

2008年9月11日

ホテル パーレンス小野屋

第26回レーザセンシングシンポジウム

# ライダー昔話

九州大学広野求和研究室との共同研究

前田三男(久留米高専)

# 経 歴

1960    ルビーレーザー

九州大学工学部電気工学科入学

1961    He-Neレーザー、Q-switchng、SHG

1962    半導体レーザー

1964    修士課程進学(宮副 泰研究室)

Arレーザー、CO<sub>2</sub>レーザー

1966    博士課程進学

色素レーザー



# 色素レーザーの開発

Qスイッチ・ルビーレーザー励起

**P.P.Sorokin and J.R.Lankard: IBM J.Res. & Dev. 10, 162 (1966)**

Chloro-aluminum Phthalocyanine

**M.L.Speath and D.P.Bortfeld: Appl.Phys.Lett. 9, 179 (1966)**

Polymethine Dyes 9月

**F.P.Schafer et al.: Appl.Phys.Lett. 9, 306 (1966)**

Polymethine Dyes 10月

1966年4月 博士課程進学

Qスイッチ可飽和色素の研究

**Y.Miyazoe and M.Maeda:Appl.Phys.Lett. 12, 206 (1968)**

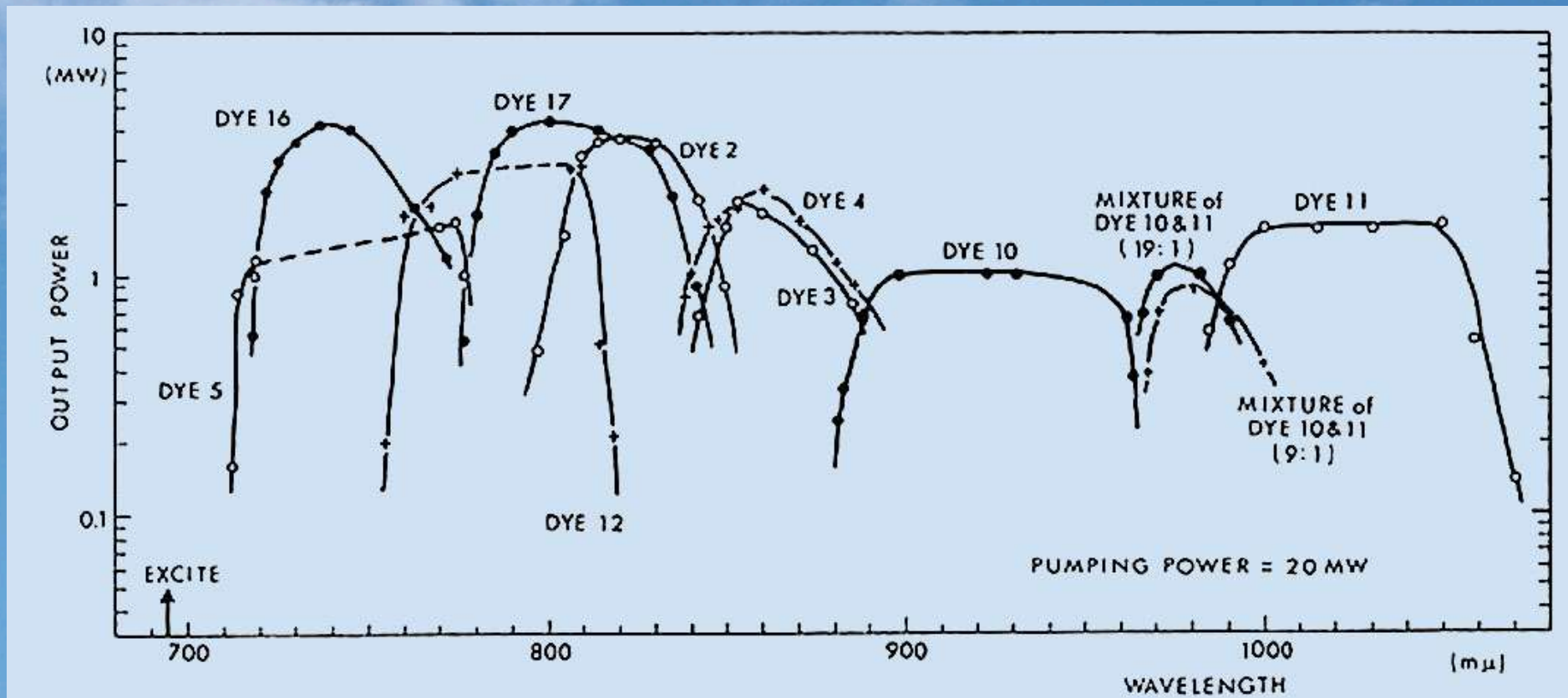
Stimulated Emission from 19 Polymethine Dyes

-- Laser Action over the Continuous Range 710-1060m $\mu$

投稿 1968年1月 掲載 5月

Y.Miyazoe and M.Maeda: Appl.Phys.Lett. 12, 206 (1968)

