Analysis and Development of Spaceborne Water Vapor DIAL

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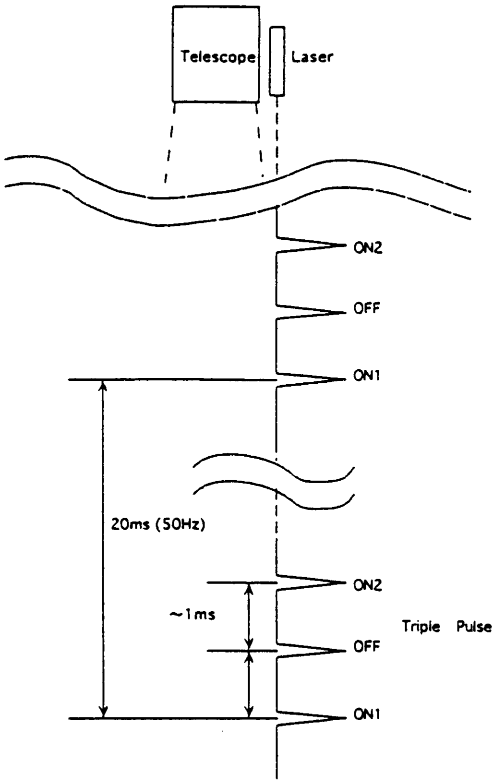
This paper presents the result of the analysis study for atmospheric water vapor measurements from spaceborne DIAL and the progress of water vapor DIAL development for future spaceborne lidar missions in Japan. We think that a solid state laser pumped Ti:sapphire laser is available to use with the spaceborne water vapor lidar at present. Then the water vapor absorption lines used in these calculations are in near infrared spectral region. The measurement accuracy strongly depends on the distribution of water vapor, and the water vapor concentrations depend on the altitude, the season and the global area. Our analysis results suggest the existence of the most suitable pairs among the on-off laser lines commonly under these environments for global measurements of water vapor profiles from the spaceborne DIAL.

Refering to these results, we are developing an electrically efficient, compact, reliable and long life laser system consisting of an injection seeded Ti:sapphire laser. This Ti:sapphire laser is excited by a diode pumped Nd:YLF laser. The injection seeder consists of a single longitudinal diode laser. The tunable system consits of the wavemeter, the PA cells filled with water vapor and the fequency controller .

Transmitter	
Pulse energy	100mJ (ON & OFF)
Repetition rate	50Hz
Wavelength	810~820nm
Spectral width	<0.5pm
Wavelength stability	<±0.05pm
Spectral purity	0.999
Altitude	460km
Ground velocity	7km/s
Receiver	
Aperture	1m
Field of view	0.1mrad (day) 1mrad (night)
Filter bandwidth (FWHM)	0.05nm (day) 1.0nm (night)
Optical transmittance	30%(day),50%(night)
Detector quantum efficiency	50% (APD)
Dark count	50 count/s
Δz	100m~1000m
Δx	100km (≒700shot)

Triple pulse spaceborne DIAL



The systematic errors are caused by the following systematic effects.

(1) Modification of the laser spectral profile by molecular absorption

(2) Doppler broadening of the elastically backscattered signal and other atmospheric spectral broadening effects

(3) Pressure shifts of absorption lines

(4) Temperature sensitivity of absorption lines

(5) Laser spectral purity

(6) Laser wavelength uncertainty

(7) Knowledge of laser spectral output

Influences (2) and (5) are contained in this simulation.

Influences (1), (6) and (7) are negligible under consideration of the lidar specifications.

Influence (3) can be reduced by using the low-pressure photoacoustic cell for tuning to the absorption line of the water vapor.

Influence (4) is negligible by selecting the temperature insensitive absorption line in 820nm band.

