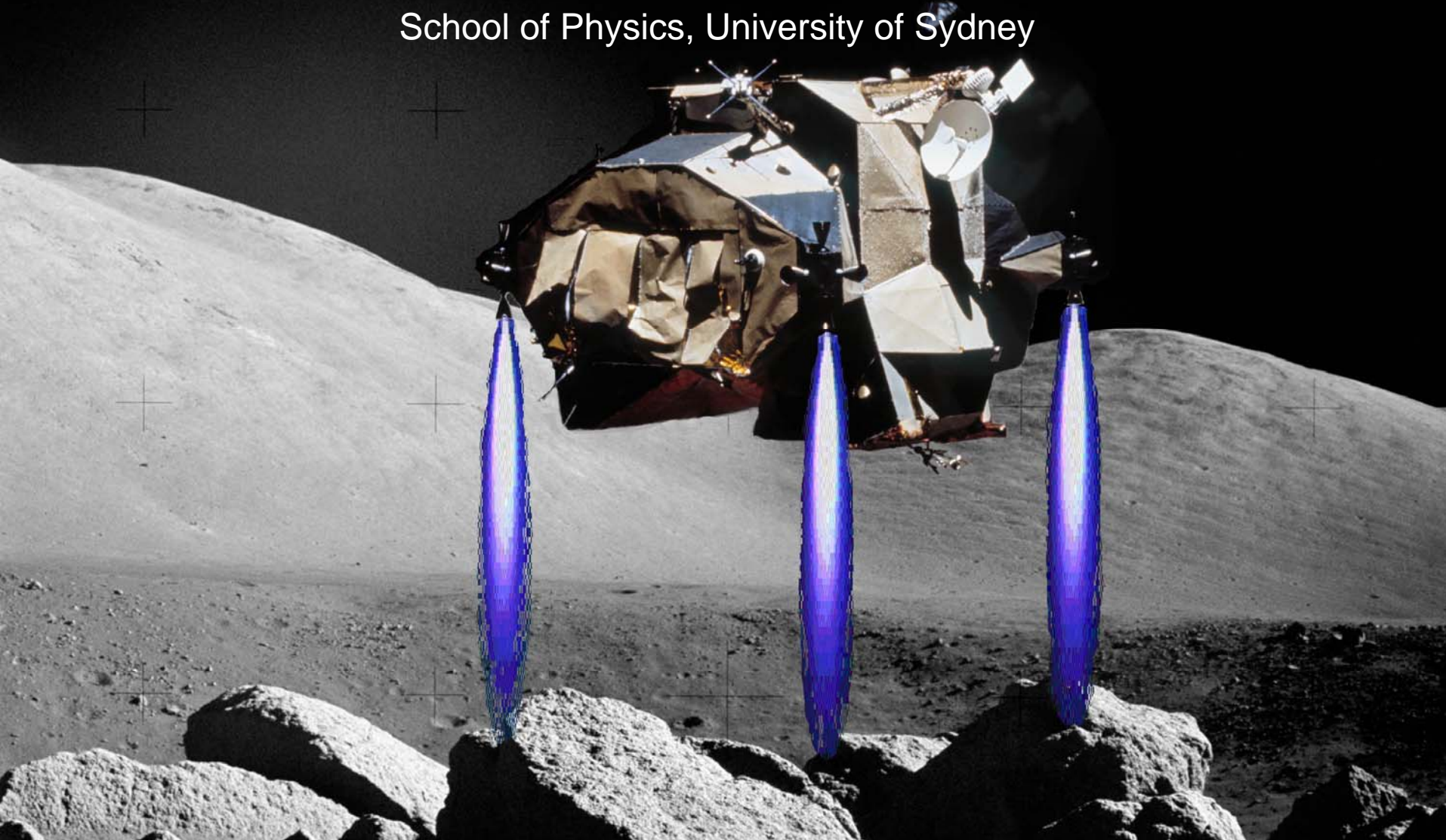


Investigations into the use of a Pulsed Cathodic Arc Spacecraft Thruster

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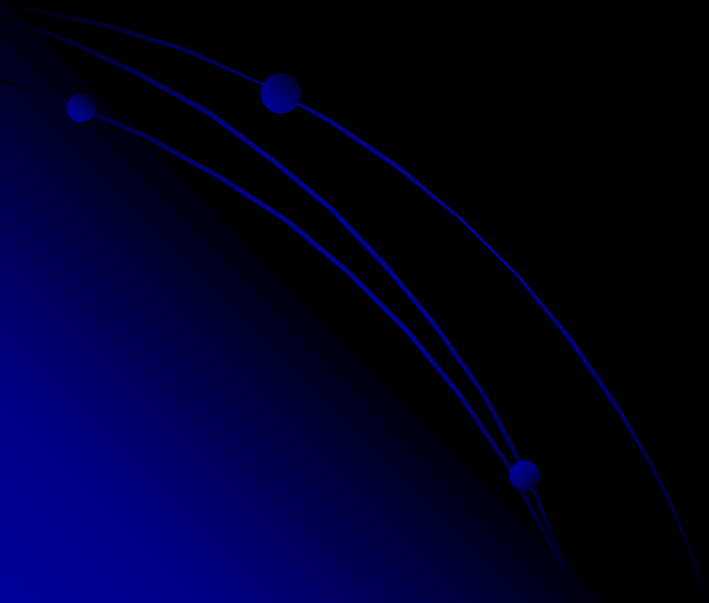


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Overview of Rocketry

- Momentum Transfer
- Exhaust Velocity and Specific Impulse (I_s)
- H_2/O_2 rocket $I_s = 350s$
- Current electric propulsion sources $I_s = 1000s$