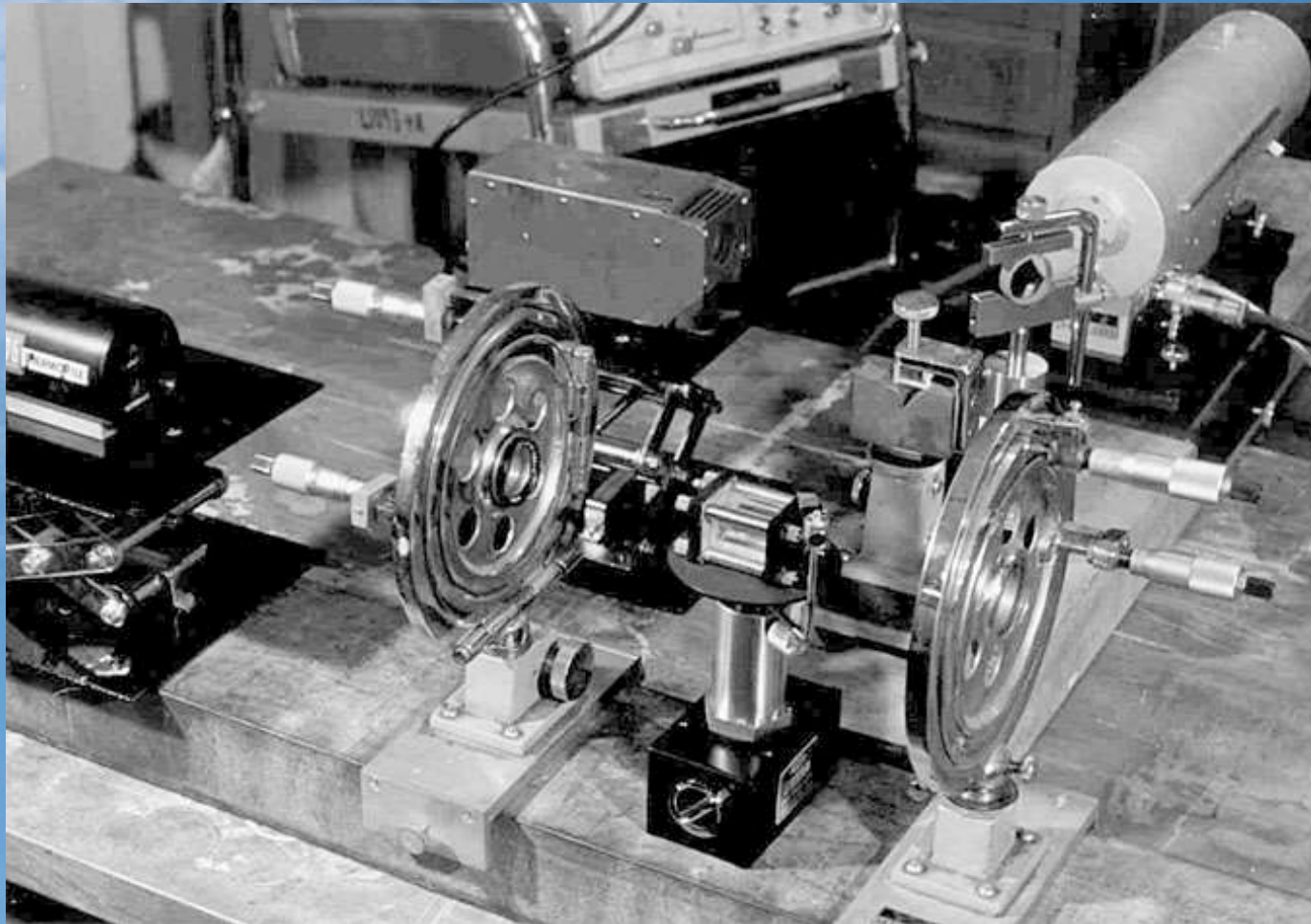
濃度チューニング



ルビーレーザー励起で710～1060nmを連続カバー



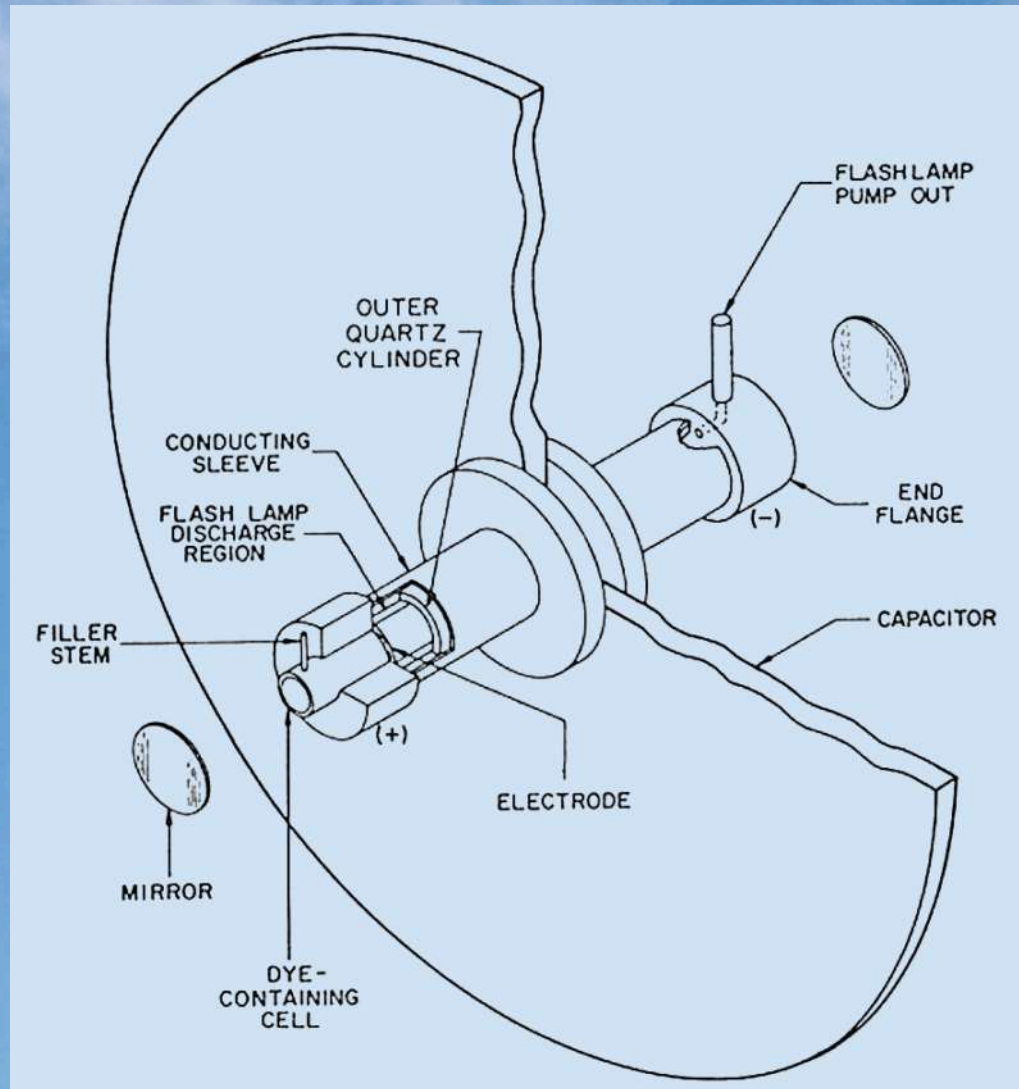
# ポリメチン色素レーザー装置



M.Bass, T.F.Deutsch, M.J.Weber : LASERS vol.3 (1971)

# フラッシュランプ励起色素レーザー

P.P.Sorokin & J.R.Lankard: IBM J.Res. & Dev. 11(1967)148



- ・ディスク型コンデンサー
- ・同軸型フラッシュランプ
- ・ローダミン色素の発振
- ・ジュールオーダーの出力

ランプ発光の  
立ち上がり時間  
1 $\mu$ sec以下



# フラッシュランプ励起 色素レーザー

宮副・前田:九大工学集報 41 (1968)



Na層のライダー観測

M.R.Bowman, A.J.Gibson, M.C.W.Sndford:

Nature 221 (1969, Feb. 1)

