ATMOS B1 Lidar

T. Itabe

(Communications Research Laboratory)

ATMOS B1 Lidar

T.Itabe
Communications Research Laboratory
Ministry of Posts and Telecommunications
4-2-1 Nukuikita, Koganei, Tokyo 184, Japan
tel +81-423-27=7546 fax +81-423-27-6667
e-mail itabe@crl.go.jp

A lidar for ATOMS B1 should be an improved one of the MDS lidar, which will be launched in 2001. Main objective of the MDS lidar is to observe top height and thickness of cirrus cloud form space. Objectives of ATOMS B1 Lidar are

(1) improvement of accuracy of the cirrus cloud thickness by adding capability for estimation multiple scattering (multi- FOV receiver, D.L.Hutt et al., 1994),
(2) depolarization measurement of the cirrus cloud and aerosol in nighttime,
(3) daytime tropospheric aerosol measurement.

It is believed that (1) and (2) will be performed by increasing the average power in one order magnitude.

The tentative lidar parameters of the MDS lidar is, as follows.

Laser	wavelength : λ	1053nm	527nm	(1053nm)
	output energy : E	90mJ	4.4mJ	(50mJ)
	repetition : (rep.)	100Hz		(100Hz)
	average power : W=Ex(rep.)	9W		(5W)
	divergence : θt	0.15mrad		(0.1mrad)
Receiver				
	Telescope : A	1m diameter		(1m diameter)
	FOV : θr	0.19mrad		(0.1mrad)
	Bandwidth : $\Delta\lambda$	0.3nm		(0.1nm)
	optical efficiency : T_0	0.4		(0.5)
	detector	Si-APD		(Si-APD)
	quantum efficiency : η	0.36		(0.3)

Design of the MDS lidar is based on feasibility studies done by a committee for space borne laser radar, which was co-chaired by Prof.Kobayashi of Fukui university and Dr.Sasano of NIES/EA from 1991 to 1994 (final report in Japanese is available from NIES). However, lidar parameters of MDS lidar are slightly difference from those parameter discussed at the feasibility studies of the committee. The lidar parameter discussed at the committee are shown at right column in the table. Signal- Noise ratio (S/N) is shown in Fig.1 (Fig.4.2.3 of the final report). Error $\delta\beta a$ of the backscattering coefficient βa is

$$\delta\beta a = \frac{\beta a}{\sqrt{m}\left(\frac{S}{N}\right)} \qquad (1)$$

where m is for averaging number of data of Fig.1. If the S/N (Day/Suraface) in Fig.1 would increase one order and m were taken to be ~~50~~ 10⁴ (horizontal resolution ~~50x1.~~ 1.5×10^4 ~~5km-75km~~),
βa can be determined to be (2.0 ± ~~0.3~~ 0.2) $km^{-1}sr^{-1}$ at a height of 5km as the aerosol backscattering profile is assumed as Fig.2. The backscattering profile is correspond to aerosol optical depth of 0.06 as the scattering parameter is 50.
The S/N for daytime observation is proportional to the following factor, (S/N)factor,

$$\left(\frac{S}{N}\right) \propto (S/N)factor = \frac{W}{\theta r\sqrt{\Delta\lambda T_0}} \qquad (2)$$

where other lidar parameters are selected as the same values of the table since they are usually so difficult to be improved. The values of the (S/N)factor of the feasibility lidar and the MDS lidar are

Feasibility Lidar	~~224~~, 111
MDS lidar	~~129~~, 52

The S/N of the tentative MDS lidar is almost half of the S/N shown in Fig.2 since the bandwidth of the receiver is 0.3nm.
Use of the Fabry-Perot etalen is the most important to increase the S/N of the daytime observation one order magnitude. According to the Instrument Panel Report of LASA (R.J,. Curran, 1987), the bandwidth and optical efficiency of the Fabry-Perot etalon are

Bandwidth :$\Delta\lambda$	0.01nm
optical efficency : T_0	0.2,

and (S/N)factor ~~2012~~ 402
where W=9, which is the same one as the MDS lidar. When the average power is increased one order magnitude to 90, (S/N)factor becomes bigger in ~~two order~~ one order magnitude and the horizontal resolution is incresed to ~~1.5~~ 12km ($m \approx 8$). It is believed that the laser of 90 W average power would be realized to be increased the repetition ratio (1k Hz) in one order magnitude.

