Evaluating and Upgrading a Fast Compact Laser Shutter Prototype

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Introduction

In Atomic, Molecular and Optical (AMO) physics experiments, it is sometimes necessary to control the radiation that reaches molecules or atoms at specific times, but there remains a demand for shutters that are inexpensive, fast, easy to replicate, produce little vibration, and are capable of blocking high laser power. In 2015, Zhang *et al.* [1] reported an inexpensive shutter design that meets these requirements. Their shutter consisted of a body and a blade that were 3D printed, and a RC circuit and DC motor that rotates the blade.

We replicated this shutter, implemented some minor modifications to the circuit design and extended their analysis of its features.

Body and Blade

- 3D printed body
- 3D printed blade with rectangular hole for motor
- Motor axle is flattened to avoid slipping
- Two 70A neoprene rubber stops (fixed with epoxy)
- Two laser alignment holes
- Hole to attach mounting post

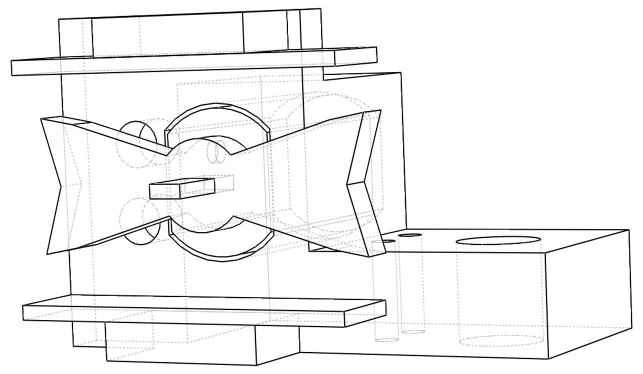

Fig. 1 – Shutter assembly from Zhang et al.'s SolidWorks file.

Driving Circuit

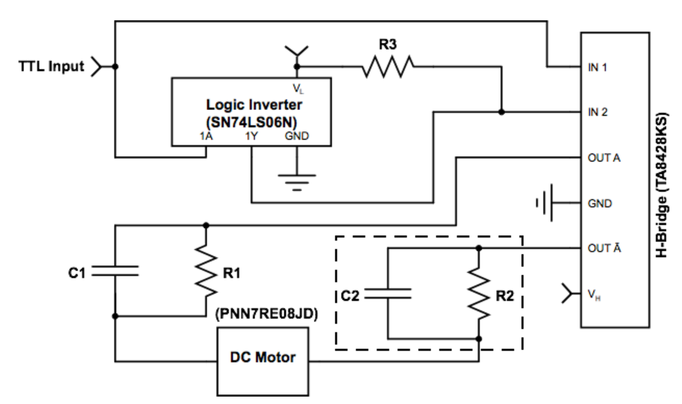

Fig. 2 - Complete driving circuit diagram. $R_1 = R_2 = 220\Omega$, $R_3 = 1\ k\Omega$ and $C_1 = C_2 = 220\ \mu F$. The dashed box part is optional.

- TTL signal comes from a function generator
- Signal branches out to H-bridge
- A logic inverter allows for two opposite voltage signals to reach the H-bridge
- Motor rotates
- RC circuit allows for energy storage and quick discharge once current switches direction.

Switching Speed

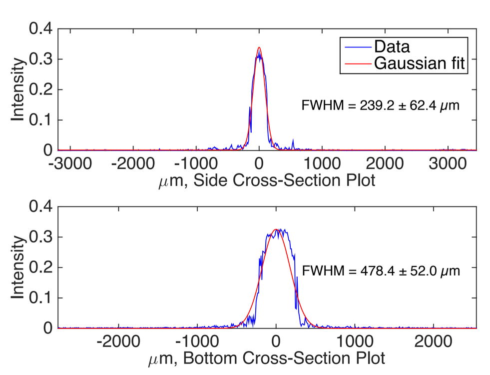

Fig. 3 – Laser spectrum acquired with CMOS camera used to measure beam size.

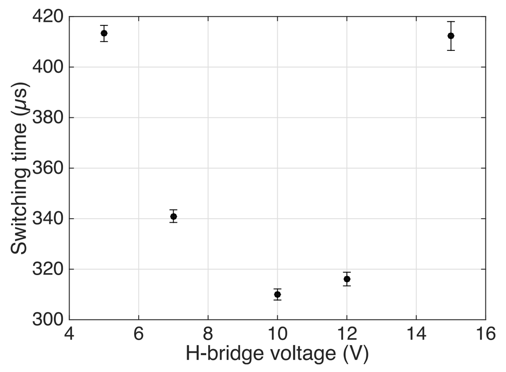

Fig. 4 – Lowest switching time and fluctation indicate optimal voltage at 10 V.

