26PB16 Spaceborne Helium-Neon Laser

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Abstract: We developed a frequency stabilized He-Ne laser used to calibrate the interferometer for absolute standard wavelength in space. We selected a simple passive design without using any resonator length control components and using fewer parts for frequency stability and satellite environment. As the result of performance, we obtained short-term(<1sec) frequency stability of the order of 10^{-13} and frequency repeatability of 5×10^{-9}.

1. Introduction

The Interferometric Monitor for Greenhouse Gases(IMG), an instrument to be flown on the Advanced Earth Observing Satellite(ADEOS) in 1996, is being developed by the Japan Resources Observation System Organization(JAROS) and Toshiba corporation for the Ministry of International Trade and Industry(MITI). The objective of IMG is global observation of distribution of greenhouse gases concentration. IMG is a Michelson-type Fourier transform spectrometer used to obtain detailed spectra of thermal infrared radiation of 3.3~14μm in wavelength (714~3030cm^{-1} in wavenumber), from the earth's surface and atmosphere. Measurement accuracy of IMG is affected by the frequency (wavelength) stability of a light source used to calibrate the interferometer for absolute standard wavelength. We will report requirements and performance of a frequency stabilized laser developed for this purpose.

2. Requirements

It is indispensable for objective of IMG that the spectral measurement accuracy is 0.005cm^{-1}. The He-Ne laser is required to have a frequency stability $\pm3\times10^{-7}$ to realize this accuracy. In addition, the laser must meet requirements for interferometer and satellite environment. These requirements and results of performance tests are presented in Table 1. The developed He-Ne laser satisfied all of the requirements.

3. Laser design

Active control of the laser resonator length is generally employed to achieve frequency stability of the order of 10^{-9}. In case of IMG, the requirement of the frequency stability is of the order of 10^{-7}, and the most preceded requirement is the reliability in the operation term, so that we selected a simple passive design without using any length control components and using fewer parts. The laser is one body structure where mirrors are mounted to

Table 1 Laser requirements and achievements comparison

	Requirements	Achievements
Wavelength	633nm	633nm
stability	$<\pm 3\times 10^{-7}$	$\pm 1\times 10^{-7}$
Mode	TEM_{00}	TEM_{00}
	Single frequency	Single frequency
Output power	$\geqq$0.2mW	0.5mW
Polarization	linear	met($>10^4$:1)
Volume[mm^3]	$<120\times 120\times 150$	$49\times 92\times 145$
Power	$\leqq$2.4W	1.9W
Mass	$\leqq$0.8kg	0.78kg
Reliability	$\geqq$0.932	0.934
Operation term: 3 years(duty0.46)		(Estimated life: 2×10^5 hours)
Environment:		
Mechanical	23Grms	met
Thermal	-40～+60℃	met
Operation	+20～+30℃	met

a glass-ceramic block by optical contacts, as shown in Fig.1. The electrodes are sealed to the body using indium. We obtained a linearly polarized output using a "L" shaped cavity with three mirrors. The glass-ceramic is Zerodur of Schott Glass Co. and has an extremely small coefficient of thermal expansion.

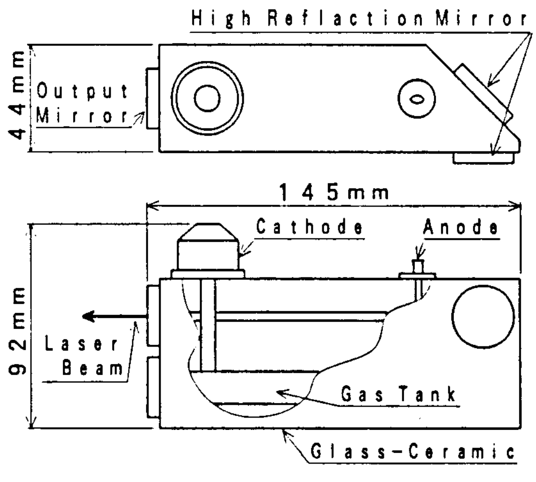

Fig.1 Laser head structure

4. Performance

4.1 Laser beam power

To achieve high reliability and low power consumption, the laser was designed to operate at lower discharge currents than a normal He-Ne laser would at. We obtained a laser beam power of 0.5mW at a discharge current of 2mA in the single frequency TEM_{00} mode and a polarization ratio of over 10^4, as shown in Table 1.