Na ランプ  
 $D_1=589.0 \text{ m}\mu$   
 $D_2=589.6 \text{ m}\mu$

濃度  $10^{-5}$  モル/l

ローダミン6G

$2 \times 10^{-5}$  モル/l

$5 \times 10^{-5}$  モル/l

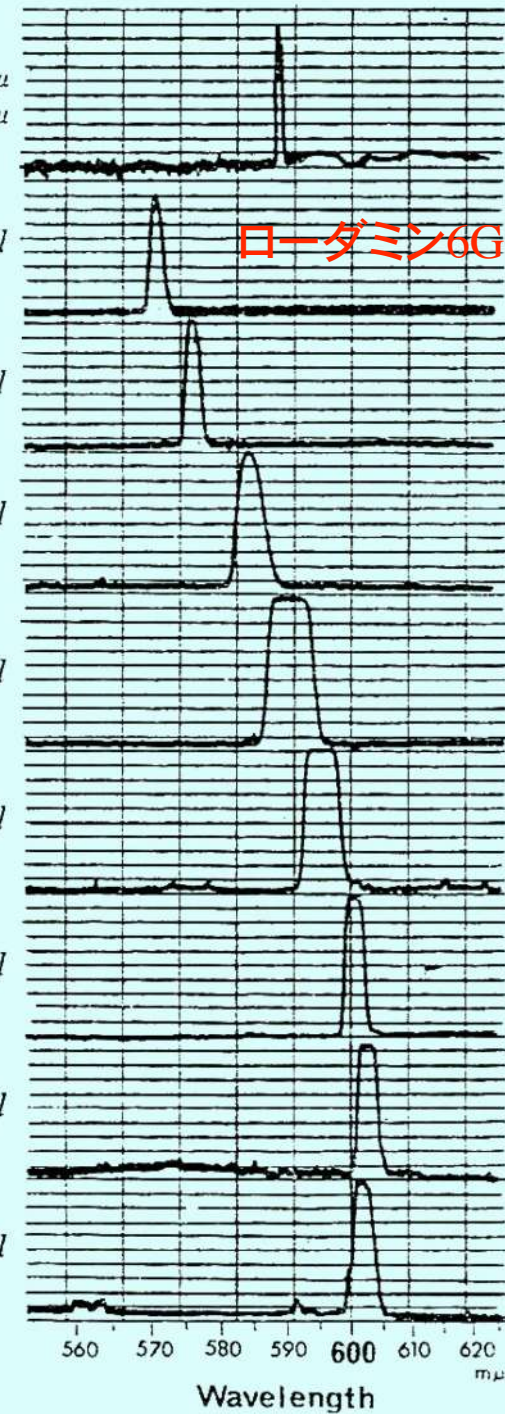
$10^{-4}$  モル/l

$2 \times 10^{-4}$  モル/l

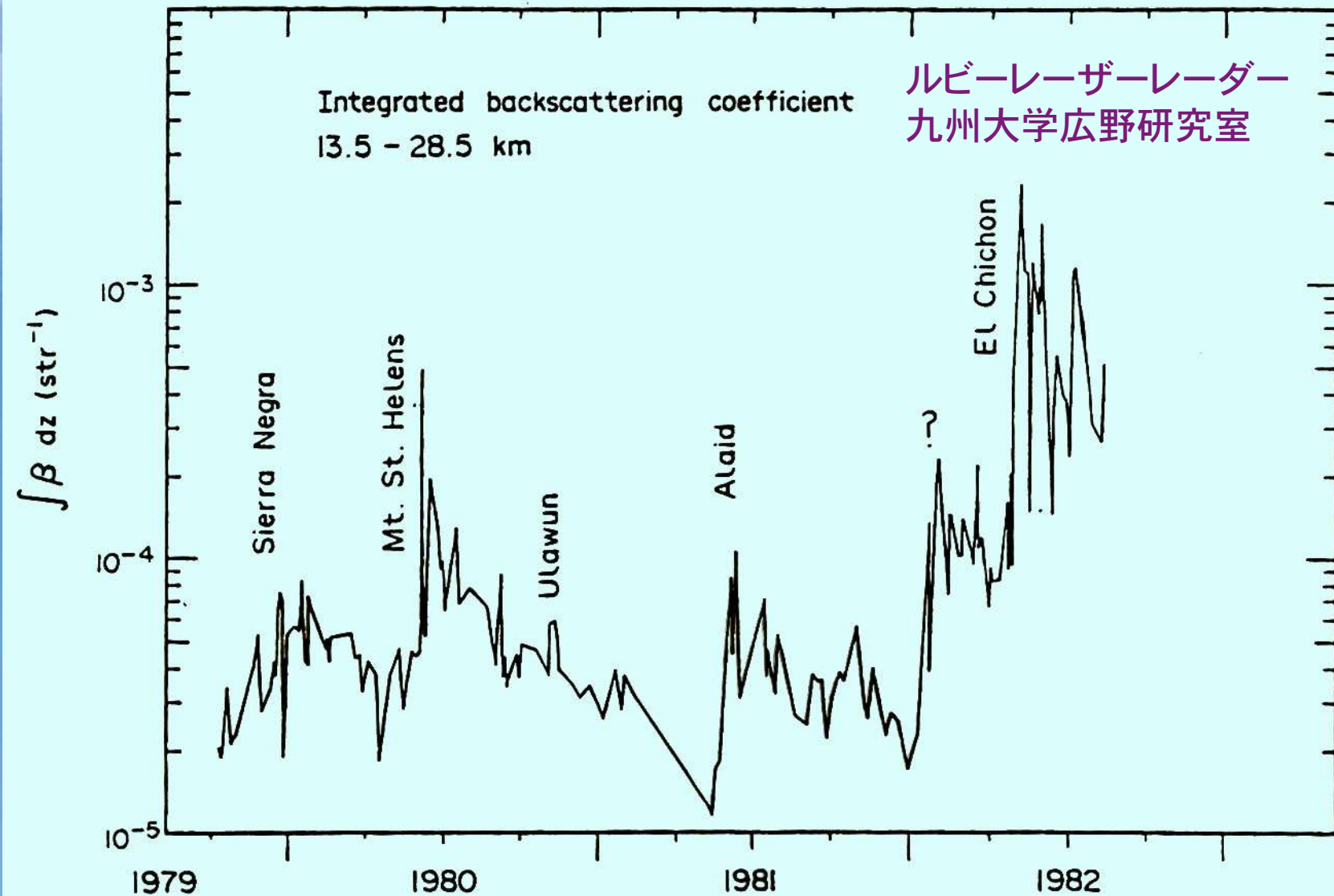
$5 \times 10^{-4}$  モル/l

$10^{-3}$  モル/l

$2 \times 10^{-3}$  モル/l



# 火山起源の成層圏エアロゾル観測



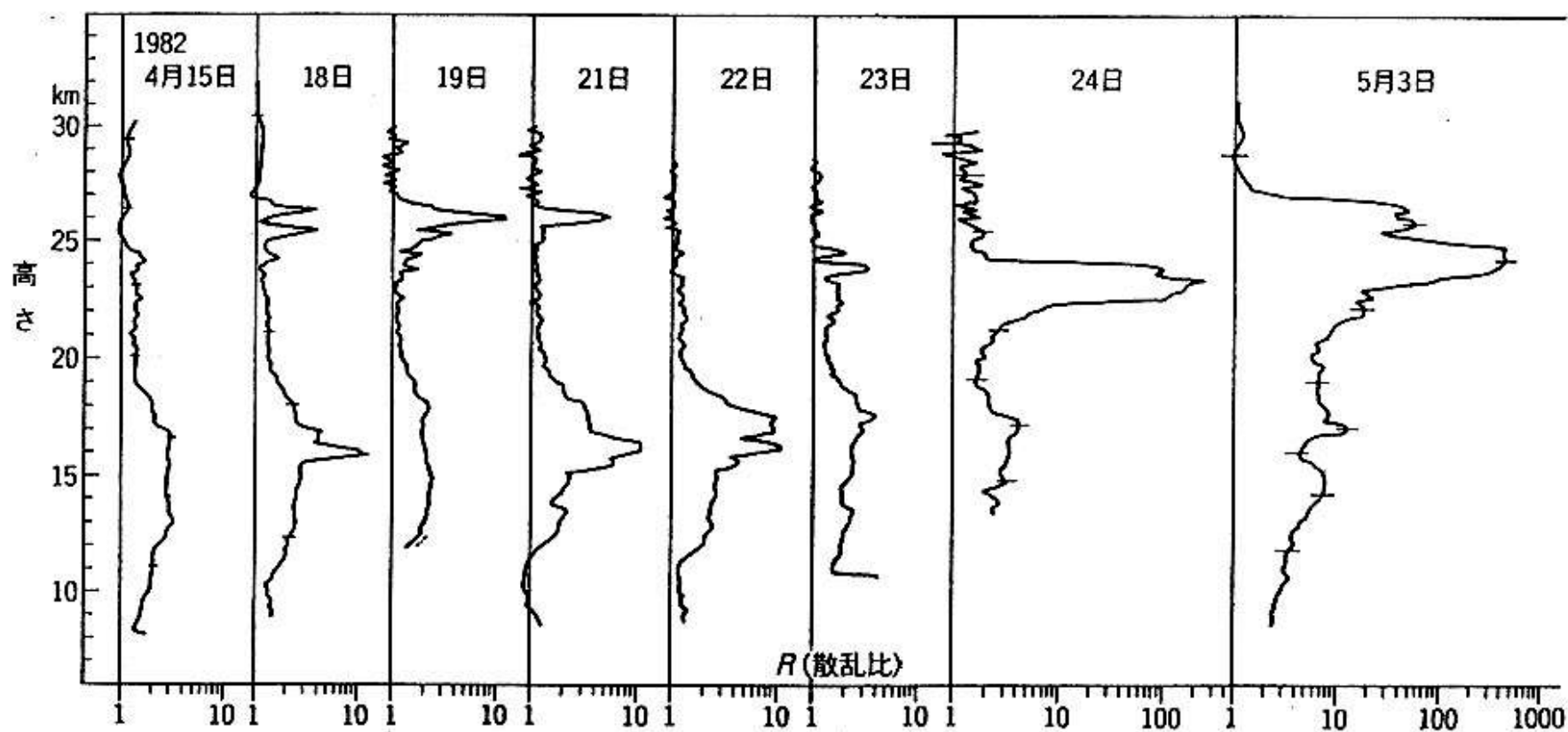


# メキシコのエル・チジョン火山の大爆発後の 成層圏エアロゾルの異常増加

爆発は1982年3月28日から4月4日にかけて起こった。

Nd:YAG Lidar @1.06 $\mu$ m

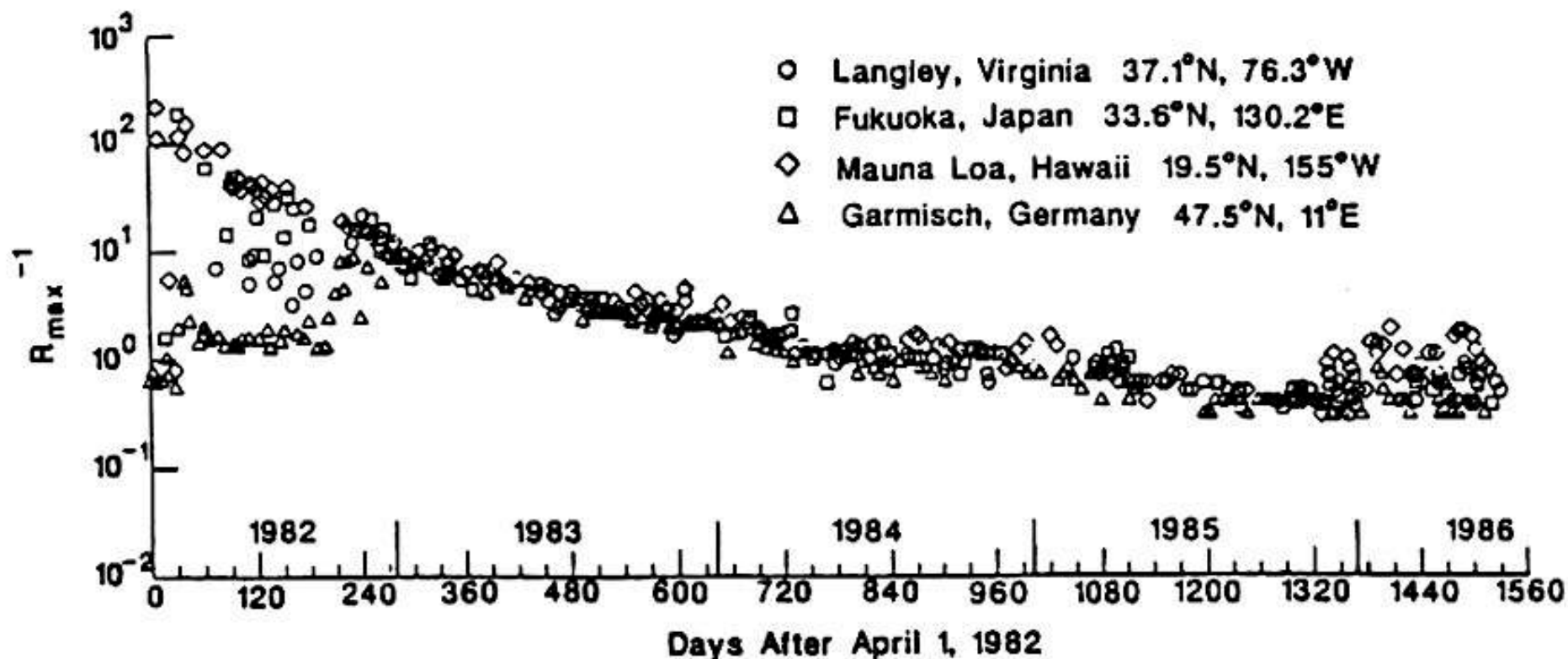
M.Hirono et al.:Geophys.Res.Let. 10 (1983) 152



成層圏エアロゾルは、数ヶ月後には  
地球を均一に覆い尽くした！

### PEAK AEROSOL BACKSCATTER RATIO

$\lambda = 0.6943 \mu\text{m}$





## 広野研との共同研究

成層圏エアロゾル      フェゴ火山 → エルチジョン → ピナツポ  
 (1974、藤原・内野修)      (1981)      (1991)  
 ルビー      YAG

ナトリウム層 (～1978、内野・板部・長沢)→  
FL励起色素(高出力化)

