HIGH BRIGHTNESS EXCIMER LASER FOR LIDAR APPLICATIONS

Tatsuo Enami, Tsutomu Kakuno and Tomoko Enami
Manufacturing Engineering Research Center
Toshiba Corporation
33, Shin-isogo-cho, Isogo-ku, Yokohama 235, JAPAN

ABSTRACT

We present design concepts and performance of a highly wavelength stabilized tunable KrF excimer laser (wavelength = 248.4 nm) for lidar applications. Output power of 8 Watts with the spectral linewidth of 1.0 pm can be obtained at the pulse repetition rate of 600 pps using a newly developed original self-amplification resonator with two etalons and one prism. Shot to shot wavelength fluctuation is passively suppressed by etalons for line-narrowing optics, and long time center wavelength drift less than +- 0.25 pm is realized with an exclusively designed wavelength active feedback system including.

1. INTRODUCTION

High brightness excimer laser meets a deep UV light source for differential absorption lidar (DIAL) and a solar blind Raman lidar for detecting atmospheric ozone and water vapor concentration in the ultraviolet region[1]. To apply the excimer laser for these applications, center wavelength (shot to shot and long term) should be stabilized.

In recent years performance of the excimer laser has been making rapid progress with specialized requirement of industrial needs. We have developed a specific KrF excimer laser for lidar applications with following features: (1)stable center wavelength, (2)high-brightness, (3)wide range tunability, (4)high repetition rate, and (5)automatic control with a microprocessor.

2. LASER DESIGN

The laser configuration is shown schematically in Fig.1. It shows the system is consisted of the following major modules; a discharge chamber, an HV power supply, a pulse power module, a line-narrowing module, energy and

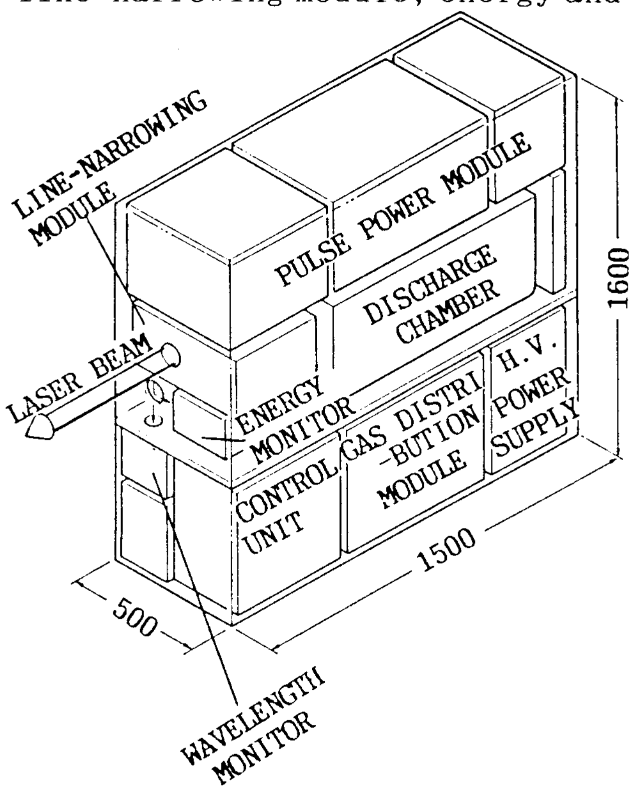

Fig.1 Schematic diagram of the excimer laser.

wavelength monitors, a gas distribution module, and a control unit.

The optical resonator is placed in the line-narrowing module. For spectral narrowing of excimer lasers, gratings (dispersive optics) or etalons (interferometric optics) have been commonly used in the resonator[2]. The high dispersive grating is used in a Littrow configuration with a prism beam expander and apertures. Generally the grating method shows long MTBM (mean time between maintenances) because of its high damage threshold. However, output power is limited by apertures used to get narrower linewidth spectrums. Using intra-cavity etalons, high output power could be obtained since etalons show high efficiency for line-narrowing without any apertures. However etalons suffer from a short lifetime due to its low surface damage threshold.

From the viewpoint of shot to shot wavelength fluctuation, we chose etalon method according to the result of experiments about the center wavelength stability. To satisfy the need for both high power and long lifetime of the etalon at the same time, a resonator has been developed with a new concept of self-amplification. The resonator is consisted of two air-spaced etalons, a prism beam expander and two high-reflective mirrors (Fig.2). The etalon lifetime is elongated since the power density on etalons are lowered by a prism beam expander. Furthermore, higher laser output can be obtained because any optics are not placed at the exit of the laser beam where the laser power is maximized. One etalon is used for a coarse narrowing and the other is for a fine narrowing. The laser beam spectrally narrowed by the etalons is reflected back to the gain region and is output-coupled with the diffraction effect. The estimated intra-cavity laser power density through the etalons is 1/10 of that used in a conventional narrow linewidth resonator.

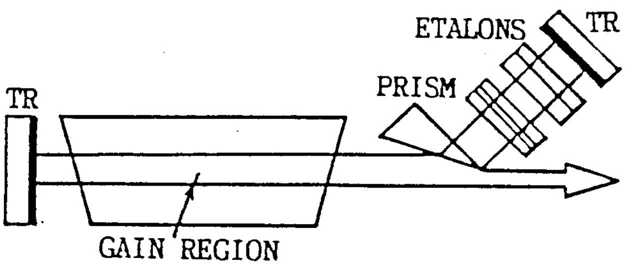

Fig.2 Self-amplification narrow linewidth resonator.