We would like to conclude that the most important issue of the ATMOS B1 Lidar development is the use of the narrow band Fabry-Perot etalon.

References

R.J.Curran: "LASA (lidar Atmospheric Sounder and Altimer; Instrument Panel Report for the Earth Observing System",EOS Instrument Panel Report IIg(1987)
D.L.Hutt, L.R.Bsissonnnette and L.Durand: "Multiple field of view lidar, returns from atmospheric aerosols", Appl.Opt.,**33**,2338-2348(1994).
Y.Sasano and T.Kobayasi:"Feasibility study on space lidars for measuring global atmospheric environment No.4, Final Report:",F-82-'95/ NIES(1995).

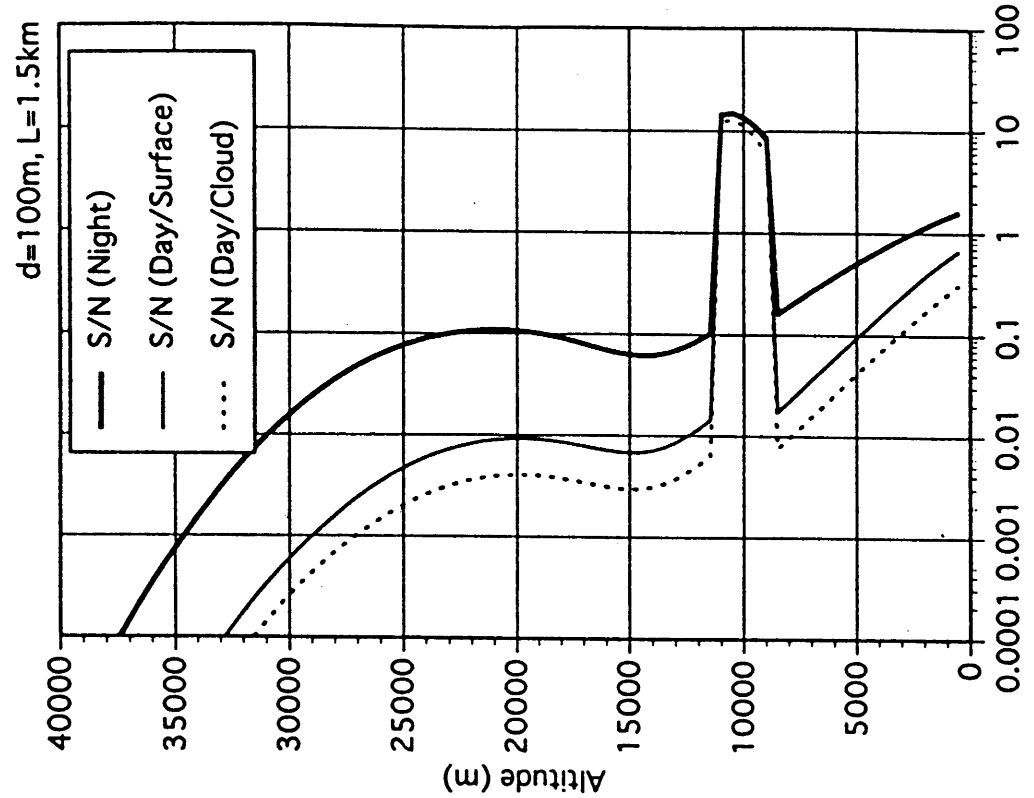


Fig.1 Signal to Noise ratio of the feasibility lidar.