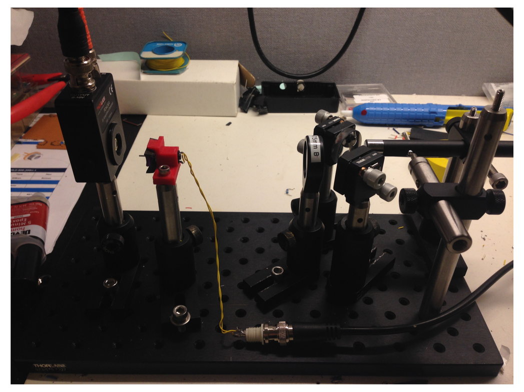

Fig. 5 – Optical setup used to measure switching time. Photodetector detects light signal.

Switching Speed (Continued)

Beam size measurement → Blocking/ unblocking time measurement → Speed calculation

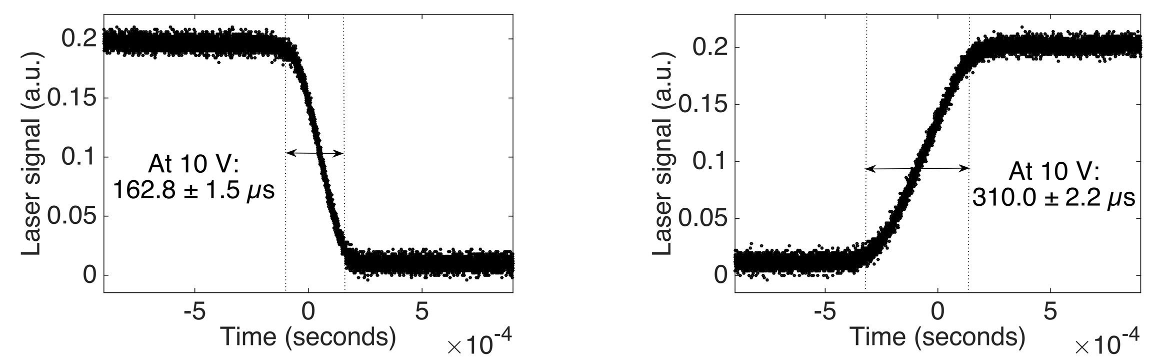

Fig. 6 – Example of blocking (left) and unblocking (right) time measurements.

Blade speed					
	number of capacitors	upper hole blocking	upper hole unblocking	lower hole blocking	lower hole unblocking
PLA blade	one	(2.14 ± 0.13) m/s	(1.23 ± 0.08) m/s	(0.81 ± 0.05) m/s	(1.06 ± 0.06) m/s
	two	(1.37 ± 0.08) m/s	(1.29 ± 0.08) m/s	(0.82 ± 0.05) m/s	(0.94 ± 0.06) m/s
metal blade	one	(0.83 ± 0.05) m/s	(0.63 ± 0.04) m/s	(0.45 ± 0.03) m/s	(0.53 ± 0.03) m/s

Blocking/unblocking speed asymmetry can be fixed with the addition of a second capacitor to the circuit.

Shutter Frequency

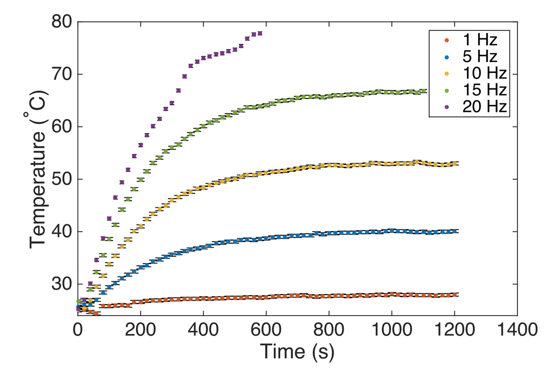

Fig. 7 – Motor temperature variation with time.

We let the shutter run uninterruptedly for 20 minutes at different frequencies and measured the motor's temperature variation with a thermal imaging camera. The shutter can run up 10 Hz safely and up to 20 Hz for periods of operation under 10 minutes.

We also measured an average delay of 2.8±0.3 ms for the shutter to respond to a signal.