3.PERFORMANCE

Figure 3 shows the shot to shot wavelength fluctuation of initial 5 pulses (a) and middle 5 pulses (b) in a burst mode operation. In the figure, any significant fluctuation of wavelength is not

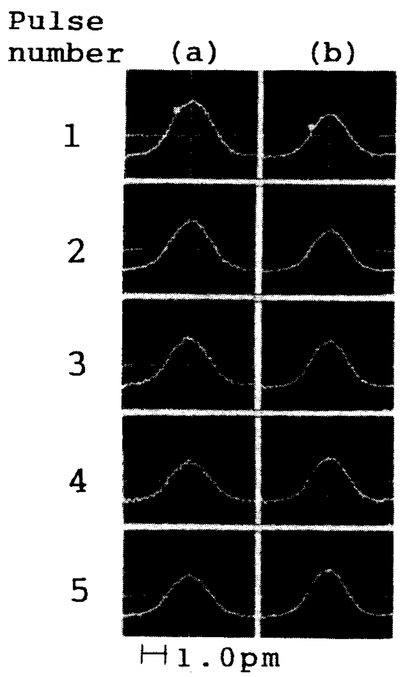

Fig.3 Shot to shot wavelength fluctuation in a burst mode: (a) initial, (b) middle

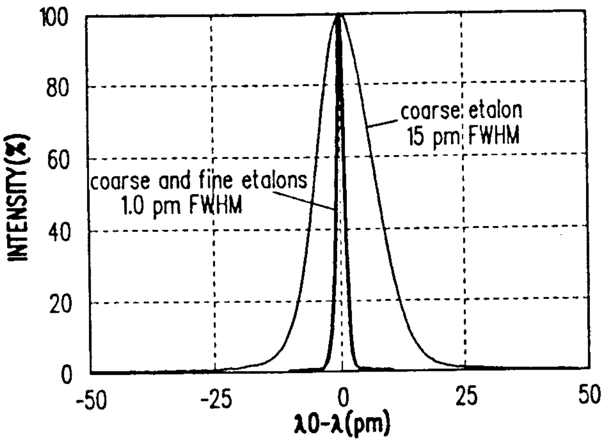

Fig.4 Laser beam spectral profiles.

observed even in the beginning of the burst operation. Figure 4 shows the laser beam spectral profiles. The spectral linewidth of a free running KrF excimer laser is approximately 300 pm (FWHM). Linewidth of 15 pm using a coarse etalon (FSR = 560 pm) and 1.0 pm using a coarse and a fine (FSR = 40 pm) etalons were obtained with center wavelength at 248.398 nm. Wavelength can be automatically tuned by 20 pm linewidth in the case of 1.0 pm, and approximately 500 pm in the case of 15 pm with the microprocessor by adjusting the incident angle for the etalon. In the manual operation the tuning range is 500 pm in the both case.

Table 1 shows other performance characteristics of this laser. Average output power of 8 Watts with the linewidth of 1.0 pm and 15 Watts with the linewidth of 15 pm can be obtained at the pulse repetition rate of 600 pps. Output power has been stabilized less than +- 5 % by the microprocessor. Long term center wavelength drift was measured with the built-in high resolution spectrometer including monitor etalons and an Hg lamp for wavelength calibration. The drift has been stabilized within +- 0.25 pm for at least a few months. The gas lifetime of an excimer laser is one of the most important factor in applications. Introducing non-organic dielectric materials to the laser head the specific gas lifetime is extended to 40 M shots 8 times larger compared to that of a conventional excimer laser.

4.SUMMARY

A narrow linewidth KrF excimer laser has been developed. High wavelength stability (< +- 0.25 pm) for both shot to shot and long term base was realized by using etalons for line-narrowing optics and a wavelength active feed back system with a high resolution spectrometer including monitor

Table 1 Performance specifications.

	2 etalons	1 etalon
Center wavelength (nm)	248.398	248.398
Spectral linewidth (pm)	1.0	15
Tuning range (pm)	20	500
Wavelength stability (pm)	+- 0.25	+- 4.0
Average output power (W)	8	15
Power stability (%)	+- 5	+- 5
Repetiton rate (pps)	600	600
Gas life time (shots)	40 M	40 M

etalons and an Hg lamp. The developed laser can select the lasing spectral linewidth (1.0 pm, 15 pm, 300 pm) and wavelength tuning range (20 pm for 1.0 pm and 500 pm for 15 pm linewidth). An averaged output power of 8 Watts (for 1.0 pm) and 15 Watts (for 15 pm) can be obtained at the pulse repetition rate of 600 pps. The above mentioned characteristics meet a deep UV light source for lidar applications.

5. REFERENCES

1. Takashi Shibata, Terunobu Fukuda, Tohru Narikiyo, and Mitsuo Maeda, "Evaluation of the solar-blind effect in ultraviolet ozone lidar with Raman lasers", Appl.Opt.26, 2604(1987).
2. T.J.Mckee, "Spectral-narrowing techniques for excimer laser oscillators", Can.J.Phys.63, 214(1985).