Why Pulsed Arc

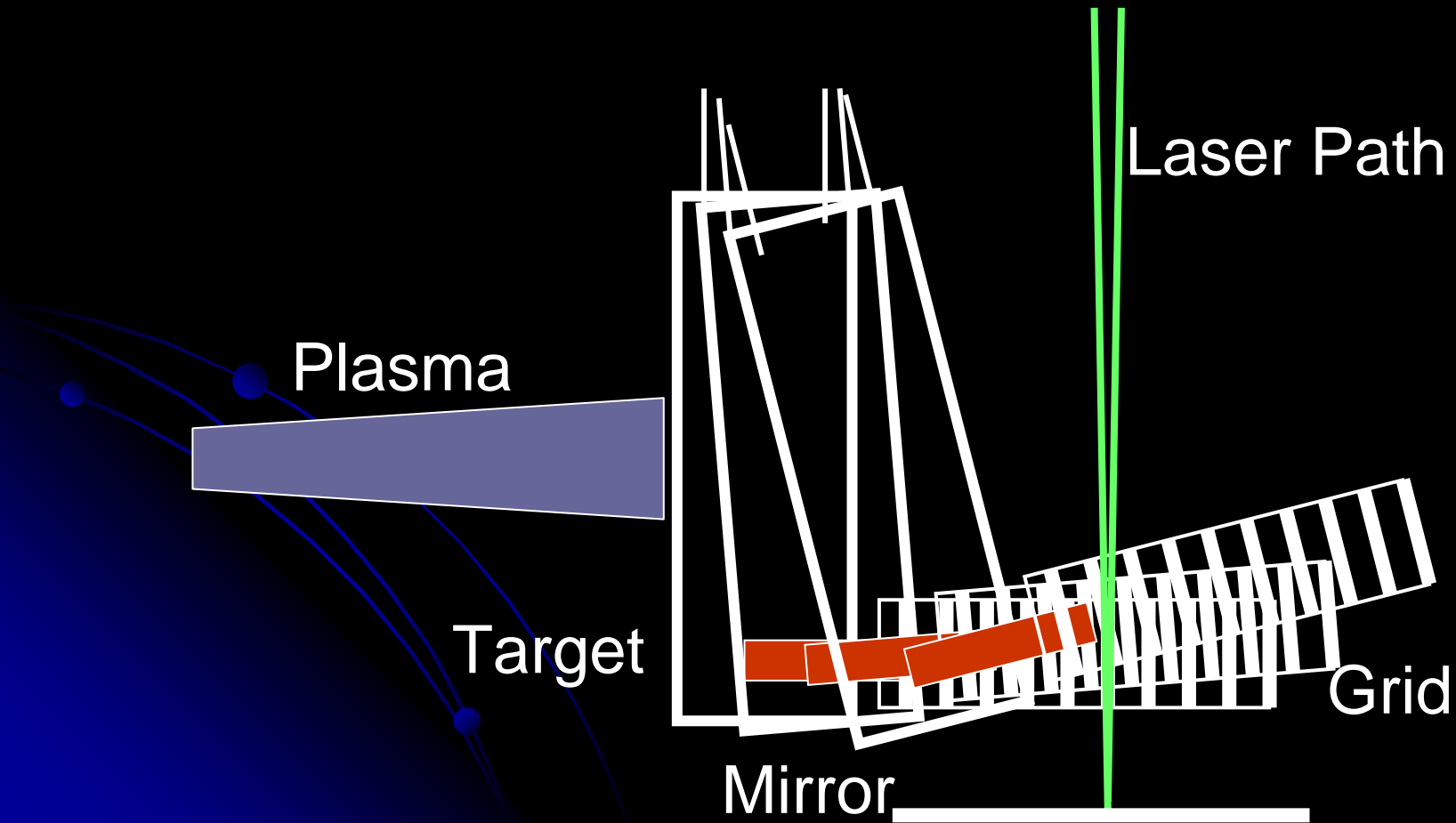
- Short, highly reproducible pulses
- Pulse frequencies can exceed 10Hz
- Highly ionised plasmas
- Ion velocity $1-2 \times 10^4 \text{m.s}^{-1}$
- $I_s = 1000-2000\text{s}$

Experiment

- Use of pendulum as momentum measurement system
- Use periodic opacity grating to interrupt laser beam
- Measure light intensity with photodiode
- Use digital oscilloscopes to capture photodiode trace for analysis

Target Operation

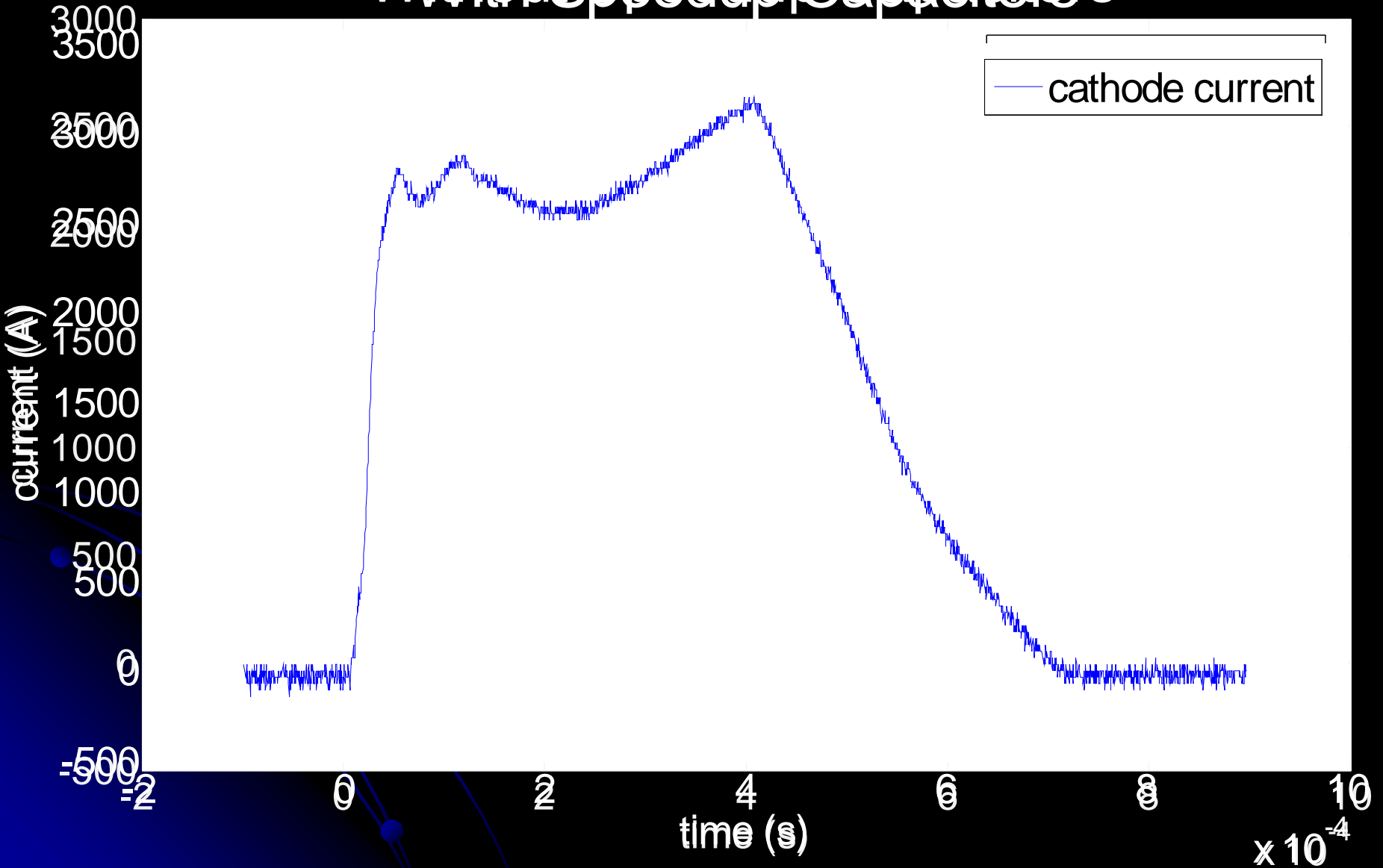
Grid Feature Pitch of 1.7mm



Experimental Parameters

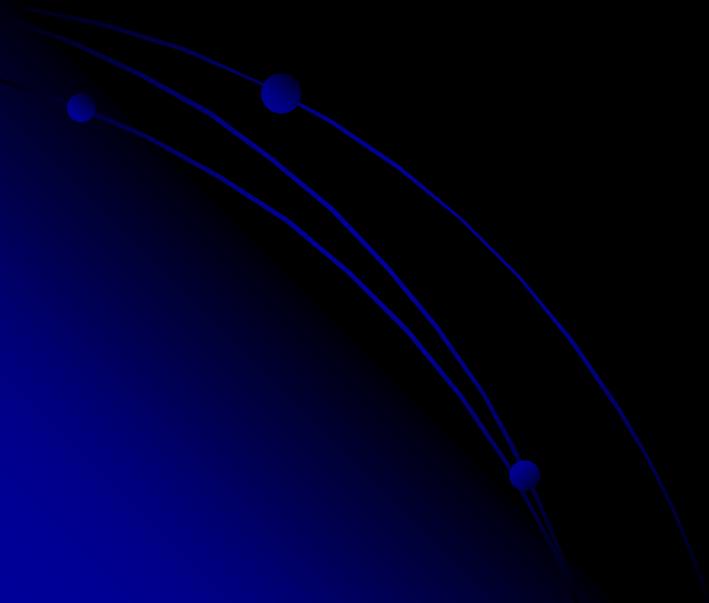
- Use 50mm titanium cathode as source of plasma
- Vary Pulse Duration – 400us or 500us
- Vary Cathode current
- Use 1.5mF “Speed-up” Capacitors to vary Pulse Shape – Square or sawtooth
- Vary Anode Geometry