Laser Power Handling

Laser with power up to 300 mW + Infrared camera → Measurement of temperature vs. applied power

PLA plastic blade

Extrapolating the linear fit to 75ºC, half of the PLA melting point, [8] we estimate that a maximum power of about 700 mW could be safely supported.

Stainless steel blade

It required the use of epoxy to fix it on the motor. Regular epoxy has a glass transition temperature from 60ºC to 110 ºC. [9] Hence, using the plastic blade is preferable.

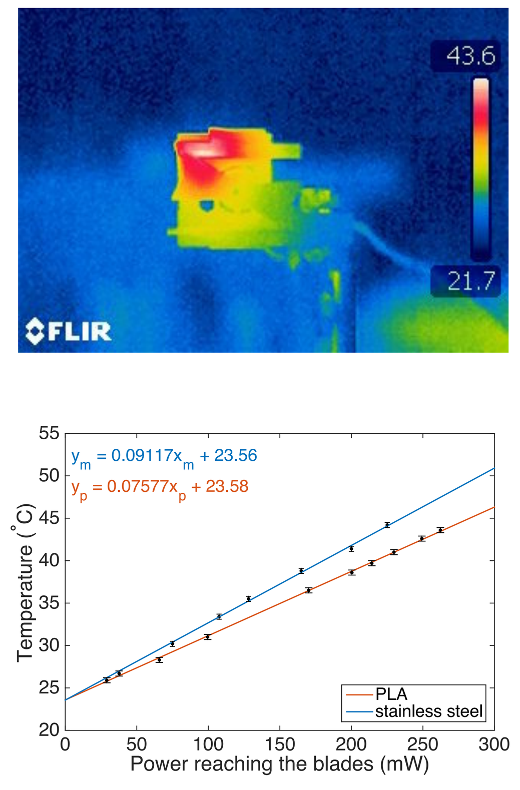

Fig. 8 –Example of IR image (top) and data fit (bottom).

Conclusion

We reported on the evaluation of a laser shutter originally developed by Zhang *et al.* (2015) [1]. We measured shutter PLA blade blocking speed at (2.14±0.13) m/s, which is slightly higher than the one reported by Ref. [1]. We also found the blocking and unblocking speeds to be slightly different. We found an optimal H-bridge voltage of 10 V, which is comparable to the 9 V reported by Ref. [1].

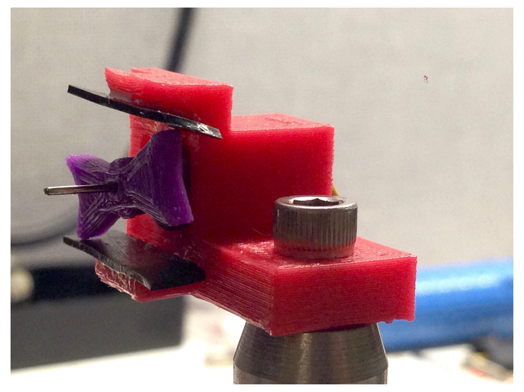

Fig. 9 – Shutter with PLA blade.

Our measurements indicate that the PLA blade can support up to 700 mW, which is much higher than the 50 mW suggested by Ref. [1]. The shutter can work at a steady frequency of 10 Hz or at a burst frequency of up to 20 Hz.

The stainless steel blade was slower than the plastic one and required the use of epoxy to glue it to the DC motor, so it did not handle much higher powers with our conditions.

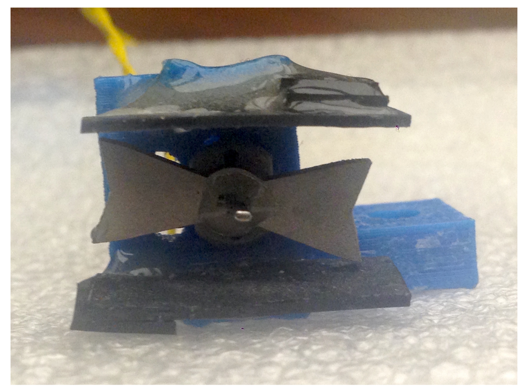

Fig. 10 – Shutter with metal blade.

Acknowledgements

We thank Grace Zhang for sharing the files of her original shutter prototype and for her prompt responses to e-mail inquiries. We also acknowledge the rest of the members of the DeMille group for their help and input. The Yale College Dean's Research Fellowship in the Sciences and the Pierson College Richter Summer Fellowship provided support for B.C.S. to conduct this project.

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