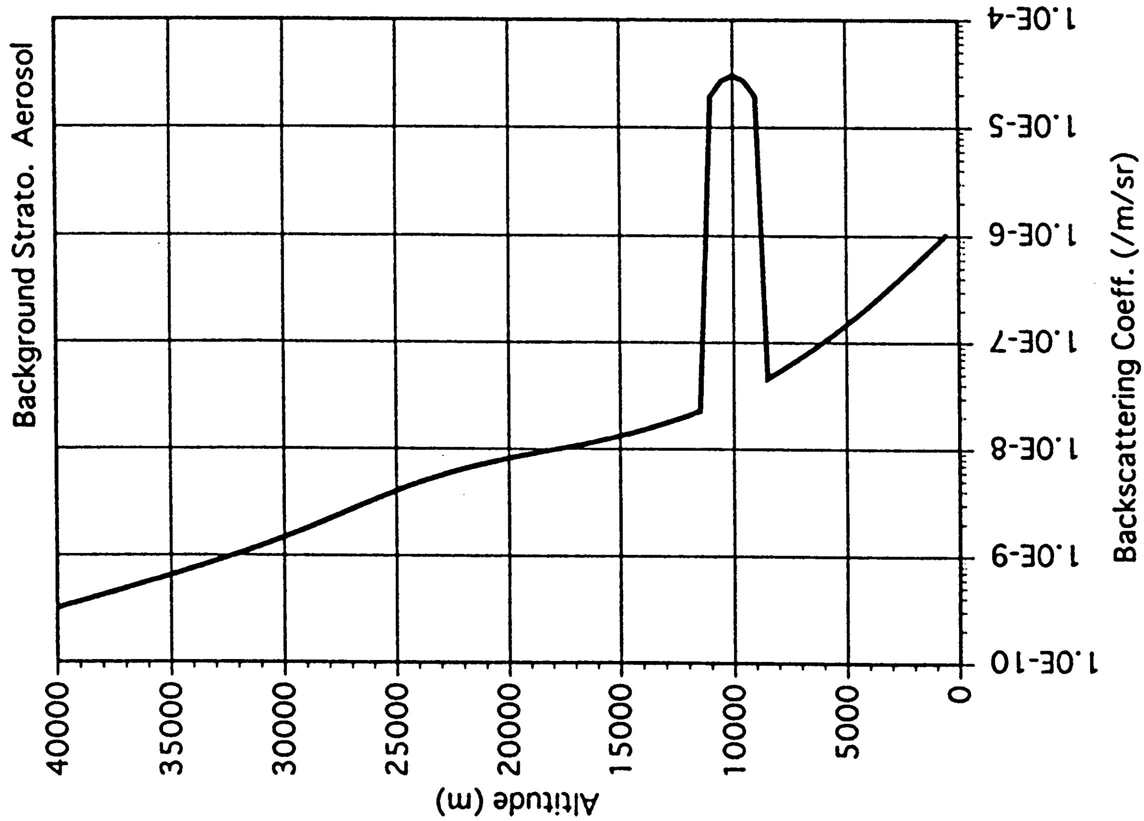


Fig.2 Backscattering profile to simulate the feasibiltiy lidar.

ATMOS B1 Lidar

T.Itabe

Communications Research Laboratory
Ministry of Posts and Telecommunications

ATOMS B1 Lidar should be an improved one of the MDS lidar.