Pulse Shapes With Speedup Capacitors



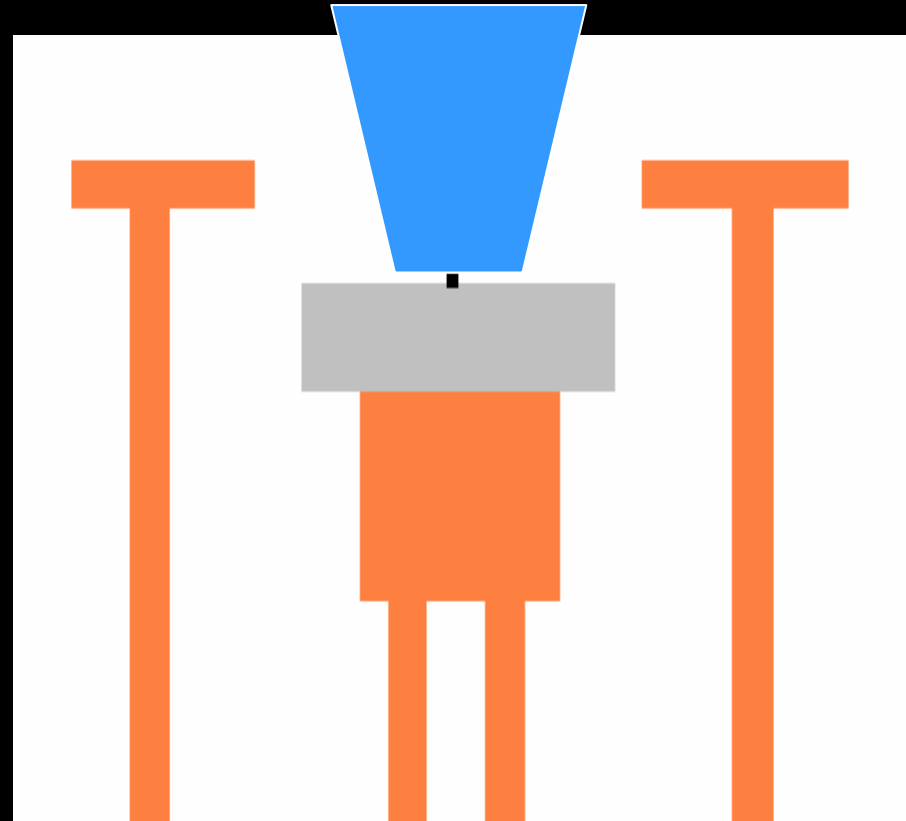
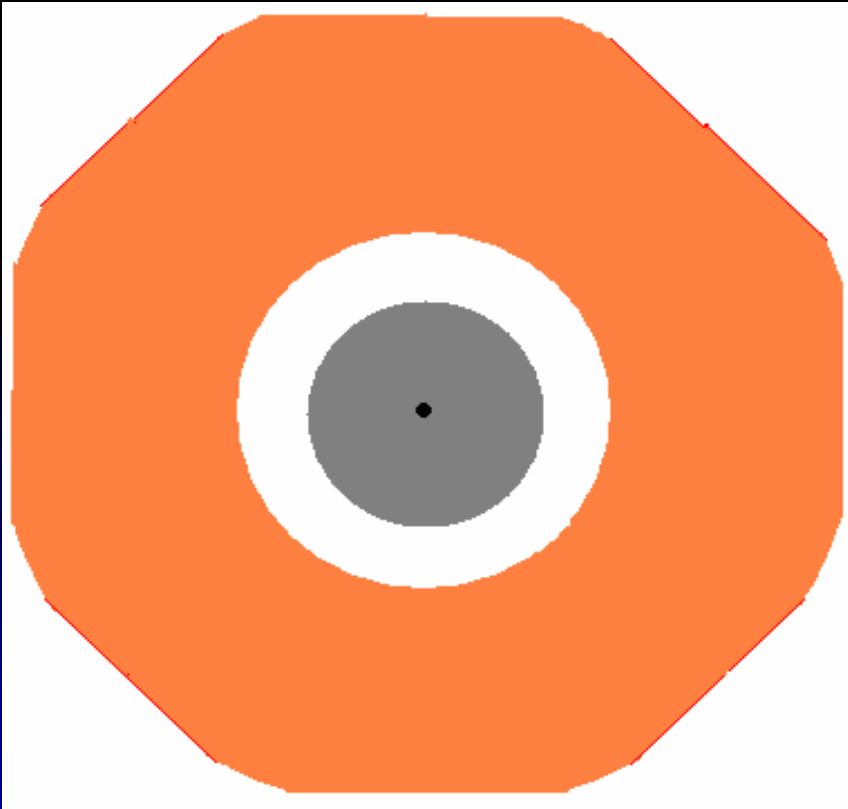
Anode Geometries

- Use Two different Anodes – Disc and Cylinder



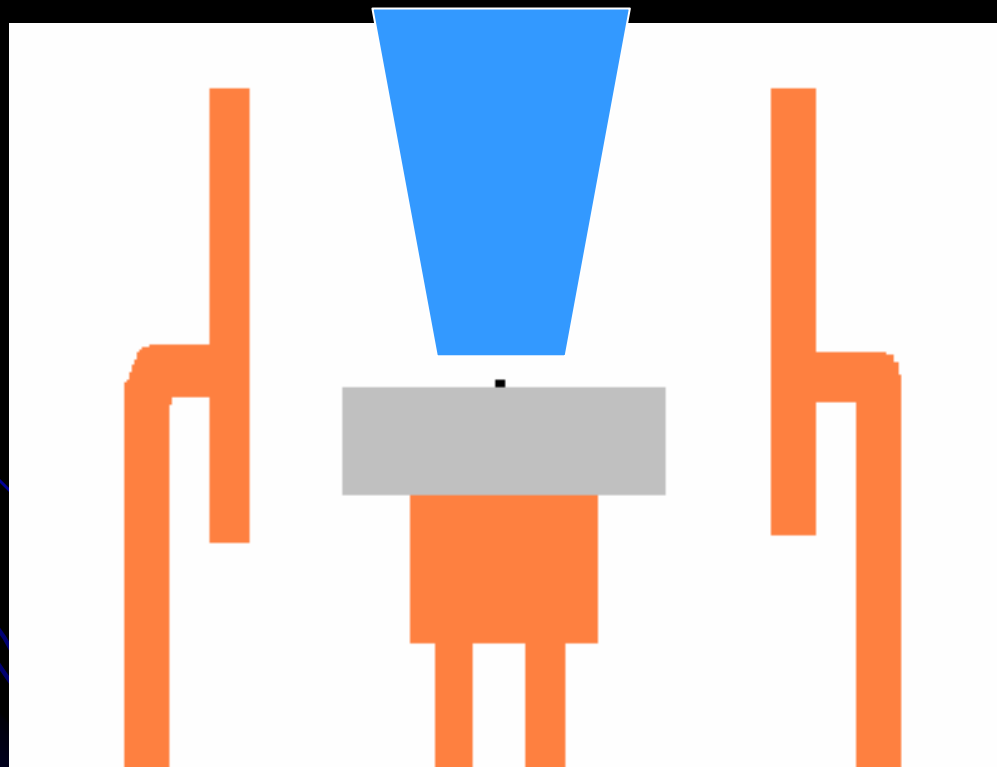
Disc Anode

Disc – rounded octagonal plate, 75mm inner hole, outer diagonal measurements ~150mm, cathode place 15-20mm behind plate