オゾン層 (1978、内野修) → → →  
色素SHG XeCl +ラマン

大気波動・温度 (1980、柴田隆)→ XeF

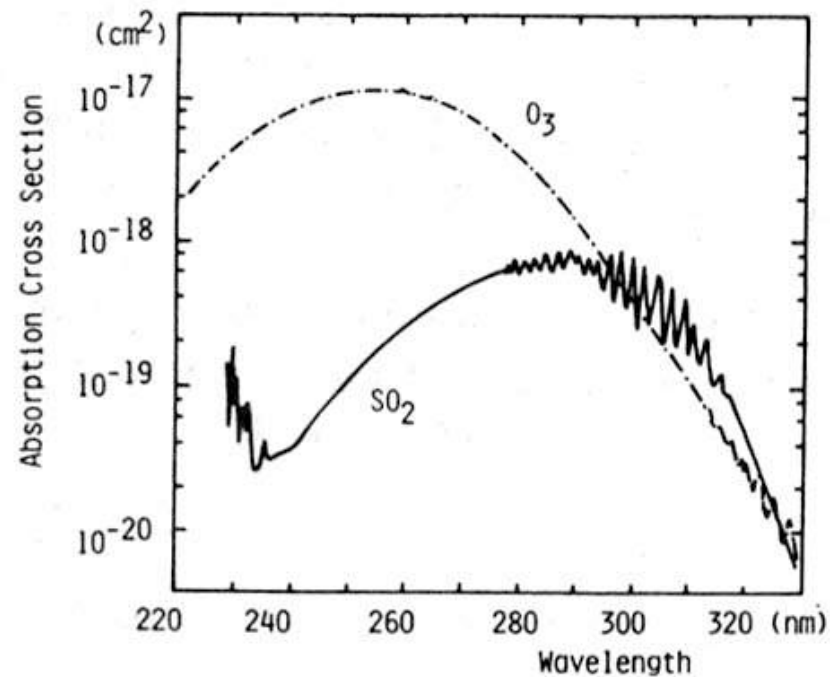
水蒸気 (1992、内海通弘)  
アレキサンドライト

# オゾンDIAL

## 最初のオゾンライダー

A.J.Gibson and L.Thomas:  
Nature 256 (1975) 1975

Megie et al.:  
Nature 270 (1977) 329  
色素レーザーのSHG



フラッシュランプ励起色素レーザー  
のSHG

フラッシュランプ励起  
p-Terpenylレーザー



# エキシマーレーザーの歴史

最初の発振(固体Xe<sub>2</sub>、電子ビーム励起)

N.G.Basov et al.:Soviet Phys. JETP Lett. 12 (1970) 329

高出力希ガス系エキシマー(電子ビーム励起)1972~74

希ガスハライド系エキシマー(電子ビーム励起)

S.K.Searles and G.A.Hart:Appl.Phys.Lett. 27 (1975, 8月) 243

Naval Research Lab., Avco Everett(1975,9月), Northrop,  
Sandia, Los Alamos, etc.

希ガスハライド系エキシマー(放電励起)

R.Burham et al.: Appl.Phys.Lett. (1976, 1月)

エキシマーレーザーの市販品が現れるのは1980年代

Lumonics社(カナダ) Lambda Physik社(ドイツ)

希ガスハライド系エキシマー

ArF 193nm KrF 248nm XeF 353nm

XeCl 308nm

# 日本での初期エキシマーレーザー研究 (1976～)

電総研 柏木・渡部(東大)・佐藤・宮崎(京大)

慶應義塾大学 藤岡・小原・緑川(理研)・神成

大阪大学 山中千・加藤・藤原

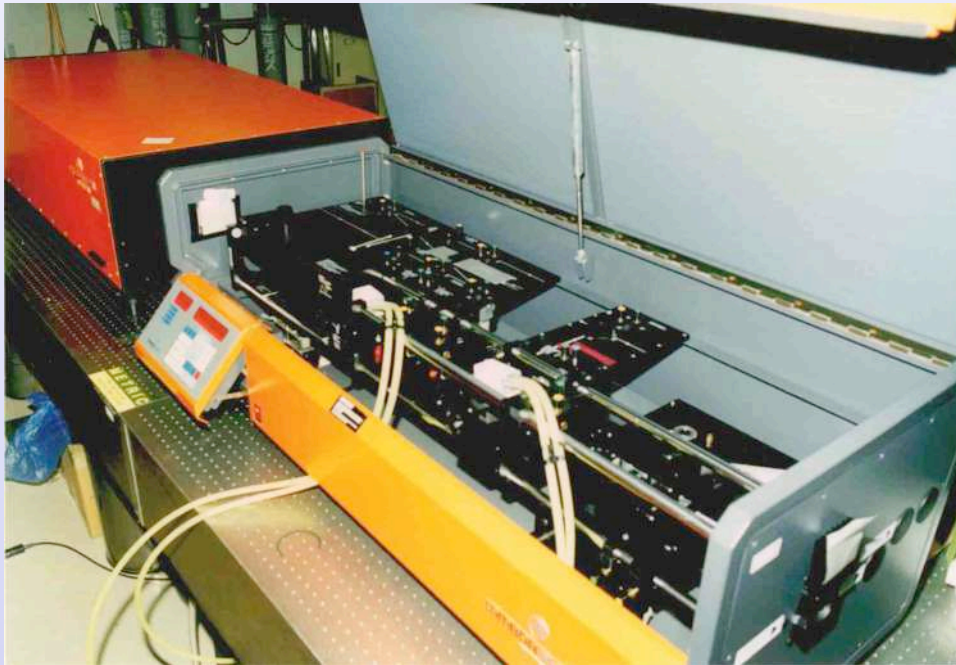
→ 電通大 宅間・植田

東京教育大(筑波大) 島内

九州大学 前田 XeCl(308nm)

科学研究費エネルギー特別研究「新型レーザー」(代表者:宅間)

