Performance Evaluation of a DC Motor-Driven Mirror Mount for an Automatic Laser Alignment System

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Abstact

Precise laser beam alignment is essential in Atomic, Molecular, and Optical (AMO) physics experiments, but beam drift often occurs due to mechanical and environmental disturbances. This work presents an automated laser alignment system using a DC motor–driven kinematic mirror mount controlled by an Arduino-generated pulse signal and the beam position was monitored using a CMOS camera.Beam displacement along the horizontal (X) and vertical (Y) axes was measured for pulse widths ranging from 10 to 500 ms. The results show a strong linear relationship between pulse width and beam displacement for both forward and reverse motions, with positioning errors below approximately 5% for pulse widths above 100 ms. These results demonstrate that the proposed system provides predictable and stable beam positioning, making it suitable for automated optical alignment in precision experiments.

Introductions

Precise laser beam alignment is essential in Atomic, Molecular, and Optical (AMO) physics experiments. However, environmental disturbances such as thermal expansion and mechanical vibration can cause beam drift, leading to instability in the optical path of the system.Conventional manual beam walking is commonly used to correct misalignment but is limited by slow response and difficulty in compensating dynamic drift.This work develops an automated mirror alignment system using a DC motor–driven kinematic mirror mount with closed-loop feedback control to stabilize the laser beam position in real time, improving alignment stability for precision optical experiments.

Experiments

- **Experimental Setup for Precision Testing of Motorized Mirror Angle Adjustment**

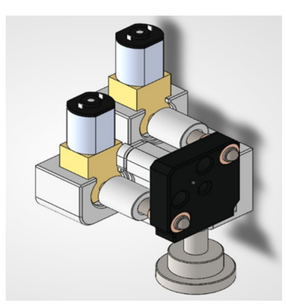


Figure 1: Custom dual-axis motorized mirror mount for automated laser beam alignment.

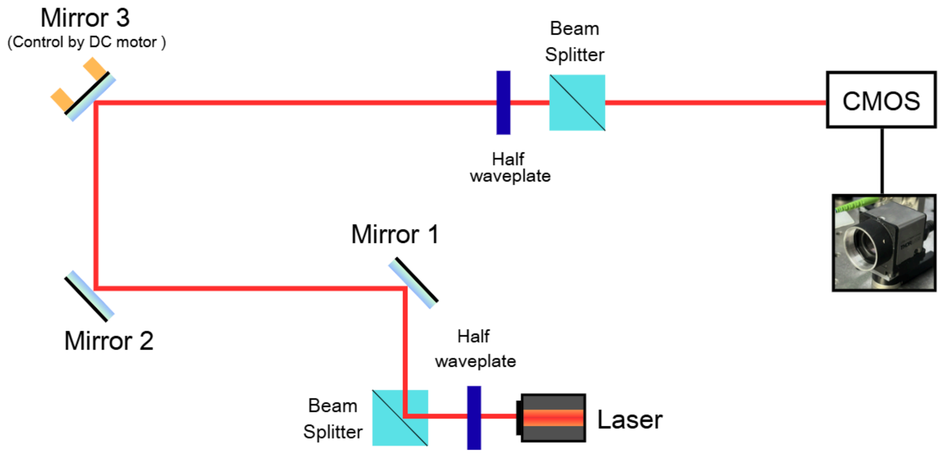
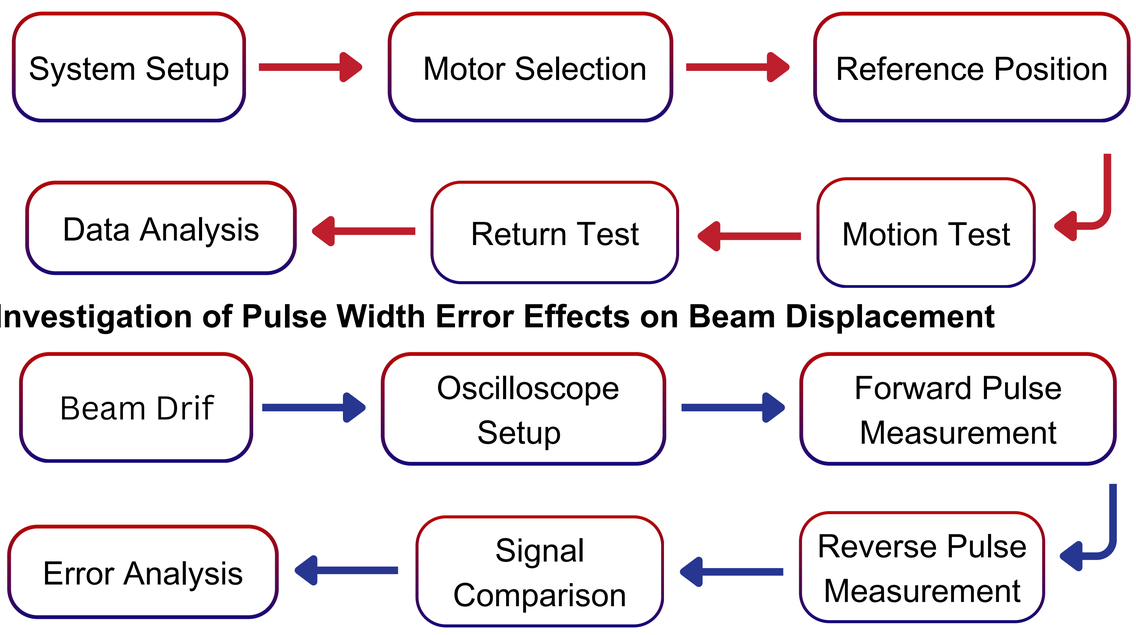


Figure 2: Experiment setup

- **Linearity Analysis of a Pulse-Width Modulation (PWM) Driven Mirror Mount**



- **Investigation of Pulse Width Error Effects on Beam Displacement**

Conclusions

• Beam displacement shows a linear relationship with pulse width along both the X and Y axes for forward and reverse motions.
• The positioning error decreases with increasing pulse width and remains below ~5% for pulse widths greater than 100 ms.
• The DC motor-driven mirror mount provides stable and predictable beam control, making it suitable for automated laser alignment systems.