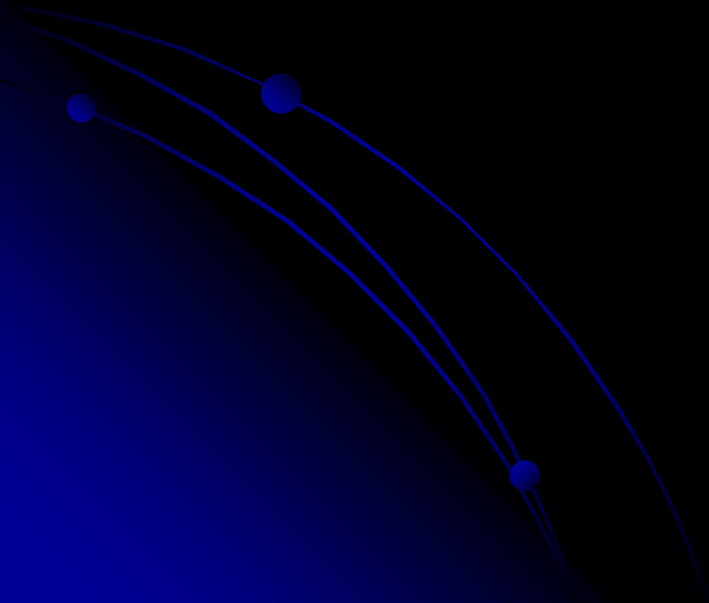
Cylindrical Anode

Cylinder – 75mm inner diameter,
80mm long, cathode towards rear



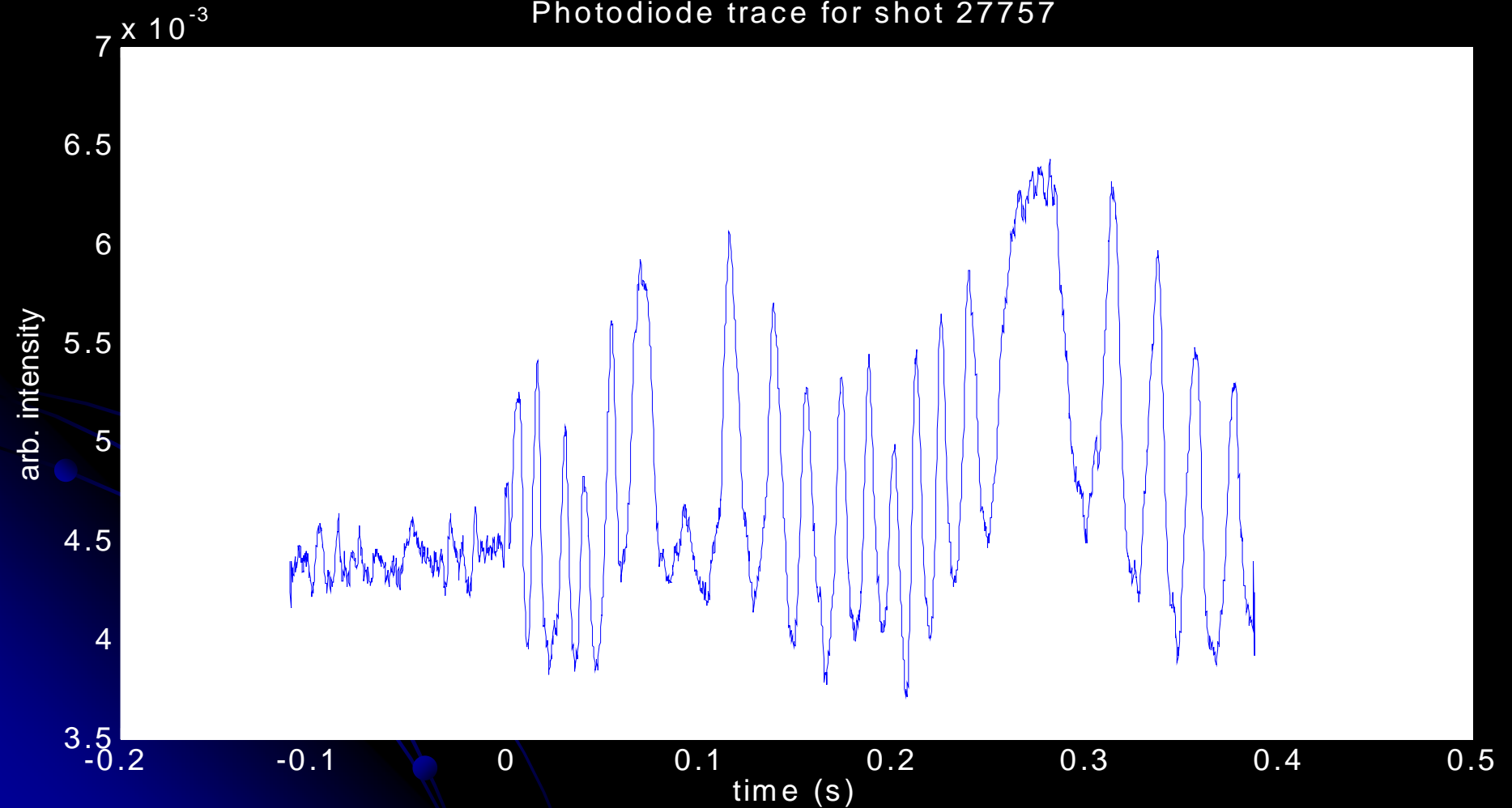
Methodology - Output

- Optically inspect photodiode trace
- Mark maxima and minima



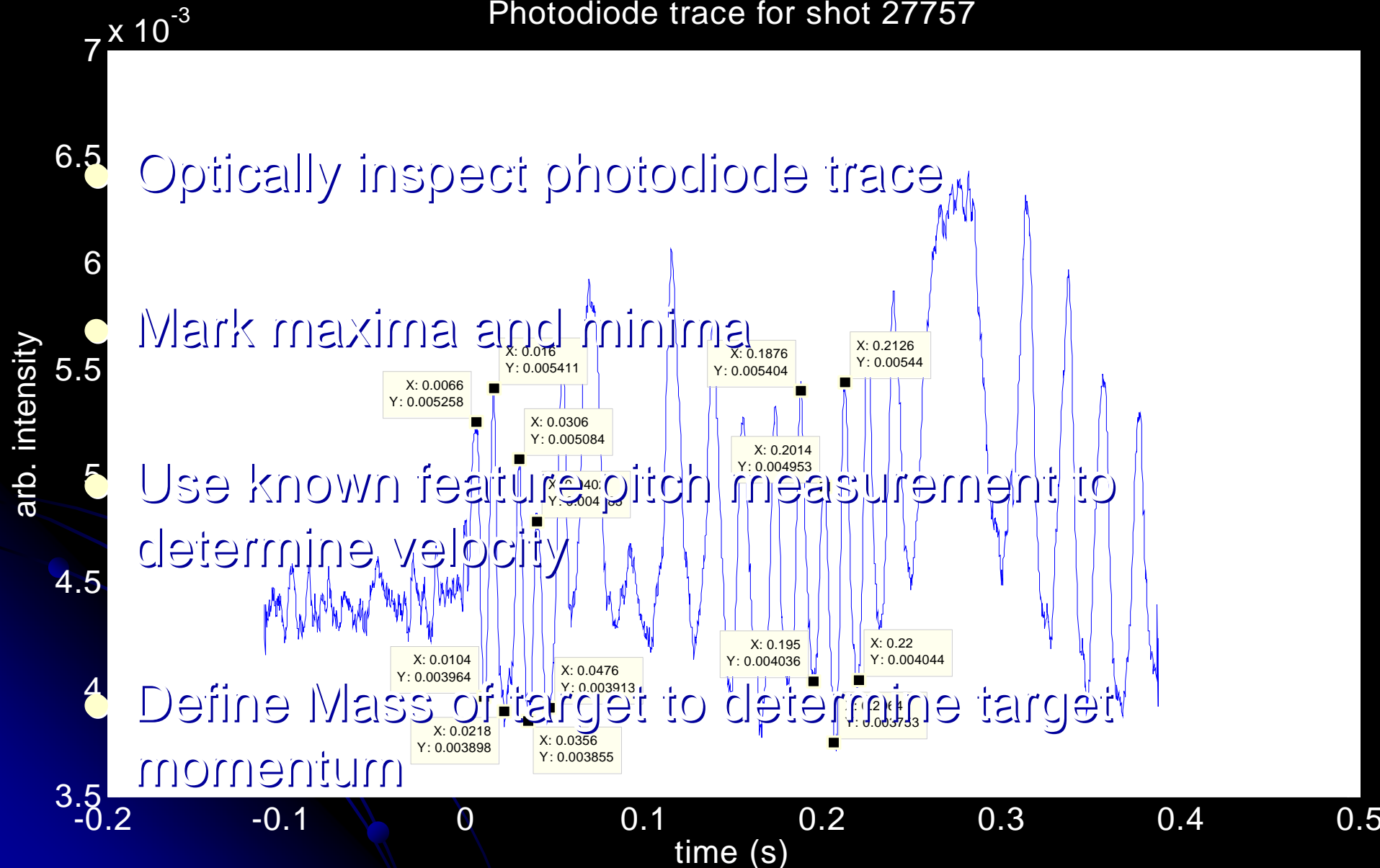
Methodology - Output

Photodiode trace for shot 27757



Methodology - Output