Relative error in the DIAL measuremment of water vapor concentration

$$\frac{\Delta n}{n}=\frac{1}{2\Delta\sigma n(R_2-R_1)}\left\{\sum_{i=1}^{2}\sum_{j=1}^{2}\left[\frac{(S_{ij}+B)F+D}{S_{ij}^{2}}\right]\right\}^{1/2}$$

$\Delta\sigma$: differential absorption cross section between the on and off wavelength

n : water vapor concentration

F : excess noise factor

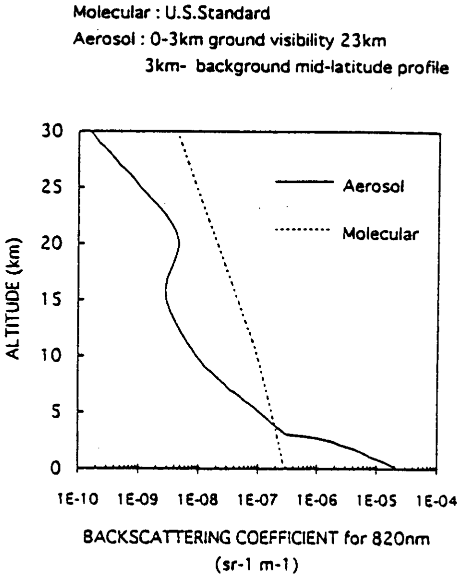
D : dark current(photoelectrons)

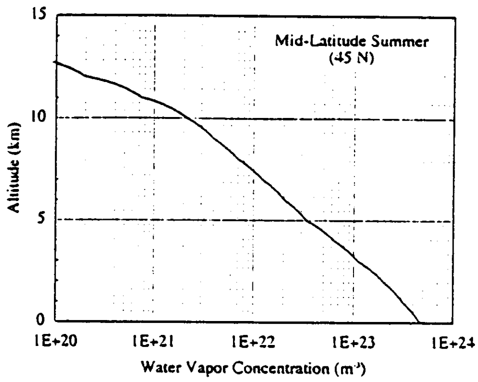
S : lidar signal (photoelectrons)

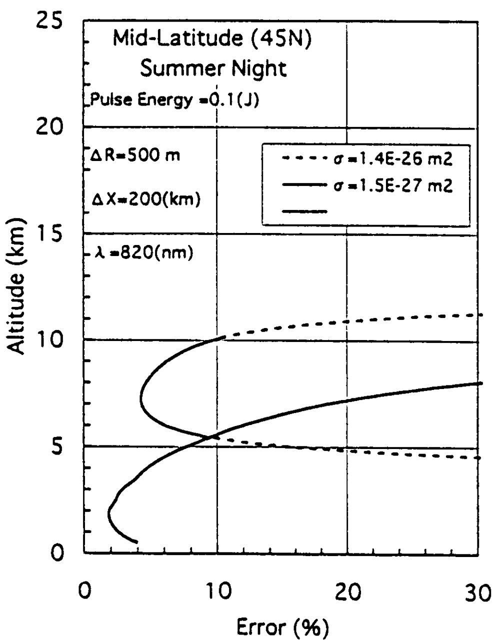
B : background signal(photoelectrons)

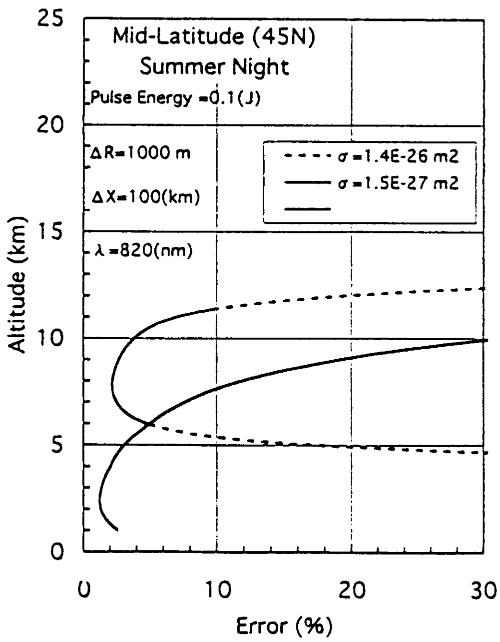
$i=1, 2$: for the range R_1 and R_2

$j=1, 2$: for the on and off signals


Molecular : U.S.Standard
Aerosol : 0-3km ground visibility 23km
3km- background mid-latitude profile
Aerosol
Molecular
ALTITUDE (km)
BACKSCATTERING COEFFICIENT for 820nm
(sr-1 m-1)
1E-10 1E-09 1E-08 1E-07 1E-06 1E-05 1E-04