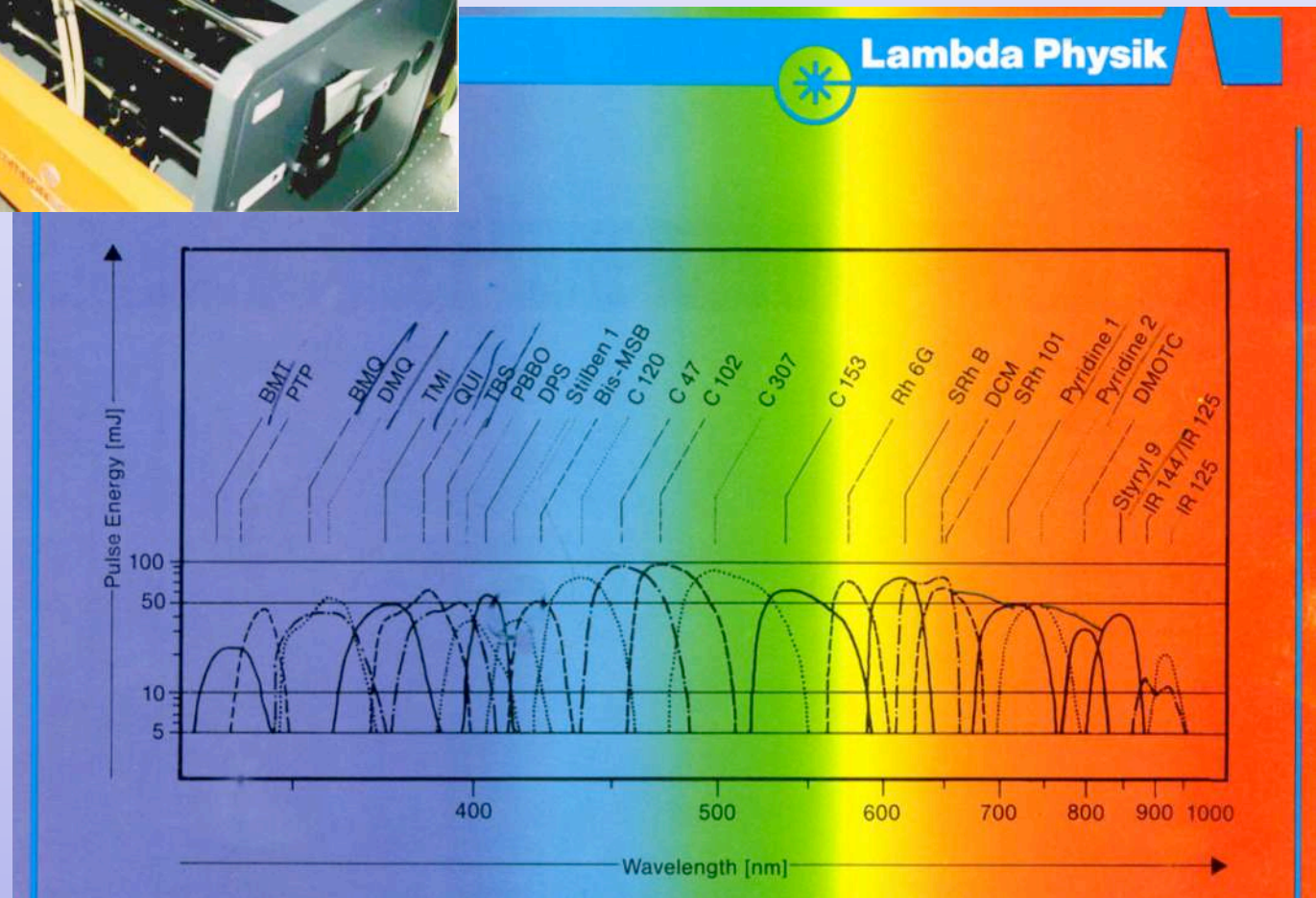




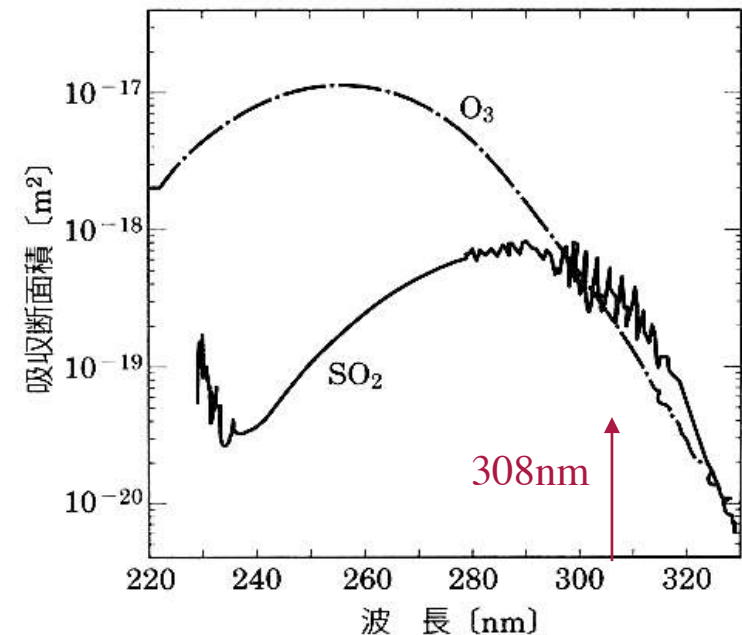
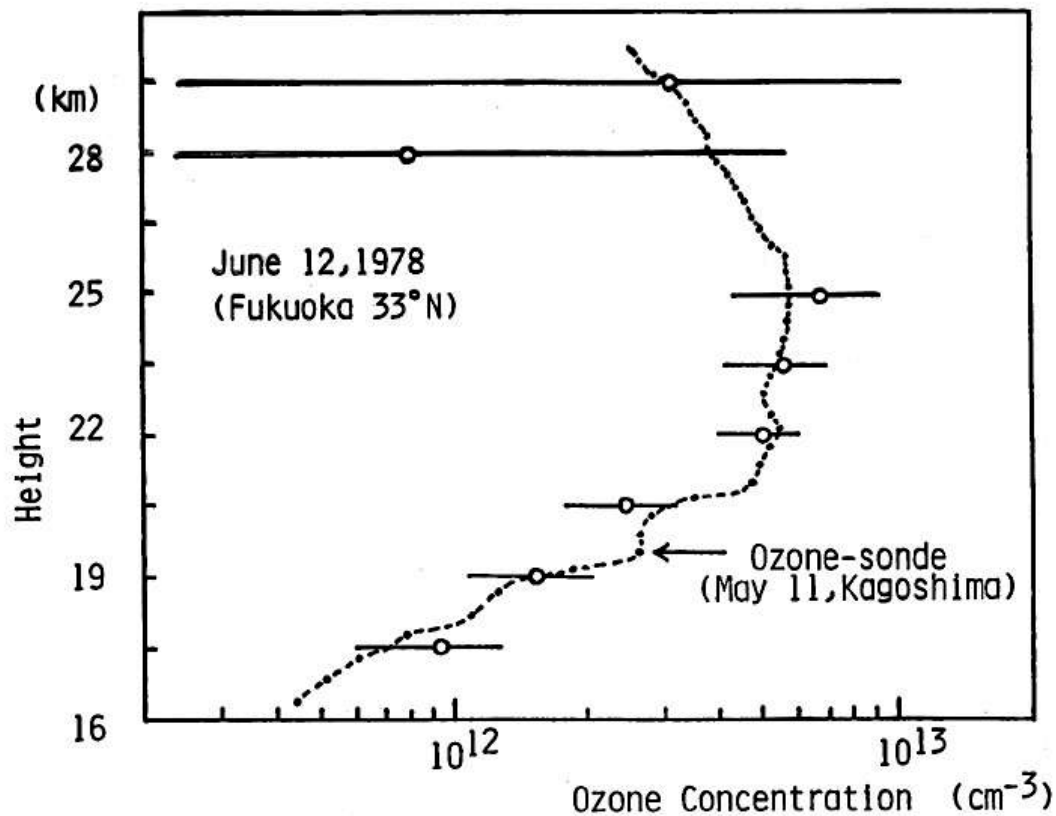
# XeClレーザー励起 色素レーザー

O.Uchino, T.Mizunami, M.Maeda, Y.Miyazoe:  
Appl.Phys. 19(1979) 35

Lambda Physik  
社の製品  
(1980年代)



## エキシマレーザーを用いた 世界で最初のオゾン層観測



308 nmで発振するXeCl  
エキシマレーザーの波長  
がオゾン計測に最適で  
あった。

差分吸収ライダー

O.Uchino, M.Maeda, J.Kohno, T.Shibata,  
C.Nagasawa and M.Hirono:  
Appl. Phys. Lett. 33 (1978) 807



# XeClレーザー を用いた オゾンライダー

TABLE I. Characteristics of XeCl lidar system.

## Transmitter

|                       |                   |
|-----------------------|-------------------|
| Wavelength            | 307.9, 308.2 nm   |
| Linewidth             | < 0.7 nm          |
| Energy per pulse      | 50 mJ             |
| Beam divergence       | $2 \times 5$ mrad |
| Pulse duration        | 20 ns             |
| Pulse repetition rate | 4 ppm             |

## Receiver

|                       |            |
|-----------------------|------------|
| Telescope diameter    | 50 cm      |
| Field of view         | 10 mrad    |
| Filter bandwidth      | 20 nm      |
| Photomultiplier       | EMI 9558QB |
| Separation from laser | 14 m       |

## Data acquisition (counter)

|                     |       |
|---------------------|-------|
| Vertical resolution | 500 m |
| Channel number      | 80    |

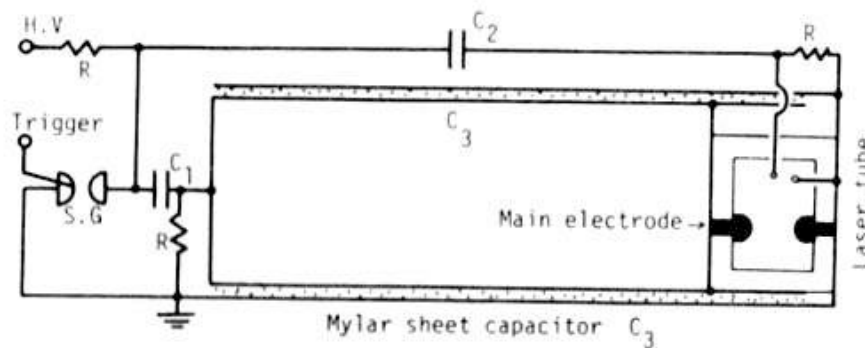
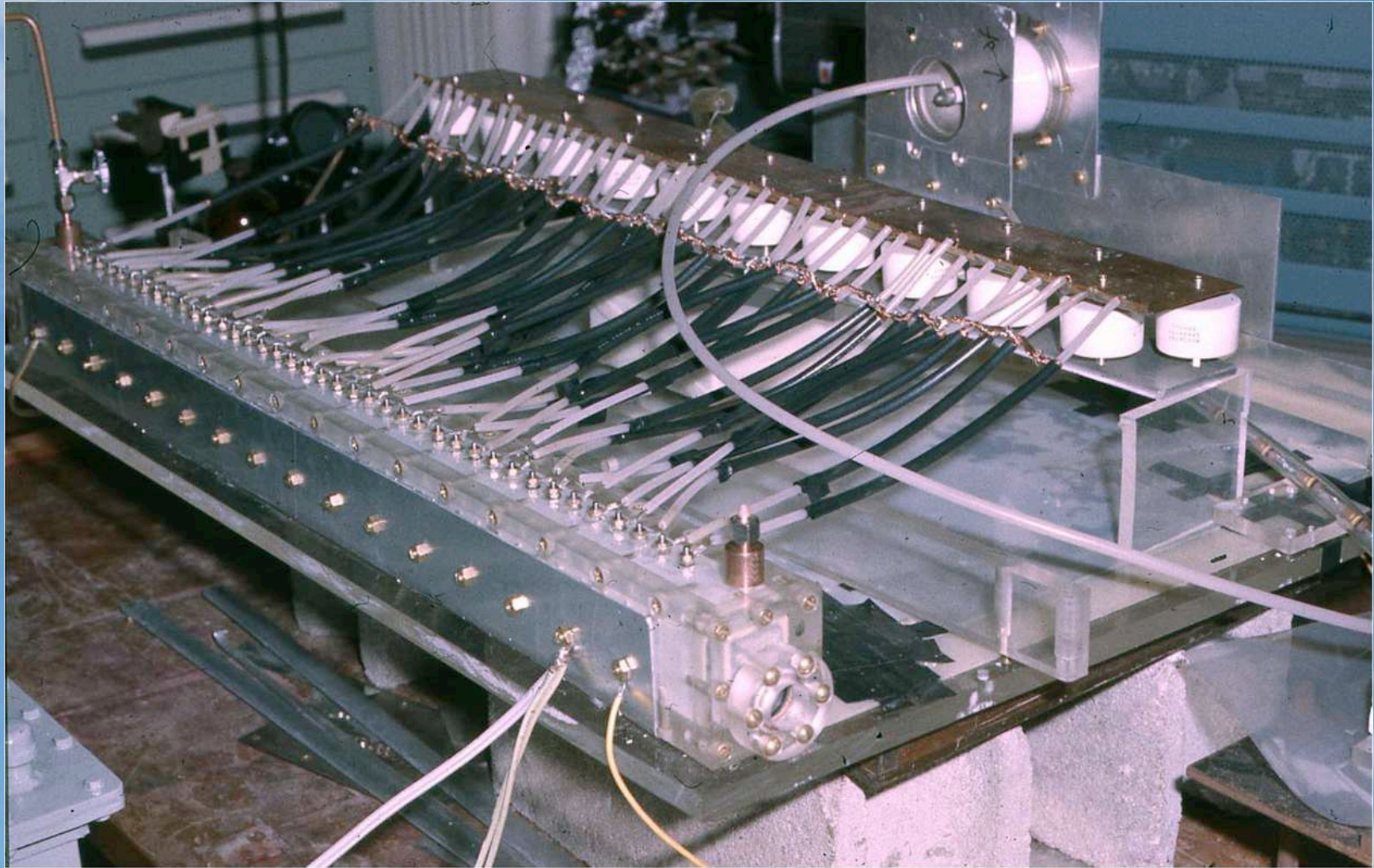


FIG. 1. Configuration of XeCl laser.