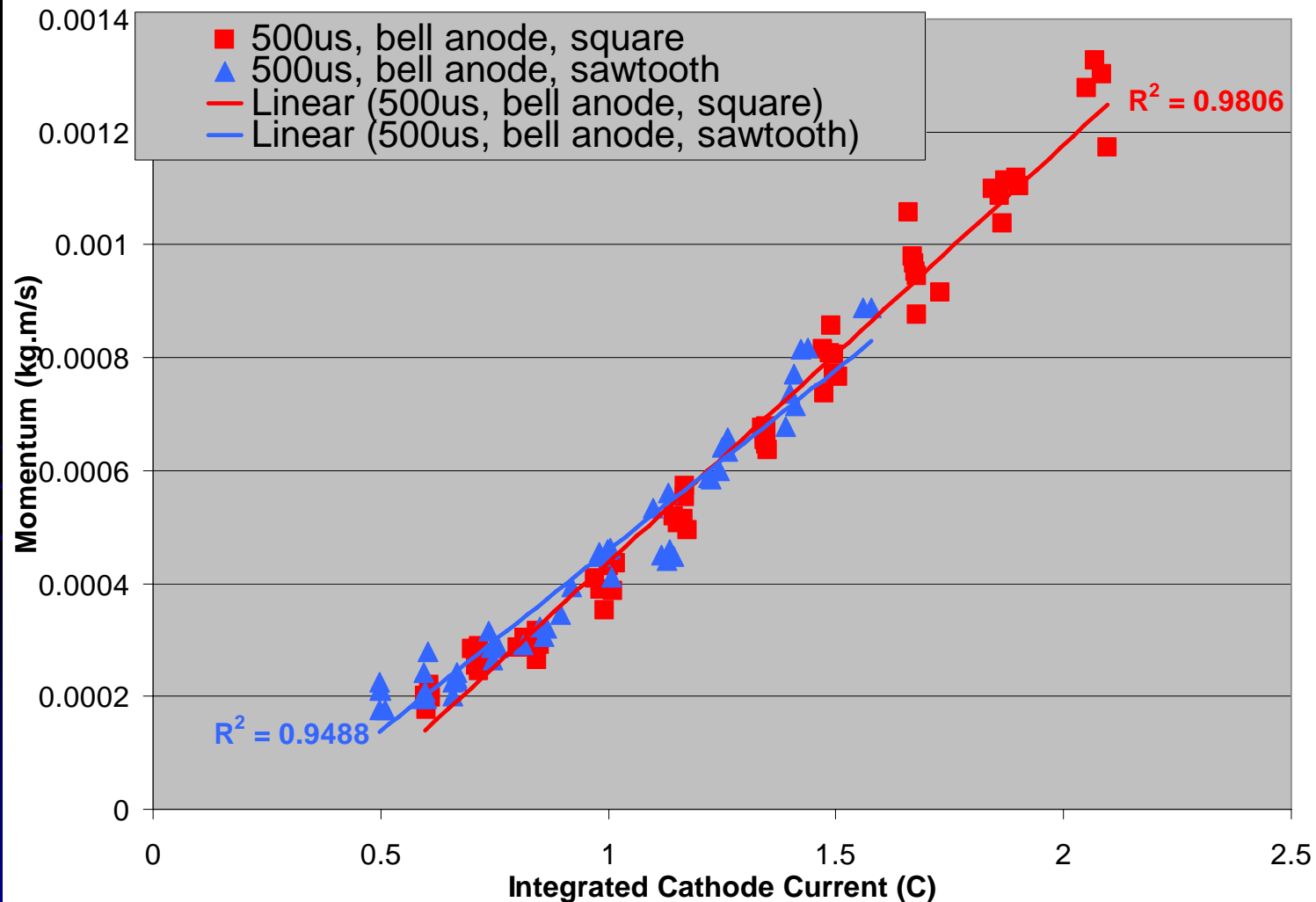
Photodiode trace for shot 27757



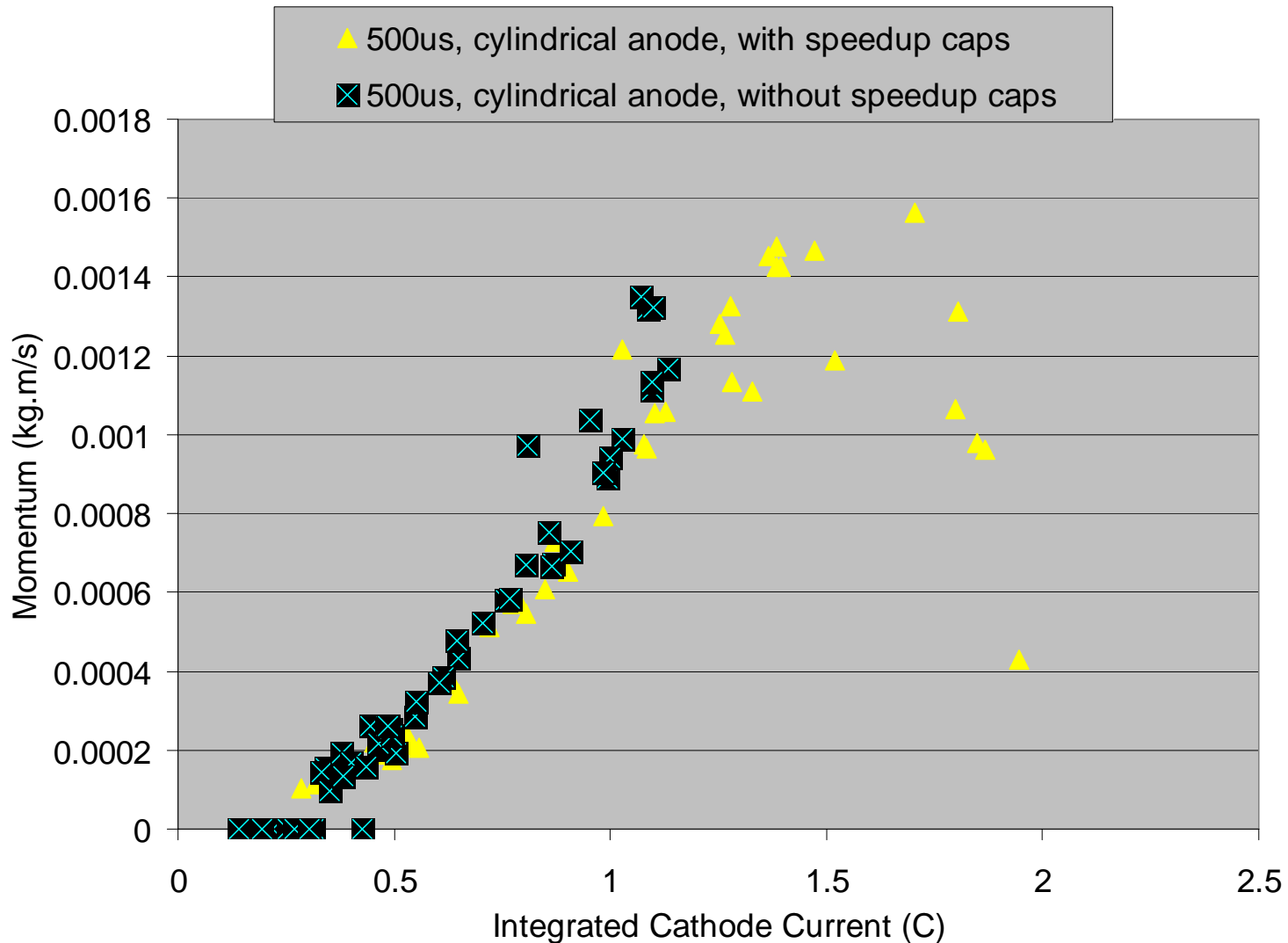
Methodology - Input

- Use Rogowski coils to determine currents through Anode (I_a) and Cathode (I_c)
- Use voltage probes to determine potential of cathode with respect to Common Earth (anode and vessel walls)
- Determine Cathode Burn voltage (V_b)