Mid-Latitude Summer
(45 N)
Altitude (km)
Water Vapor Concentration (m⁻³)
1E+20 1E+21 1E+22 1E+23 1E+24


Mid-Latitude (45N)
Summer Night
Pulse Energy =0.1(J)
ΔR=500 m
ΔX=200(km)
λ =820(nm)
σ =1.4E-26 m2
σ =1.5E-27 m2
Altitude (km)
Error (%)

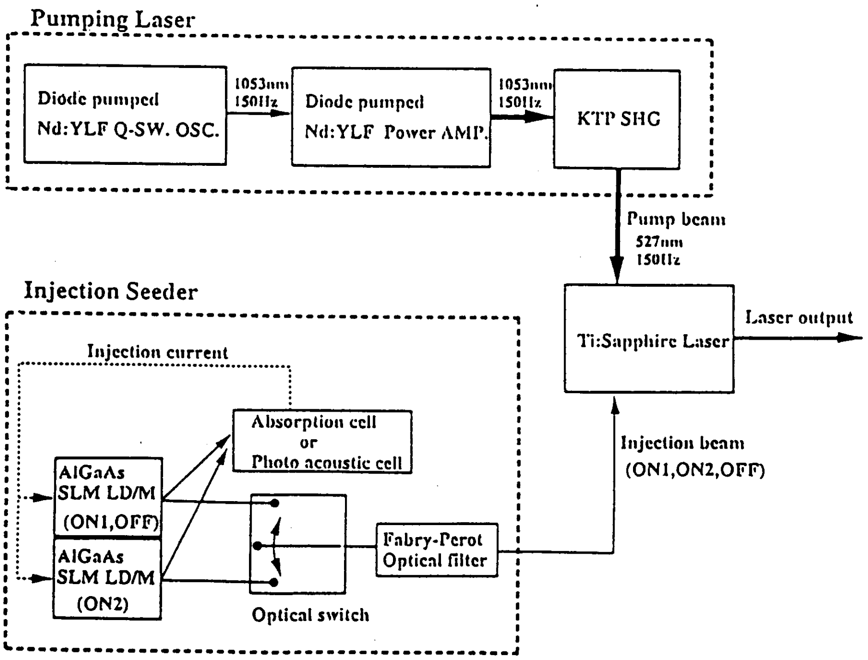

Mid-Latitude (45N)
Summer Night
Pulse Energy =0.1(J)
ΔR=1000 m
ΔX=100(km)
λ =820(nm)
σ =1.4E-26 m2
σ =1.5E-27 m2
Altitude (km)
Error (%)

Schedule for a spaceborne water vapor DIAL

1996	Development of an LD pumped Nd:YLF laser
1997	Development of a Ti:sapphire laser with injection seeders Development of an airborne water vapor DIAL
1998	Test flights of the airborne DIAL
1999	Development of a spaceborne water vapor DIAL
2003 ?	Launch of a spaceborne water vapor DIAL

Specifications of the water vapor DIAL laser system

Single pulse output energy	> 100 mJ (ON1, ON2, OFF)
Repetition rate	50 Hz (ON1, ON2, OFF)
Stability of the output energy	< ±10 %
Pulse width	~20 ns
Lasing wavelength	(ON1, ON2, OFF) (818.3086 nm, 818.1814 nm, 818.15 nm) or (ON1, ON2, OFF) (816.5329 nm, 816.8815 nm, 816.60 nm)
Spectral width	< 0.5 pm
Wavelength stability	< ±0.05 pm (ON1, ON2) < ±1.0p m (OFF)
Side mode suppression ratio	> 30 dB (ON1, ON2)



Block-diagram of a water vapor DIAL laser system.