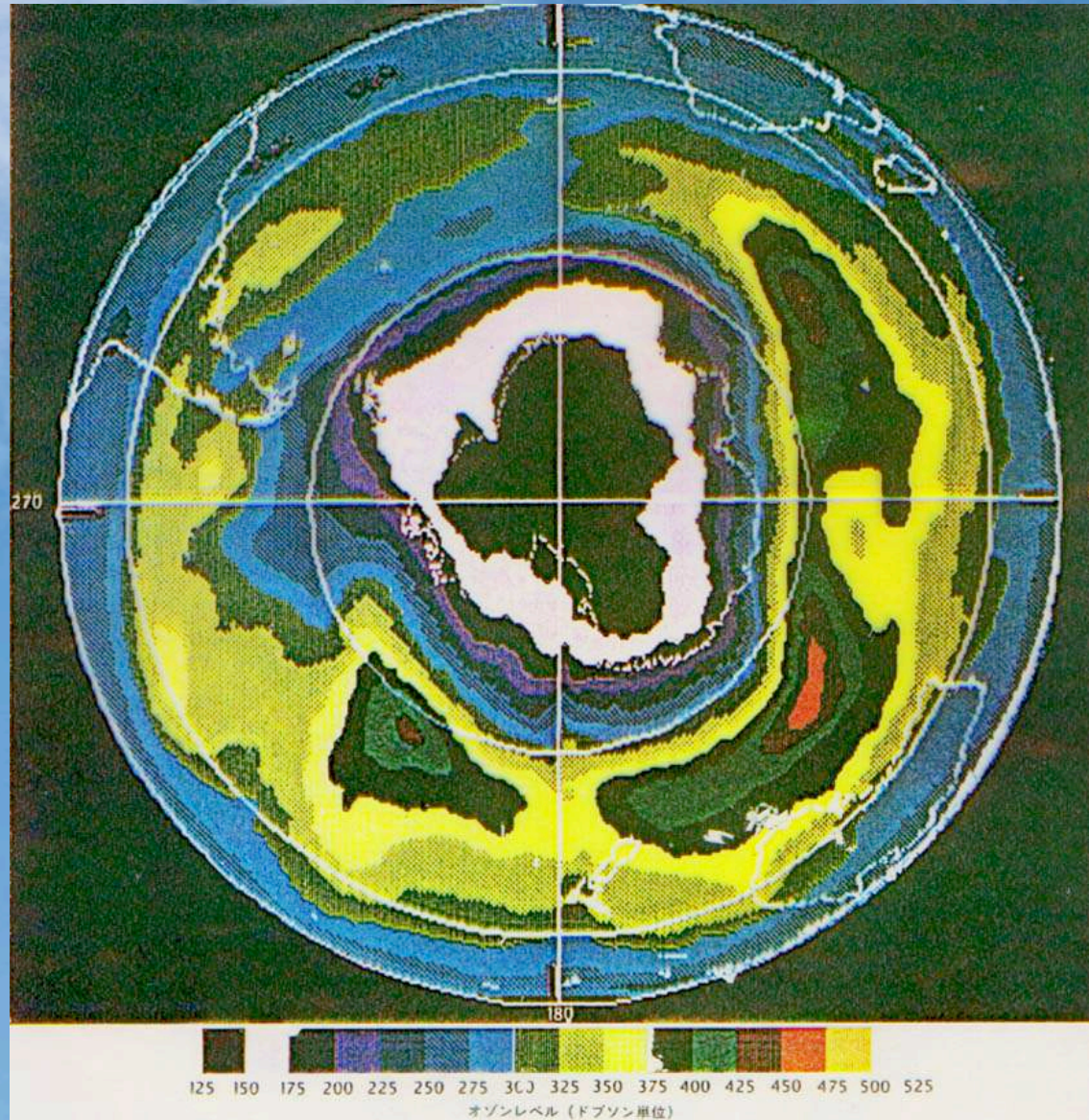
O.Uchino, M.Maeda, J.Kohno, T.Shibata,  
C.Nagasawa and M.Hirono:  
Appl. Phys. Lett. 33 (1978) 807

# 手作りのエキシマレーザー(1978)





# 南極にオゾンホール発見！

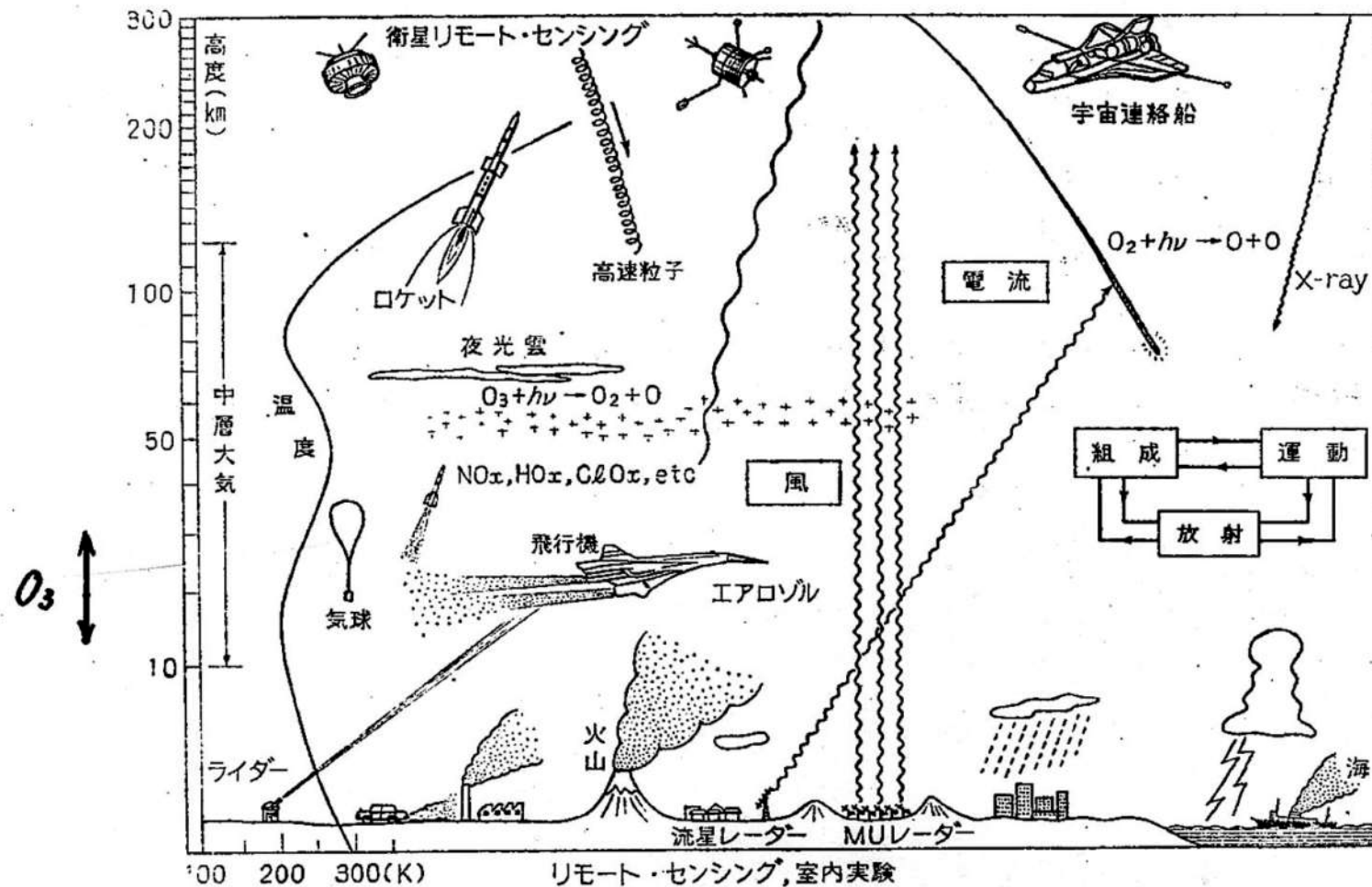


1987年  
10月5日

NASA  
ニンバス7



# 中層大気国際共同観測 MAP計画(1982-1985)



第1図 MAP の概念図 (京都大学工学部, 加藤研究室作成).