Results – Cathode Current



Results – Cathode Current

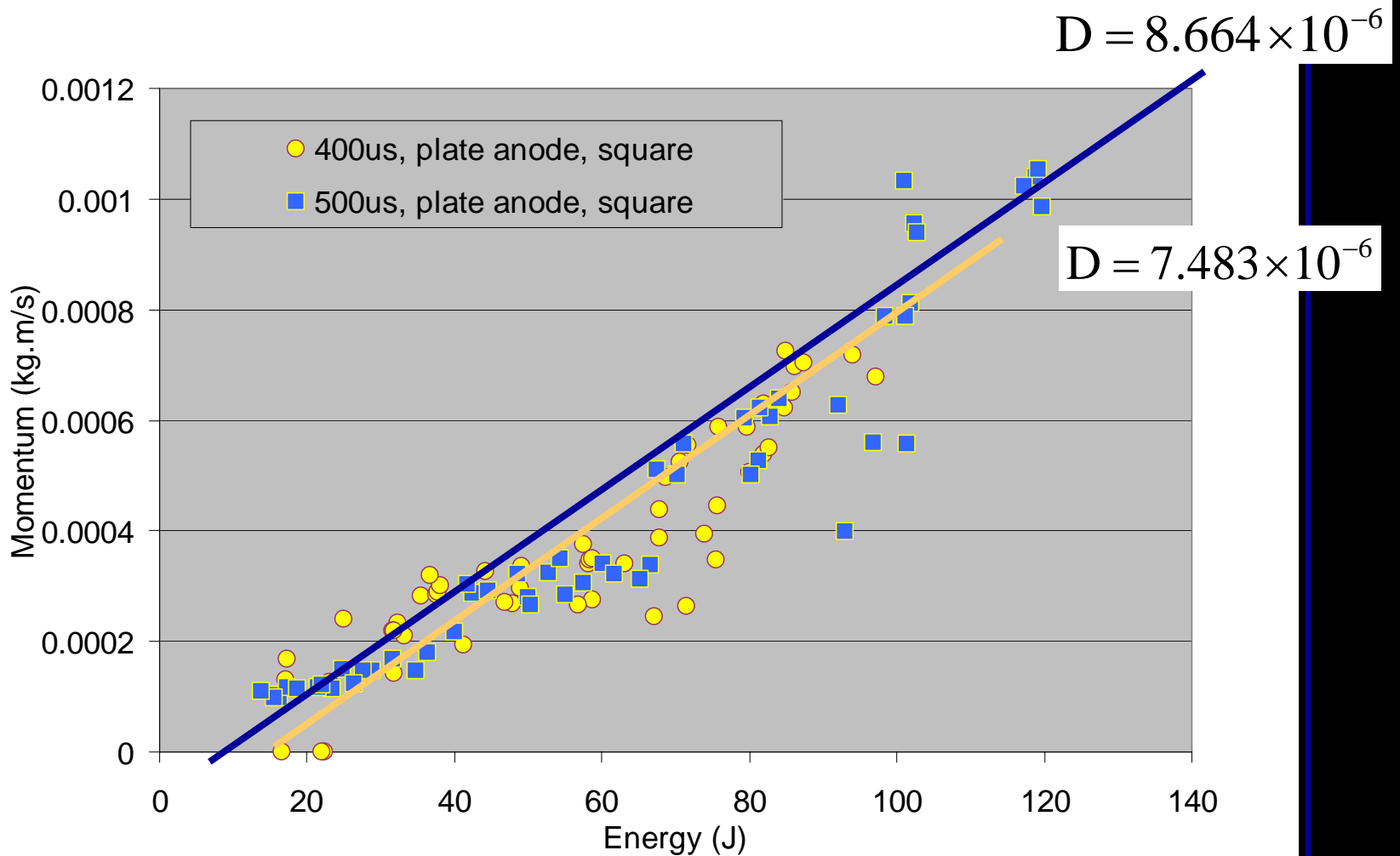


Methodology - Processing

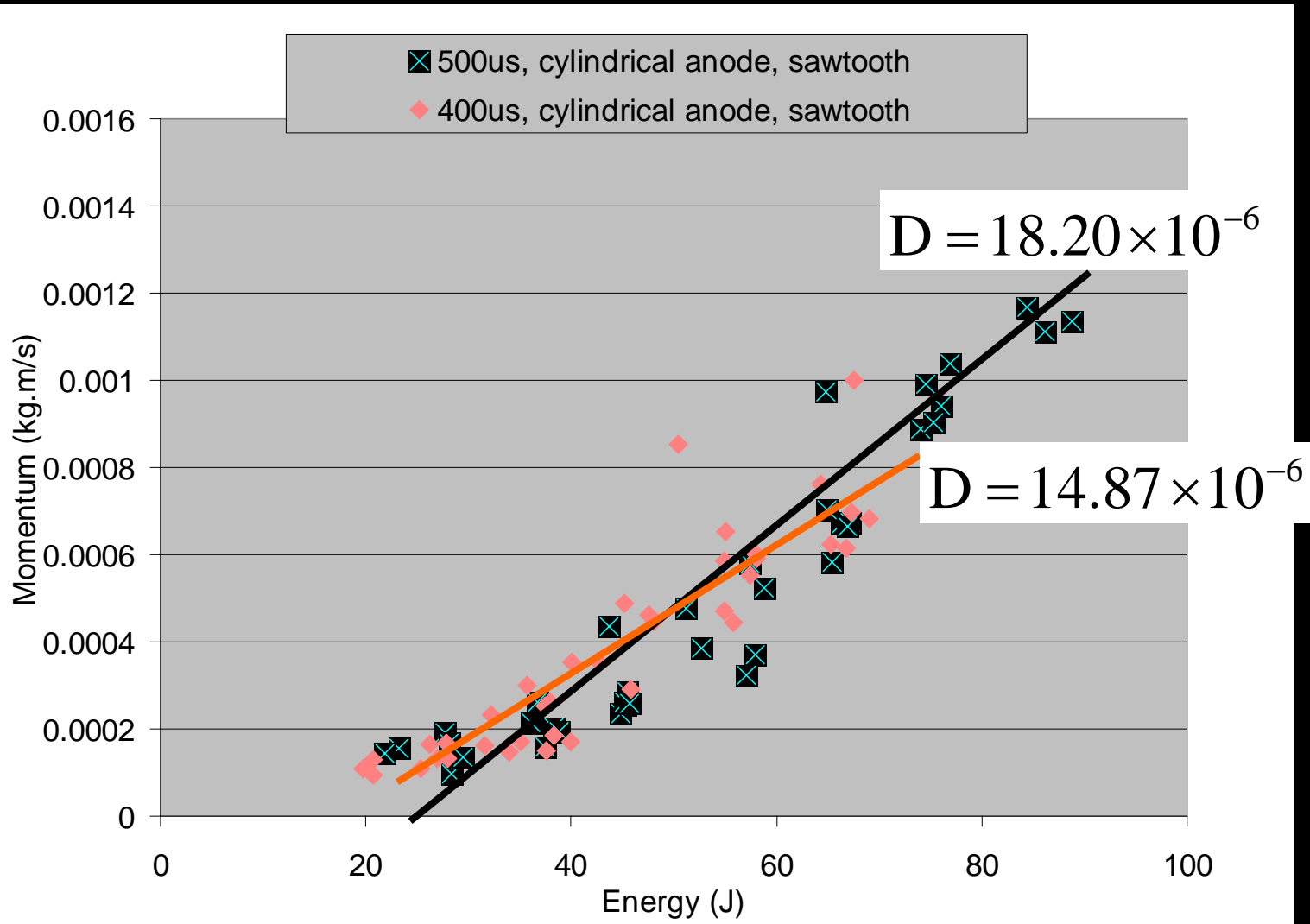
- Instantaneous input power is $I_c \times V_b$
- Integral of instantaneous power gives input energy

- Define a Factor of Merit, D , $D = \frac{dP}{dE}$ where P is the pulse momentum and E is the input energy