Main objective of the MDS lidar

Observation of top height and thickness of cirrus cloud

Objectives of ATOMS B1 Lidar

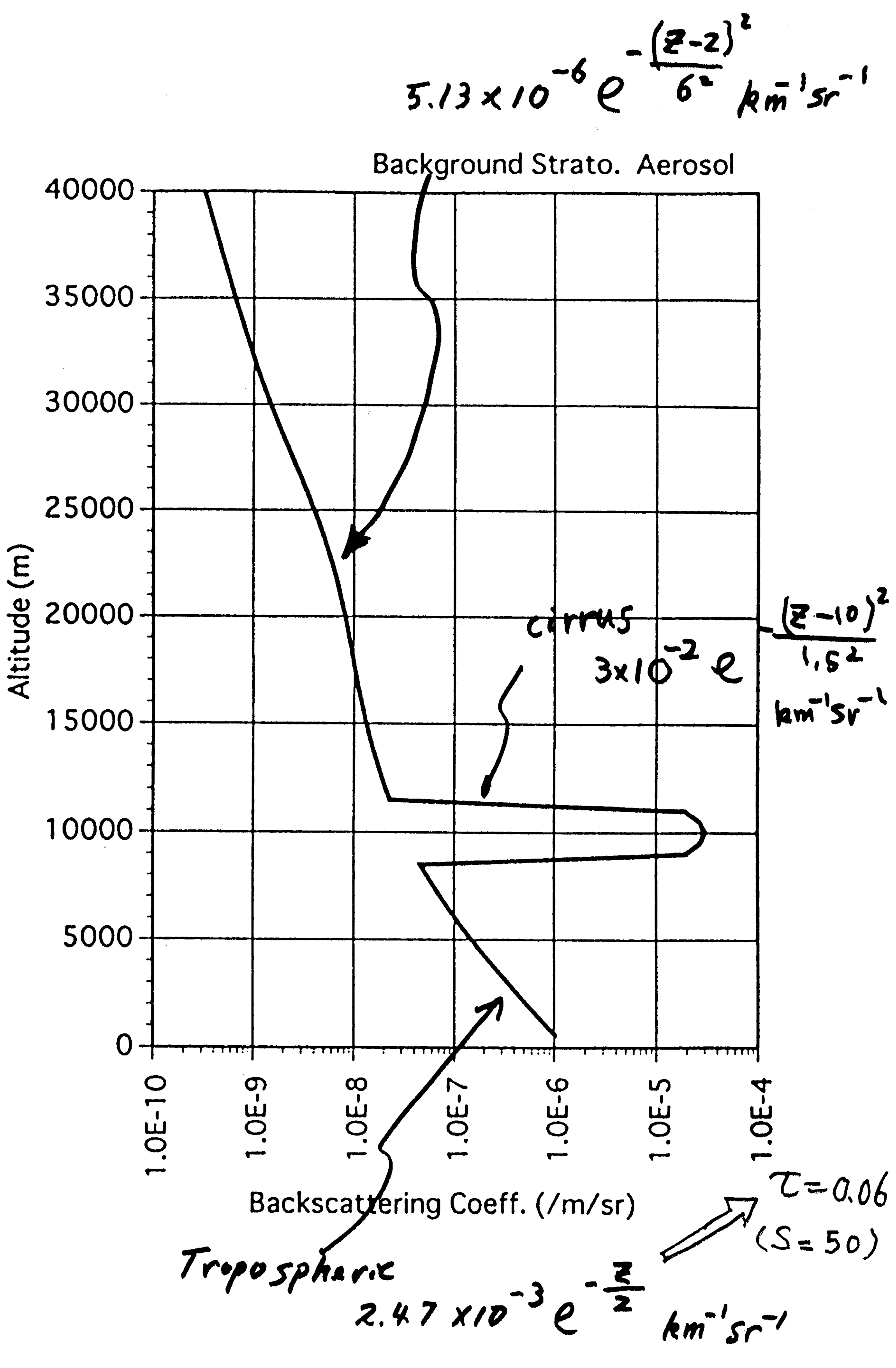
(1) improvement of accuracy of the cirrus cloud thickness by adding capability for estimation multiple scattering
(multi- FOV receiver, D.L.Hutt et al., 1994),

(2) depolarization measurement of the cirrus cloud and aerosol in nighttime,

(3) daytime tropospheric aerosol measurement.