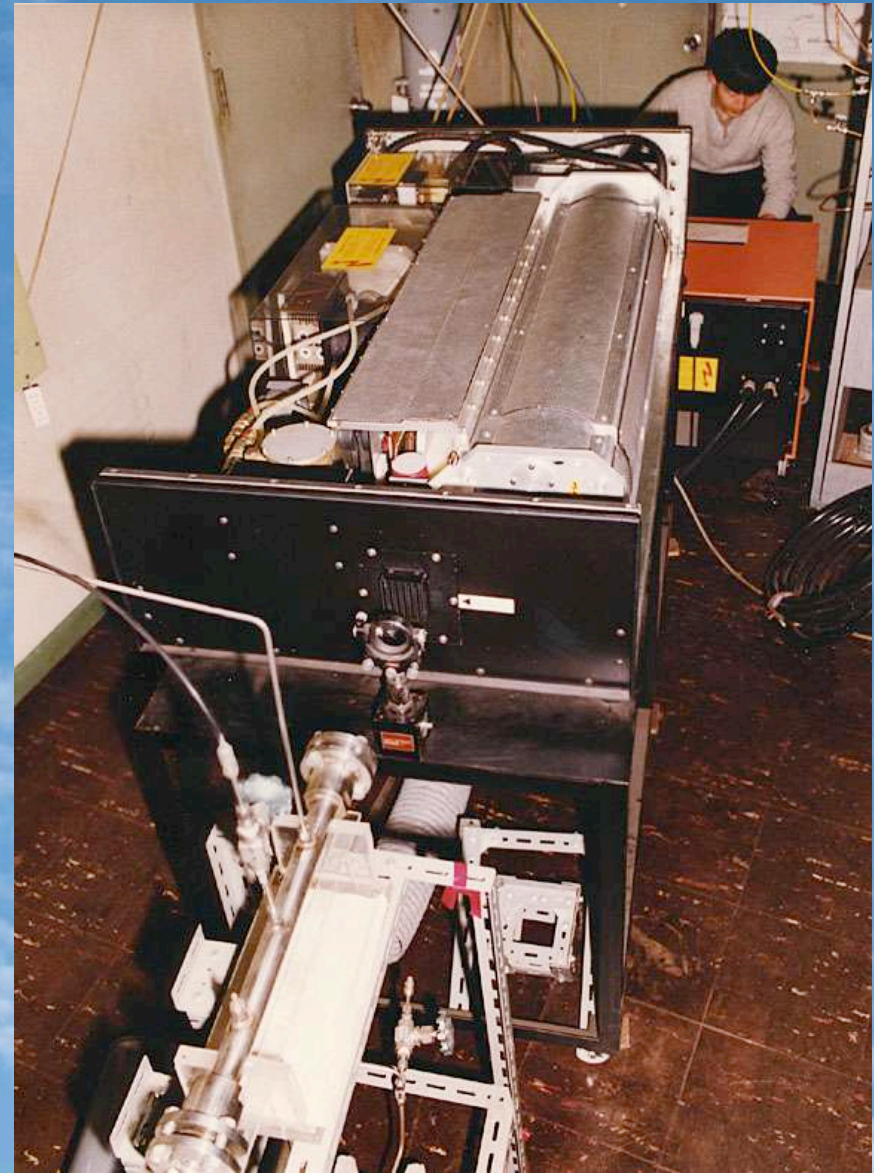
MAP (Middle Atmosphere Program) 1982-1985



# 九州大学のオゾンライダー



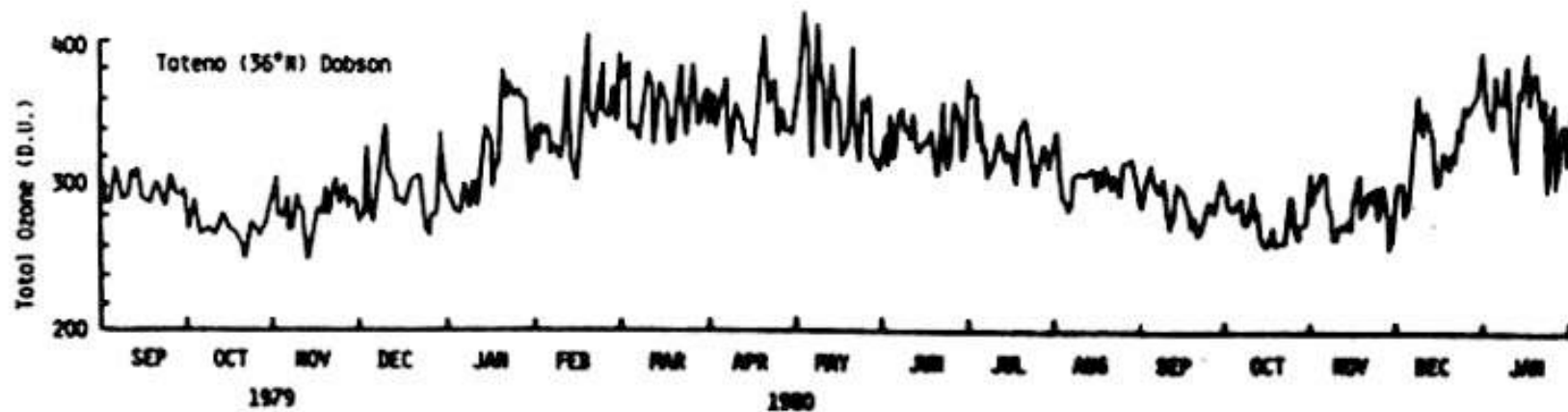
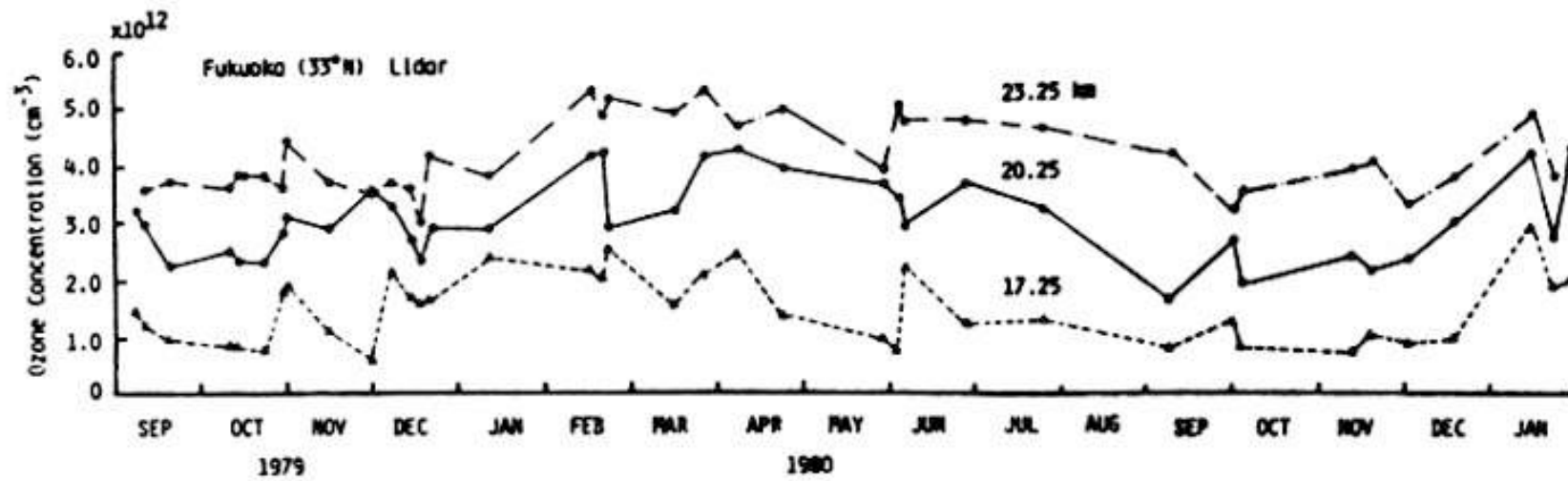
受信部: 直径50cmの望遠鏡



送信部: XeClエキシマレーザー

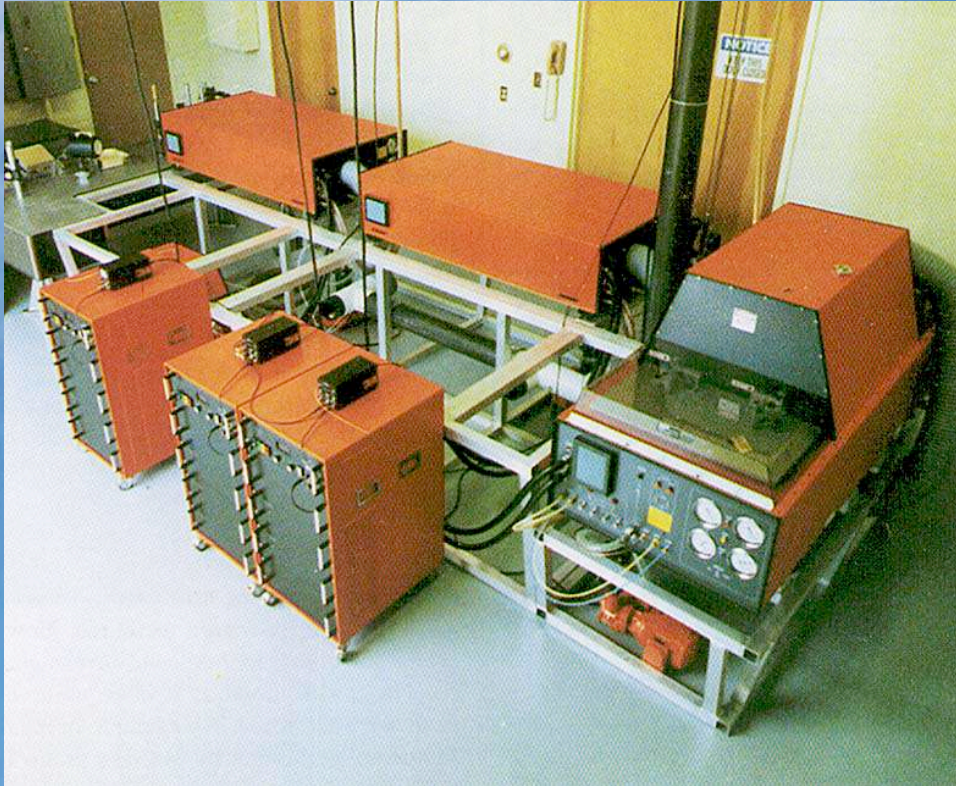
# 九州大学でのオゾン層観測(1979~80)