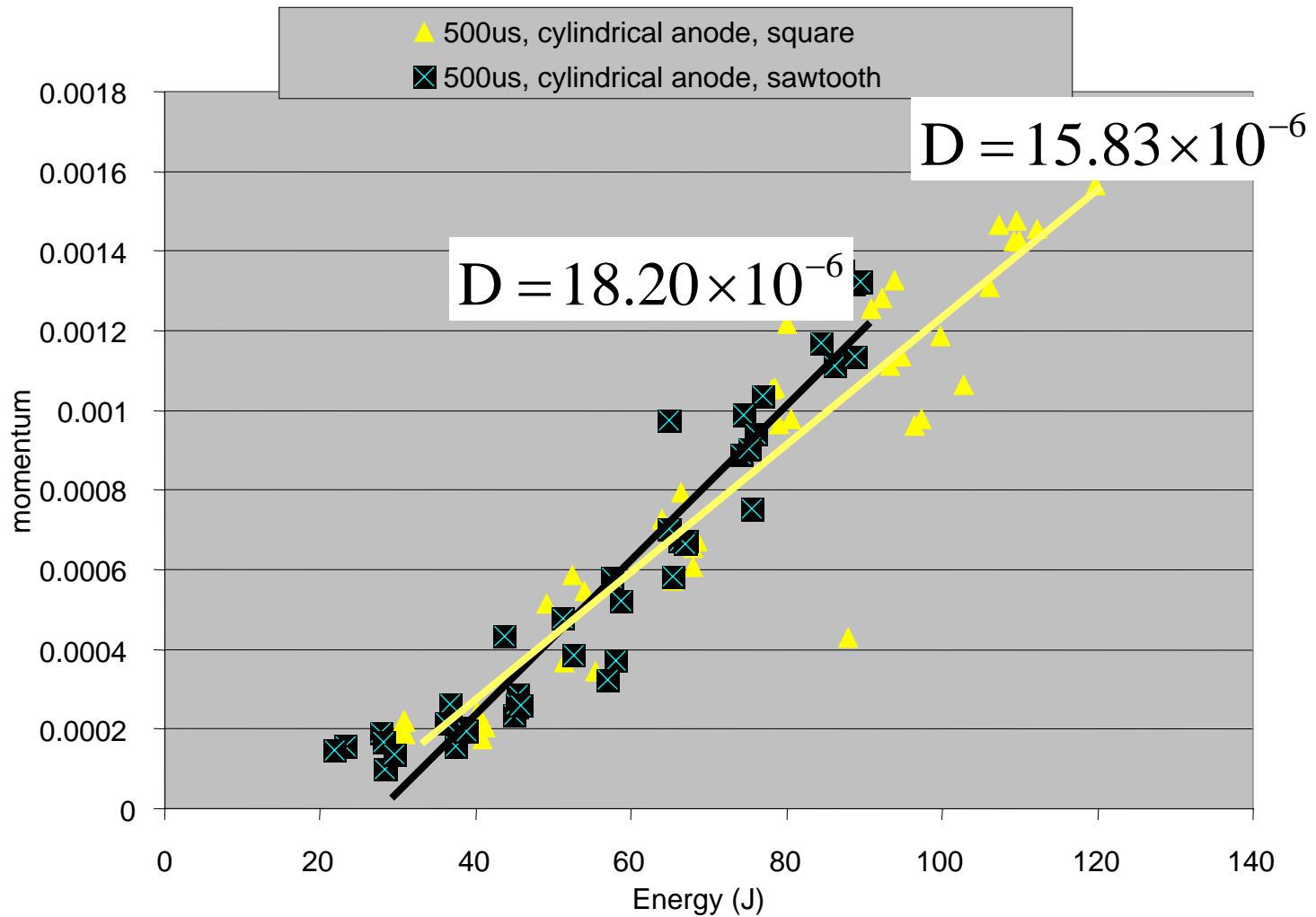
Results – Pulse Length



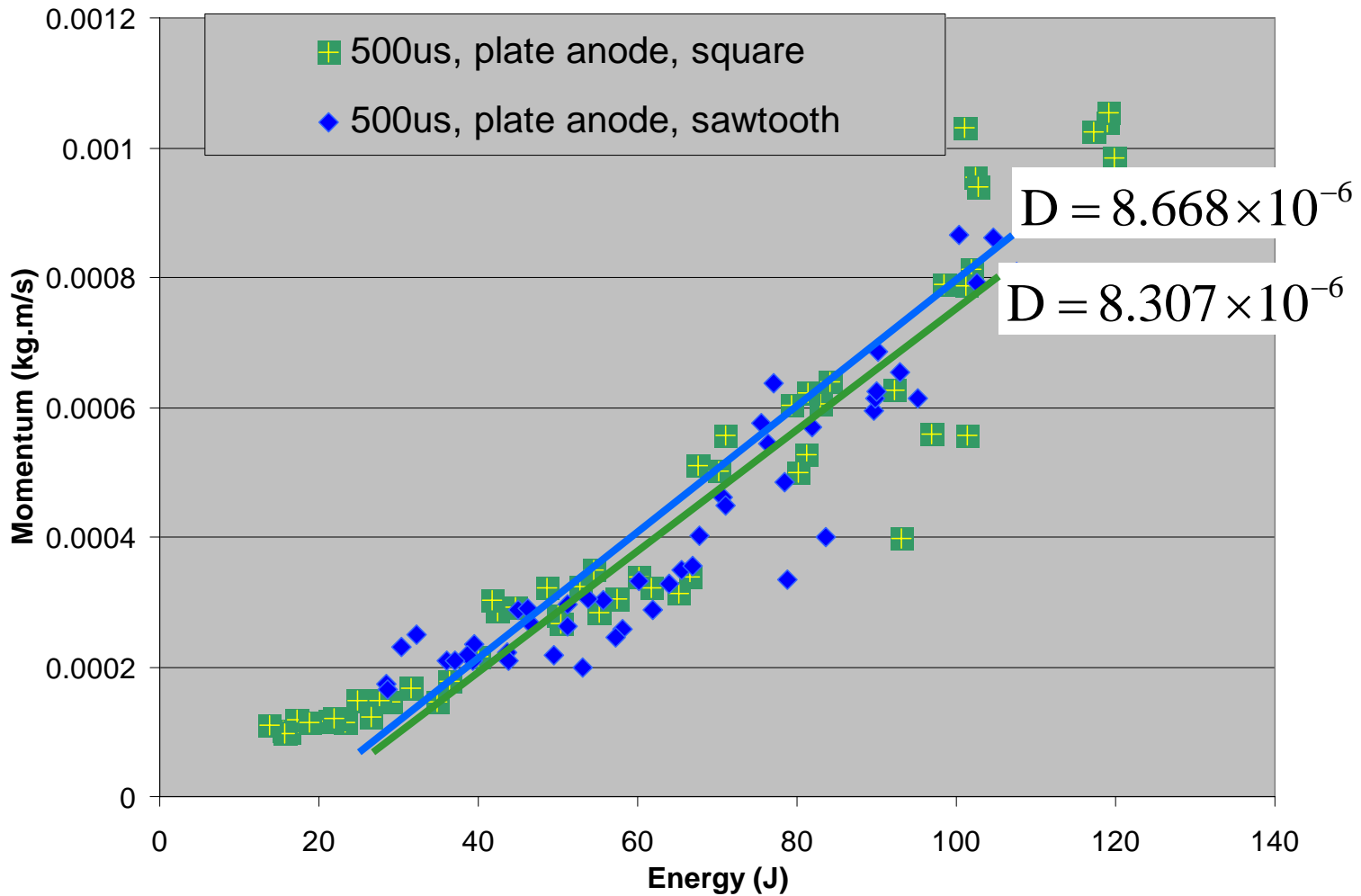