Lidar parameters

		MDS Lidar		Feasibility Lidar
Laser	wavelength : λ	1053nm	527nm	(1053nm)
	output energy : E	90mJ	4.4mJ	(50mJ)
	repetition : (rep.)	100Hz		(100Hz)
	average power : W=Ex(rep.)	9W		(5W)
	divergence : θt	0.15mrad		(0.1mrad)
Receiver				
	Telescope :A	1m diameter		(1m diameter)
	FOV : θr	0.19mrad		(0.1mrad)
	Bandwidth :Δλ	0.3nm		(0.1nm)
	optical efficiency : T0	0.4		(0.5)
	detector	Si-APD		(Si-APD)
	quantum efficiency : η	0.36		(0.3)


$5.13\times10^{-6}\, e^{-\frac{(z-2)^2}{6^2}}\ \mathrm{km^{-1}sr^{-1}}$
Background Strato. Aerosol
cirrus
$3\times10^{-2}\, e^{-\frac{(z-10)^2}{1.5^2}}\ \mathrm{km^{-1}sr^{-1}}$
Altitude (m)
40000
35000
30000
25000
20000
15000
10000
5000
0
1.0E-10
1.0E-9
1.0E-8
1.0E-7
1.0E-6
1.0E-5
1.0E-4
Backscattering Coeff. (/m/sr)
$\tau = 0.06$
$(S=50)$
Tropospheric
$2.47\times10^{-3}\, e^{-\frac{z}{2}}\ \mathrm{km^{-1}sr^{-1}}$

