and anticipant prospect.

Keywords: Mach–Zehnder interferometer; Doppler frequency shift; interference contrast; lidar backscatter ratio


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