Results

- **The beam motion was analyzed in both forward and backward directions to compare the system response to the applied pulse signals.**

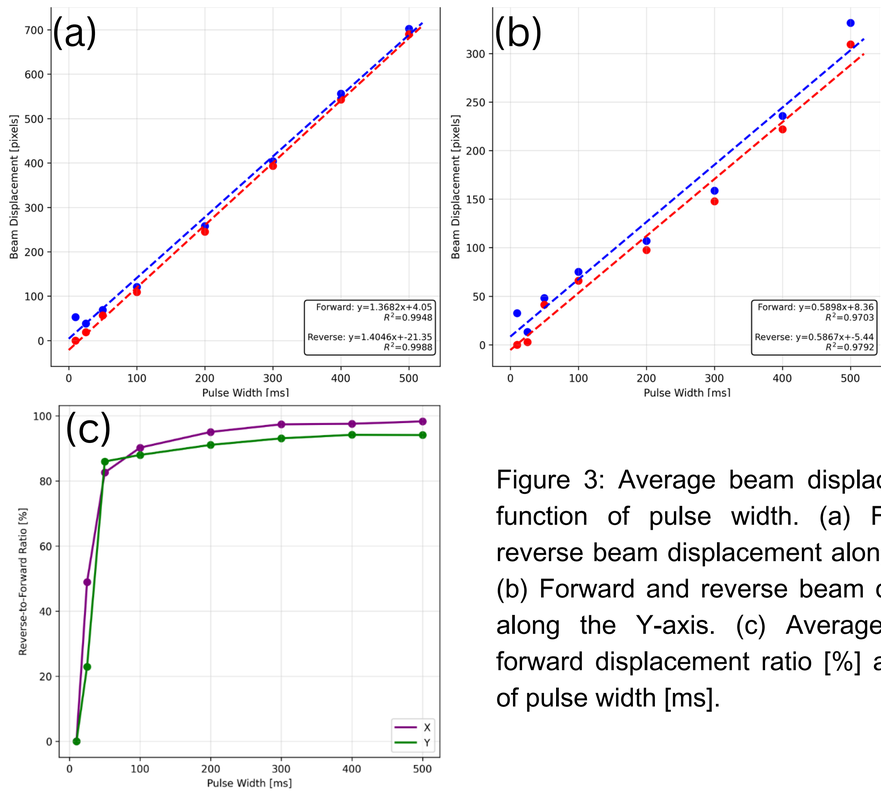


Figure 3: Average beam displacement as a function of pulse width. (a) Forward and reverse beam displacement along the X-axis. (b) Forward and reverse beam displacement along the Y-axis. (c) Average reverse-to-forward displacement ratio [%] as a function of pulse width [ms].

- **The control pulse signals were measured using an oscilloscope by considering the forward and reverse motion directions separately. The percentage error (%error) was calculated by comparing the measured real pulse width [ms] with the commanded pulse width [ms].**

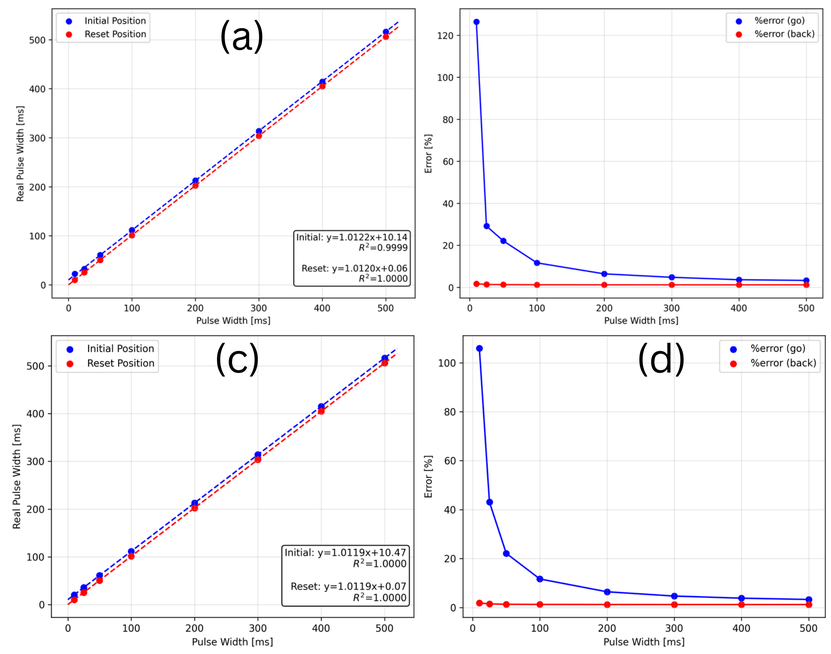


Figure 4: Relationship between the commanded pulse width and the measured real pulse width. Panels (a) and (c) show the real pulse width versus the commanded pulse width along the X and Y axes, respectively. Panels (b) and (d) show the corresponding percentage error as a function of pulse width.

System Performance

- Linear beam displacement response ($R^2 \approx 0.99$)
- Positioning error < 5% for pulse width > 100 ms
- Suitable for automated beam alignment in AMO experiments

Reference

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