4.2 Dependence of frequency on laser temperature

Frequency of the laser is affected by the laser body temperature. Fig.2 is the variational rate of frequency calculated from results obtained by measuring variation of frequency with laser temperature. We used the Spectra-Physics model 117A stabilized He-Ne laser with a stability of $\sim 10^{-9}$ as a reference laser. The largest variation of frequency per ℃ in the operation temperature was 2×10^{-8}, which is similar

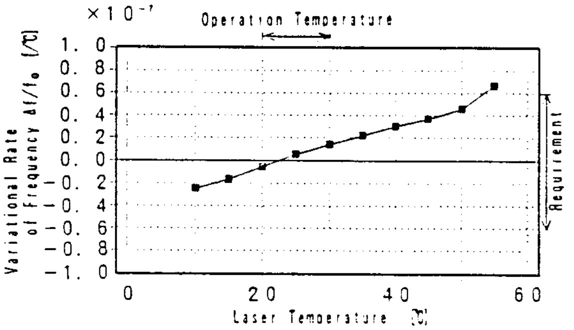

Fig.2 Change rate of laser frequency with temperature

to the coefficient of thermal expansion of Zerodur. As this result indicates, we verified that variation of frequency was defined mostly by thermal expansion of Zerodur. Frequency stability under the operation temperature is $\pm 1\times 10^{-7}$, as shown in Table 1.

4.3 Frequency stability by Allan variance

To estimate stability, we measured Allan variance which was calculated from 1ms to 1000s sampling time by using the successive difference standard of 20 measurements between two similar but independent lasers. The result is shown in Fig.3. The short-term stability(<1sec) under little variation of temperature was very high with a square root of Allan variance of the order of 10^{-13} using the passive stabilization method. But the long-term stability(>1sec) is lowered because of drift in the free-run mode.

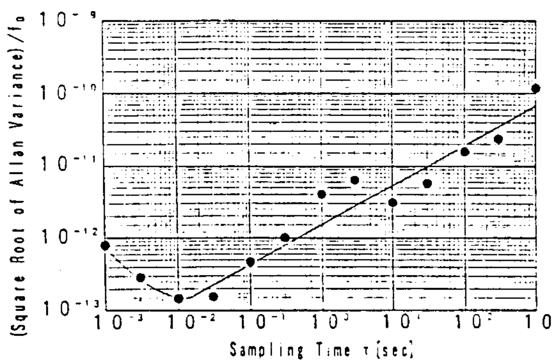

Fig.3 Relative Allan variance between two the He-Ne lasers

4.4 Frequency repeatability

Measurements of repeatability was performed between the laser and a stabilized He-Ne laser using intracavity saturated absorption of $^{127}I_2$ at 633nm wavelength. Reproducibility of the $^{127}I_2$ stabilized He-Ne laser which has been compared with the international standard laser of the Bureau International des Poids et Mesures was better than 10^{-11}.(1) After two weeks and a cycle of temperature ±5℃, repeatability of the laser was 2.2MHz($=5\times 10^{-9}$). The repeatability is much smaller than the requirement of frequency stability, which will never cause trouble.

4.5 Reliability

Life of the laser of this simple design is mostly determined by the electrode (cathode) life. We have been conducting cathode life tests. From these we estimate a life of 2×10^{5} hours. Reliability for 3 years of operation term is 0.934 from this life, which meet the requirement.

5. Conclusion

We verified that the present He-Ne laser meets the required specifications for IMG. Particularly it is to be noted that the laser is capable of operating in the space environment and has a maintenance-free high frequency stability. We realized it with using laser design technique, processing technique of glass-ceramic and vacuum technique. ADEOS carrying IMG is scheduled to be launched by using a H-2 rocket from Tanegashima Space Center in early 1996.

References

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