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High-stable Mode-locked Fiber Lasers for Absolute Distance Measurement based 3D-Coordinate Positioning

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We describe highly stable and reliable mode-locked lasers to be exploited in a 3D-coordinate position system. The 3D-coordinate position system has been realized by measuring horizontal, elevation angles, and distance based on the time-of-flight method using a dual mode-locked laser. The mode-locked laser was developed using Er-doped gain fibers to generate a 1550 nm pulse train with a 50 MHz repetition rate. In order to ensure stable and reliable mode-locking operation, the laser was built on a nonlinear amplification loop mirror (NALM) cavity using polarization maintaining fibers (PMF) and fiber components. In addition, a retro-reflector was adopted at the free-space part to obtain wide repetition-rate control with high stability. Finally, we validated the stable and reliable laser operation under shock and vibration environment without any mode-locking expire as well as long-term operation of more than 24 hours.

NOMENCLATURE

PMF = polarization maintain fiber
PZT = piezoelectric transducer
fs = femtosecond

1. Introduction

For precise machining of mobile machining platform, accurate positioning of mobile machine is necessary. For this purpose, the absolute distance measurement technology using a femtosecond laser has been studied for three-dimensional absolute coordinate measurement equivalent to the current displacement interferometer[1-2]. When a femtosecond laser with a pulse width of several hundred femtoseconds (fs) is applied to absolute distance measurement, it is possible to secure the same level of resolution as the existing laser tracker interferometry-based distance measurement. For this perpomance, should be able to be maintained for a long time in an industrial site with severe external disturbance. It was developed based on polarization-maintaing fiber and retro-reflector to minimize the effect on mode locking by external disturbance.

To measure absolute distance, pulse repetition-rate must be stabile. One of the method for control pulse repetition-rate is adjusting cavity length. is to artificially increase the fiber length by winding the fiber around the PZT and then operating the PZT[2]. In this way, when the volume of the PZT is increased, the fiber is also stretched, so the L value increse. However, in this case, the fiber must be sufficiently long and cannot be applied to fiber lasers with high pulse repetition rates. Another method is to adjust the distance between the collimator lens and the mirror, but as mentioned above, it becomes vulnerable to vibration. In this study, the reflectance according to the tilt of the flat mirror and the retro-reflector in free-space was calculated through the cavity length adjustment simulation as in figure 2 (b).

2. Simulation

The simulation condition is a simple structure in which light from the fiber is reflected in the mirror and then enters the optical fiber again. The wavelength of the laser source is 1550 nm, the numerical aperture(NA) of the fiber (PM1550-XP) is 0.125, and the refractive index[3] is 1.44938. Therefore, the NA of the collimator lens was selected as 0.15, which is larger than that of the fiber. In order to measure only the light that has passed through the core of fiber, a mirror that forms 45 degrees with the core is located behind the fiber. The light from the inside of the fiber is reflected in this mirror and is measured by the photodetector. The distance between the collimator lens and the mirror was 100 mm. The reflectance according to the tilt of the flat mirror and the retro-reflector was measured, as follows figure 2 (a) and (b). The measurement of reflectance was performed in the range of -10 degrees to 10 degrees.

The small peak seen in the flat mirror in figure 2 (c) is attributed to the phenomenon that the light focused on the clad is refracted to the core.

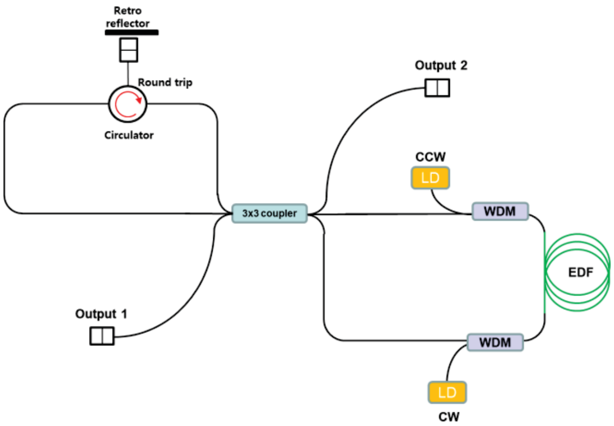

Fig. 1 Nonlinear amplifying loop-mirror laser cavity

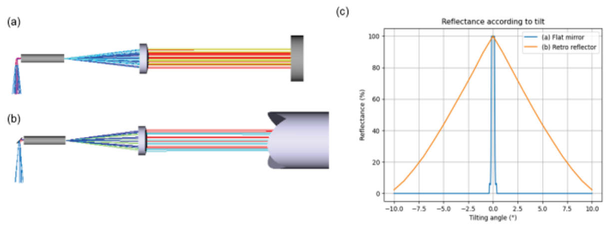

Fig. 2 Simulation model to compare reflectance between standard mirror and retro-reflector, (b) reflectance according to the tilt of the flat mirror and the retro-reflector

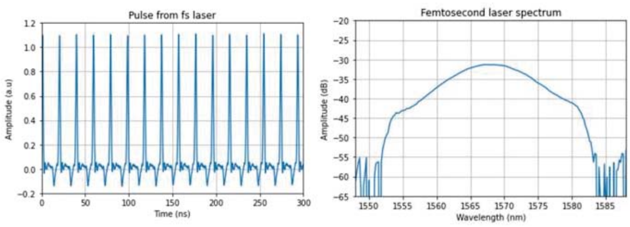

Fig. 3 pulse and spectrum graph of femtosecond laser

3. Conclusions

In this study, flat mirrors were shown to be effective at capturing 90% reflectance for skew tilt errors less than 0.17 degrees (tilt range provided from -0.178 to 0.178 degrees); however, it plummets to 10% when tilt is increased. The retro-reflector was proposed to use in this simulation demonstrated an 80% wider tilt range compared to a flat mirror with a reasonable reflectance. A free-space optics system was conducted to avoid environmental vibrations with a range offered from -1,605 to 1,605 of tilt angle and mode-lock of the laser expected to stabilize when retro-reflector on a linear stage. By using a retro-reflector we developed high stability femtosecond laser based on PMF.

Table. 1 Spec of femtosecond laser

Pulse repetition-rate	> 50 MHz
wavelength	1567 nm
Repetition-rate control range	150 Hz
Repetition-rate stability (Rb clock)	2.19×10^{-12} @ 1 s
Output intensity	33 mW

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