Error of aerosol backscatterint coefficiency βa

$$\delta\beta a = \frac{\beta a}{\sqrt{m}\left(\frac{S}{N}\right)}$$

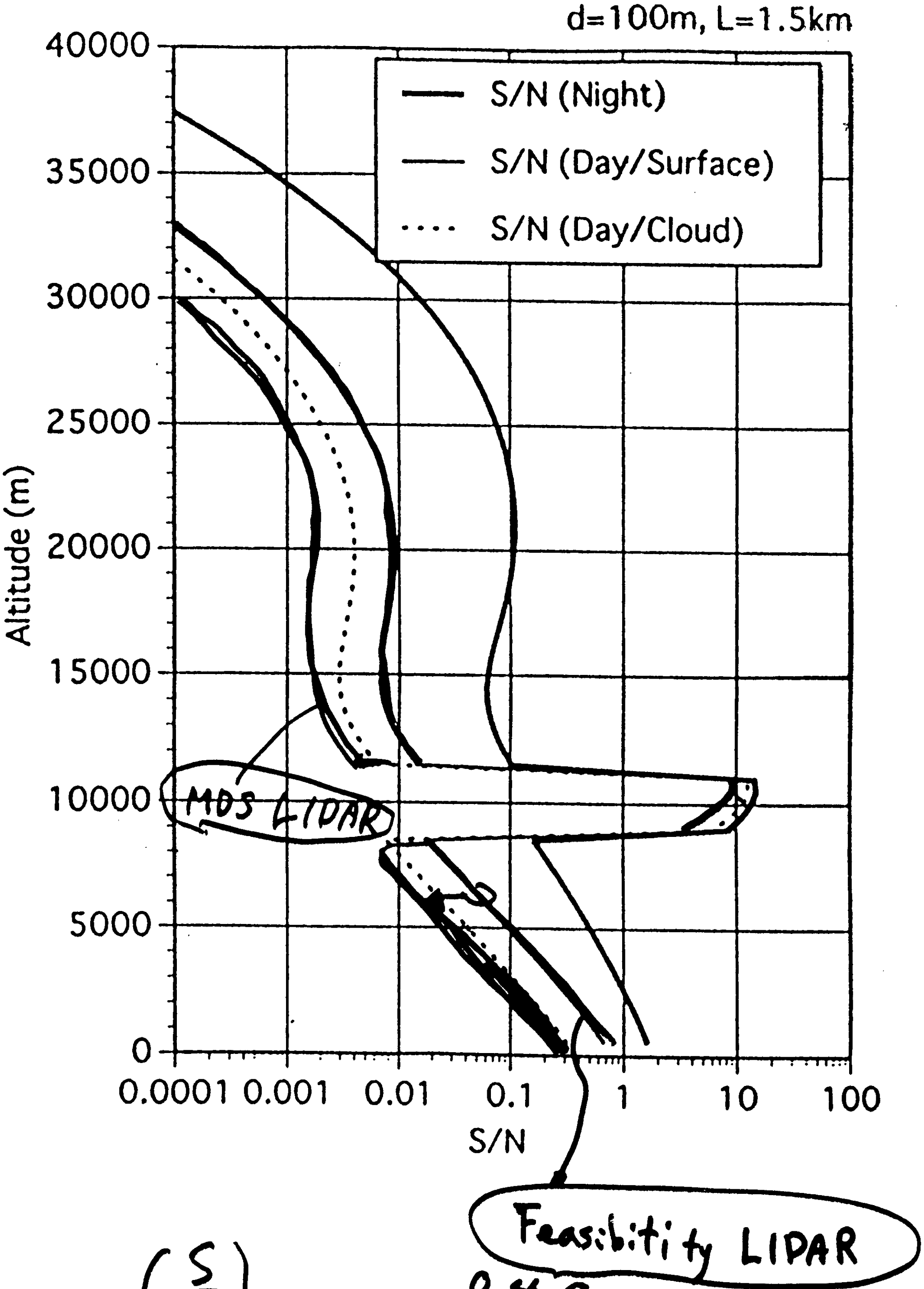
m : averaging number

$$\left(\frac{S}{N}\right) \propto \left(S/N\right) factor = \frac{W\sqrt{T_0}}{\theta r \sqrt{\Delta\lambda T_0}}$$

$\left(S/N\right) factor$ = 224 for Feasibility Lidar

129 for MDS Lidar

0.47 x $\left(S/N\right) factor$ of the Feasibility Lidar



$$\left(\frac{S}{N}\right)_{Feasibility} = \overset{0.42}{\cancel{0.58}} \left(\frac{S}{N}\right)_{MDS}$$

Lidar parameters

		MDS		Feasibility	ATOMS B1
Laser	wavelength : λ	1053nm	527nm	(1053nm)	1053nm
	output energy : E	90mJ	4.4mJ	(50mJ)	90mJ
	repetition : (rep.)	100Hz		(100Hz)	1KHz
	average power :W=Ex(rep.)	9W		(5W)	90W
	divergence : θt	0.15mrad		(0.1mrad)	0.1mrad
Receiver					
	Telescope :A	1m diameter		(1m diameter)	1mϕ
	FOV : θr	0.19mrad		(0.1mrad)	0.1mrad
	Bandwidth :$\Delta\lambda$	0.3nm		(0.1nm)	0.01nm
	optical efficiency : T0	0.4		(0.5)	0.2
	detector	Si-APD		(Si-APD)	Si-APD
	quantum efficiency : η	0.36		(0.3)	0.36

$$\left(\frac{S}{N}\right) \propto \left(S/_N\right) factor = \frac{W\sqrt{T_0}}{\theta r\sqrt{\Delta\lambda \cancel{T}}}$$

