A Galvanometer Based Fast Shutter

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ABSTRACT
A galvanometer-based fast x-ray shutter has been designed and tested. Commercial galvanometer-based motion systems have been developed for laser projections that drive fast rotating mirrors. For an x-ray shutter, the mirror is replaced by tungsten blocks that provide stopping power with up to 6mm of tungsten. The maximum aperture is 2x3 mm², with a switching time below 1 ms. For a narrow beam, switching times of a few microseconds are demonstrated by combining two shutters and exploiting the short jitter of about one microsecond. The shutter is very compact, smooth switching, and reliable, and provides an encoded analog signal for monitoring. It is controlled by a simple TTL signal, whose levels are mapped to adjustable analog position inputs via fast FET switches. The shutter was commissioned successfully and is now in use at the APS 1-ID beamline with monochromatic beams of energies up to 100 keV.

Galvanometer As X-ray Shutter

Pneumatic
- Very large aperture
- Very slow
- Strong vibrations
- Unreliable

Magnetic
- Large aperture
- Moderate vibrations
- Weak attenuation
- Heat problem
- Unreliable

Other Shutters We Tried…

- Less than 1 ms switch time
- 2x3 mm² aperture
- High energy tight (up to 100keV)
- TTL trigger
- No x-ray heating

Background / Specifications

- In air operation
- Low vibration
- Compact
- Low heat generation
- ROBUST & RELIABLE

Galvanometer ?

- Typical industrial uses today
  - Barcode scanning and etching
  - Laser material processing, imaging and printing
  - Semiconductor processing
  - High speed/precision laser positioning applications …

- Working principle
  - Actuator: Moving coil (rotor), stationary magnet (stator)
  - Feedback: Moving dielectric capacitive position detector

- Specifications
  - 1μm radian positioning resolution
  - Up to 2KHz bandwidth
  - “Life-test proven to billions of cycles of operation”

Experience / Conclusions

- Over 2 years beam-line tested at 1-ID
- No failure
- Straightforward alignment by x/y translations
- Low vibration
- Low heat production at low repetition rate
- Very compact
- Simple TTL trigger to operate

Galvanometer As X-ray Shutter

Cambridge Technology galvanometer and driver, factory tuned for optimum performance.

Galvanometer Ammeter

Cambridge Technologies model 6220H
Tungsten blades affixed to mirror mount
Max. aperture: 2x3 mm²
W path length: 3 mm (6 mm 'overclosed')
Moment of inertia: I = 0.07 g cm²

Typical industrial uses today

- Semiconductor processing
- Laser material processing, imaging and printing
- Barcode scanning and etching

Experience / Conclusions

- Switch time proportional to beam height:
  - 400 μs for full aperture (2 mm)
  - Max. slope 5.1 μm/μs
  - Jitter: about 1 μs
- Position output signal available for monitoring

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Shutter Setup In 1-ID Micro-diffraction Experiments

Detector
Sample
Stage
Rotation
Air Bearing
Controller
Encoder signals

Shutter Timing Characteristics

- Fully Open and Closed
- Driver: Cambridge Technology galvanometer
- Feedback: Moving dielectric capacitive position detector
- TTL trigger

One shutter rise time
- FWHM: 332 μs (15.5 μs/rev)
- Max. slope: 0.049°/μs (136 μs/rev) => 5.1 μm/μs
- Jitter: ± 1 μs

Two shutter window mode
- FWHM: 340 μs
- Max. slope: 0.03 °/μs
- Jitter: ± 0.02 μs

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