O.Uchino, M.Maeda, H.Yamamura, M.Hirono: J. Geophys. Res. 88 (1983) 5237





# 大型のオゾンライダー



アメリカ・ジェット推進研究所の  
オゾンライダー(左)

日本・国立環境研究所のオゾン  
ライダー(下)



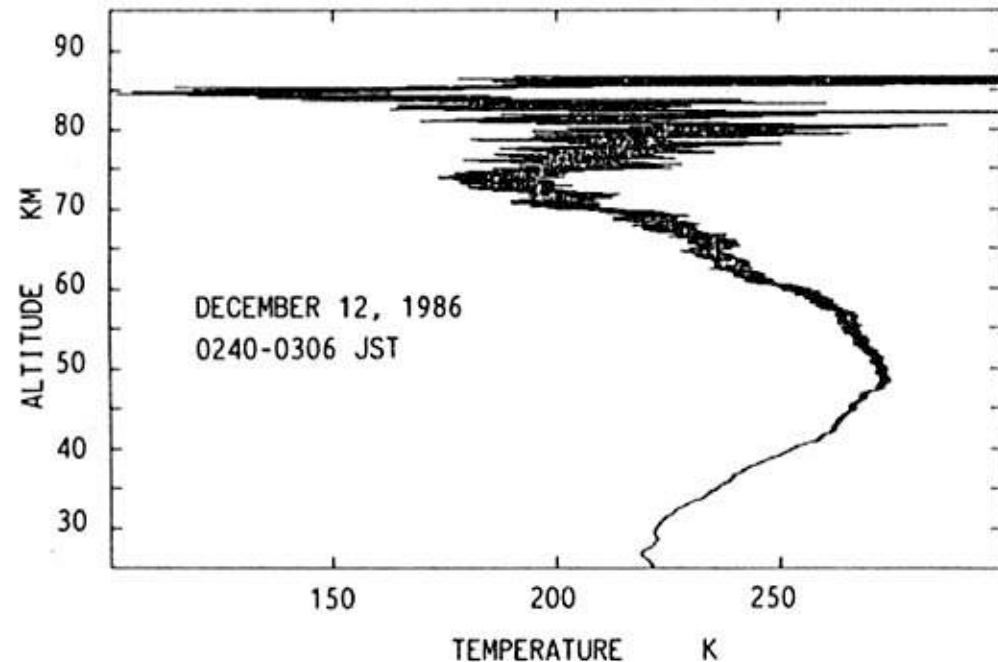
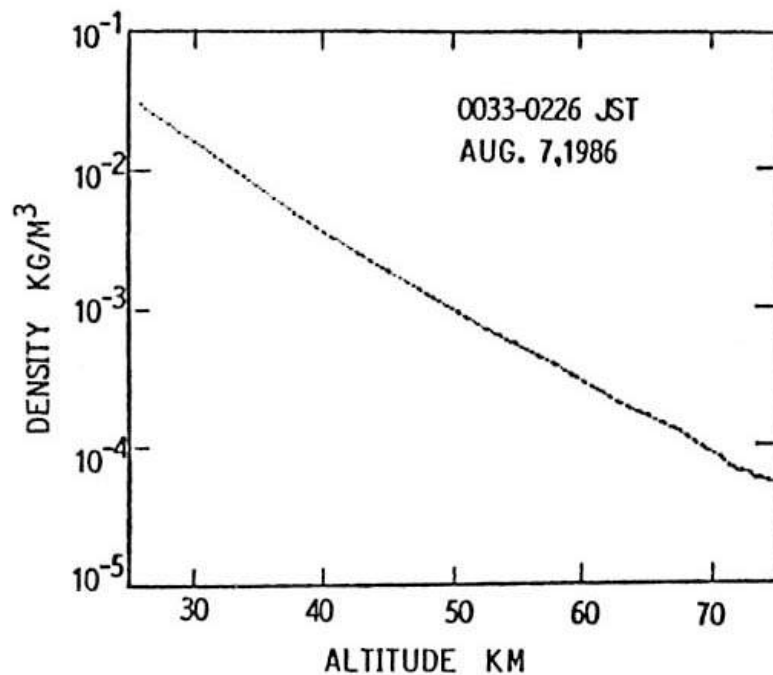


# XeFレイザーライダー XeF 200mJ, 80Hz

T.Shibata, M.Kobuchi, M.Maeda : Appl.Opt. 25 (1986) 685

Table II. Comparison of Parameters in Eq. (1)

| Laser                                 |         | XeF   | Nd:YAG SHG  |
|---------------------------------------|---------|---|---|
| Wavelength                            |         | 351, 353 nm                                       | 532 nm  |
| Rayleigh backscattering cross section | $B$     | $3.0 \times 10^{-31} \text{ m}^2 \text{ sr}^{-1}$ | $5.7 \times 10^{-32} \text{ m}^2 \text{ sr}^{-1}$ |
| Optical transmission of system        | $C$     | 0.19  | 0.48  |
| Atmospheric transmission (0-50 km)    | $T_r^2$ | 0.13  | 0.50  |
| Quantum efficiency of PMT             | $R$     | 0.3   | 0.13  |
| Ratio of $BCRT_r^2$                   |         | 1.25  | 1.00  |





# HIGHLIGHTS



LAMBDA PHYSIK

ラムダ社の社内報で紹介！

A PUBLICATION BY LAMBDA PHYSIK

AUGUST 1988

## Excimer and Dye Lasers Sensing the Atmosphere

A growing community of researchers uses Lambda Physik lasers for atmospheric research. HIGHLIGHTS (HL) reported in earlier issues on ozone research from Zugspitze (HL No. 2), the "Polarstern" departure (5), temperature profile sensing over Japan (5) and Norway (7). References are given in those issues. In this issue we give a short overview and refer to recent results in the application of excimer and dye lasers in atmospheric research and environmental monitoring.

The global connection of atmospheric parameters, conscious to the public at the latest since the discovery of the "ozone hole" around the South Pole, requires measurements to be performed worldwide including far distant regions with adverse climatic conditions. For a fairly young technology as that of excimer lasers this is a real challenge. A first example was the Zugspitze excimer laser ozone LIDAR\* which had to be operated

at about 3000 m altitude at correspondingly reduced air pressure raising enhanced high voltage shielding problems. More recent examples are the narrow-band dye laser sodium LIDAR in Northern Norway mentioned above, and the ozone LIDAR on board the "Polarstern" during its arctic travel in 1987. Afterwards this instrument was positioned in Kiruna/Sweden during last winter (Fig. 1).

The few examples show the striking advantage of laser systems for atmospheric research: remotely and continuously sensing

\* ) LIDAR: light detection and ranging, analogous to radar



ラムダ社の売上に貢献 ?!

# HIGHLIGHTS



LAMBDA PHYSIK

A PUBLICATION BY LAMBDA PHYSIK

JUNE 1987

Lambda Highlights No. 5

## XeF laser probes the atmosphere above Japan

In "Highlights No. 2" we reported on a LIDAR system using a XeCl laser for ozone detection in Germany. In this issue we would like to draw your attention to density and temperature measurements in the middle atmosphere which were performed on the other side of the globe: Professor Maeda's group at the University of Kyushu at Fukuoka, Japan, is using a XeF laser for this application. Again the UV wavelength, pulse energy and high repetition rate are the characteristics which make the excimer laser the appropriate tool.

The molecular density decreases with increasing height according to the decrease and local variation in barometric pressure, and is dependent on seasonal and local temperature. In detail these processes are rather complicated. However, in the age of increasing worldwide industrialization, we realize the necessity of understanding atmospheric physics and chemistry as completely as possible. The increase in the content of CO<sub>2</sub> and other trace gases and the problems around ozone in the atmosphere show that the influence of men's activities on atmospheric chemistry is no longer negligible.

Not only pollution measurements and trace gas analysis are key investigations; molecular density and temperature data are of primary importance. Between the altitude of 30 and 80 km, until recently there was no reliable diagnostic of atmospheric dynamics except direct measure-

mental and spatial resolution makes it possible to determine fluctuations of density and temperature. From these data information on atmospheric waves can be obtained. Such wave phenomena play a very important role in the atmospheric circulation. Tidal, planetary, and gravity waves are known to occur. Today, measuring the backscattering of light due to Rayleigh scattering is the most powerful method of observing fluctuations in this altitude range.

### The Rayleigh backscattering signal (RBS) and the XeF laser

The RBS is obtained as a photoelectron number  $P(z, \Delta z)$  due to backscattering of light within an altitude interval in the range from  $z$  to  $z + \Delta z$ , and is calculated using the LIDAR equation:

## EMG 150 MSC to the arctic

A new era is about to be opened in ozone detection using excimer lasers: daylight measurements will be investigated and used for measurements during the polar day. For that reason the research group of Professor Herbert Walther and Dr. Karl-Werner Rothe (Max Planck Institute for Quantum Optics and University, Munich) assembled a new laser-based system incorporating an EMG 150T MSC. The system is installed in a huge container on board the "Polarstern", a German research ship for investigations to be performed in polar regions. Fig. 1 shows the container on the left above the starboard bridge windows on departure from Bremerhaven, 14 May 1987. Fig. 2 shows Karl-Werner Rothe in front of the system's control panel. Fig. 3 shows Jürgen Otto, responsible for Lambda Physik's sales in Germany and Switzerland, doing the final check of the laser before he leaves the vessel. Behind him is Wolfgang Steinbrecht a member of the team of investigators.