$\left(S/_N\right) factor$ = 111 ~~224~~ for Feasibility Lidar

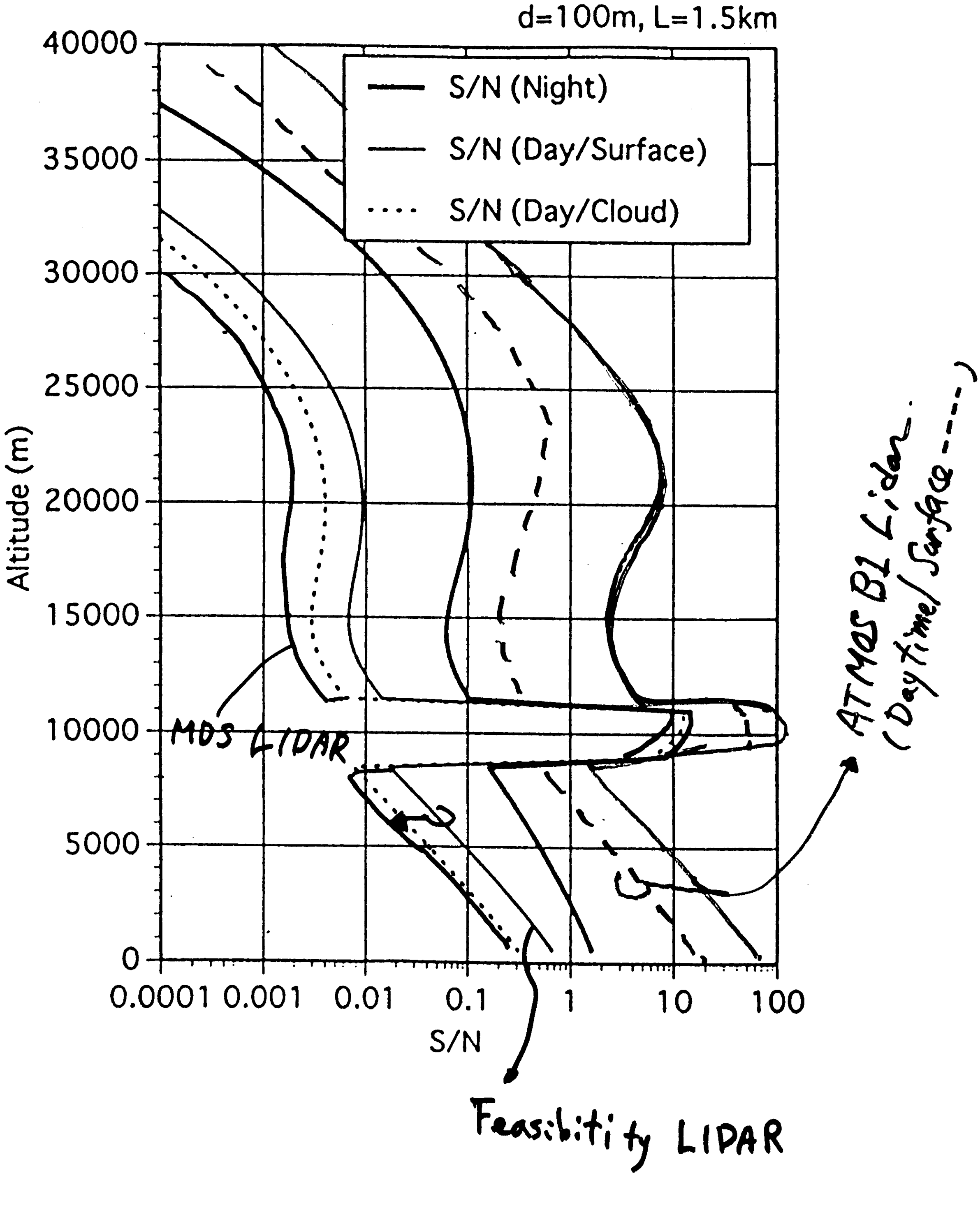
52 ~~129~~ for MDS Lidar

0.47 ~~0.056~~ x $\left(S/_N\right) factor$ of the Feasibility Lidar

ATMOS B1 Lidar

$\left(S/_N\right) factor$ = 4,020 ~~20,120~~ for ATMOS B1 Lidar

36 ~~90~~ x $\left(S/_N\right) factor$ of the Feasibility Lidar



d=100m, L=1.5km
S/N (Night)
S/N (Day/Surface)
S/N (Day/Cloud)
Altitude (m)
S/N
40000
35000
30000
25000
20000
15000
10000
5000
0
0.0001 0.001 0.01 0.1 1 10 100
MDS LIDAR
ATMOS B1 Lidar
(Daytime/Surface ----)
Feasibitity LIDAR