Results – Pulse Length



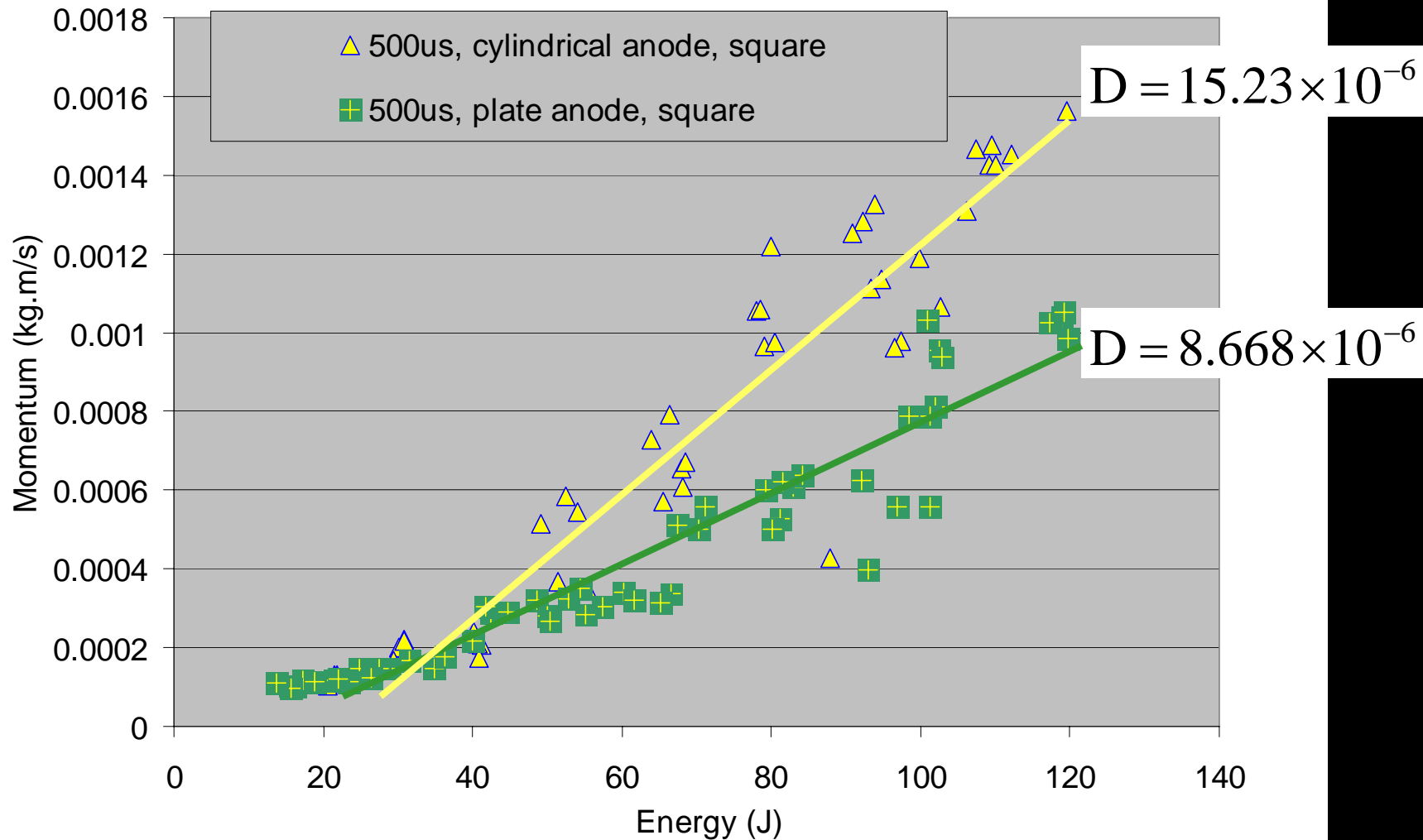
Results – Pulse Shape



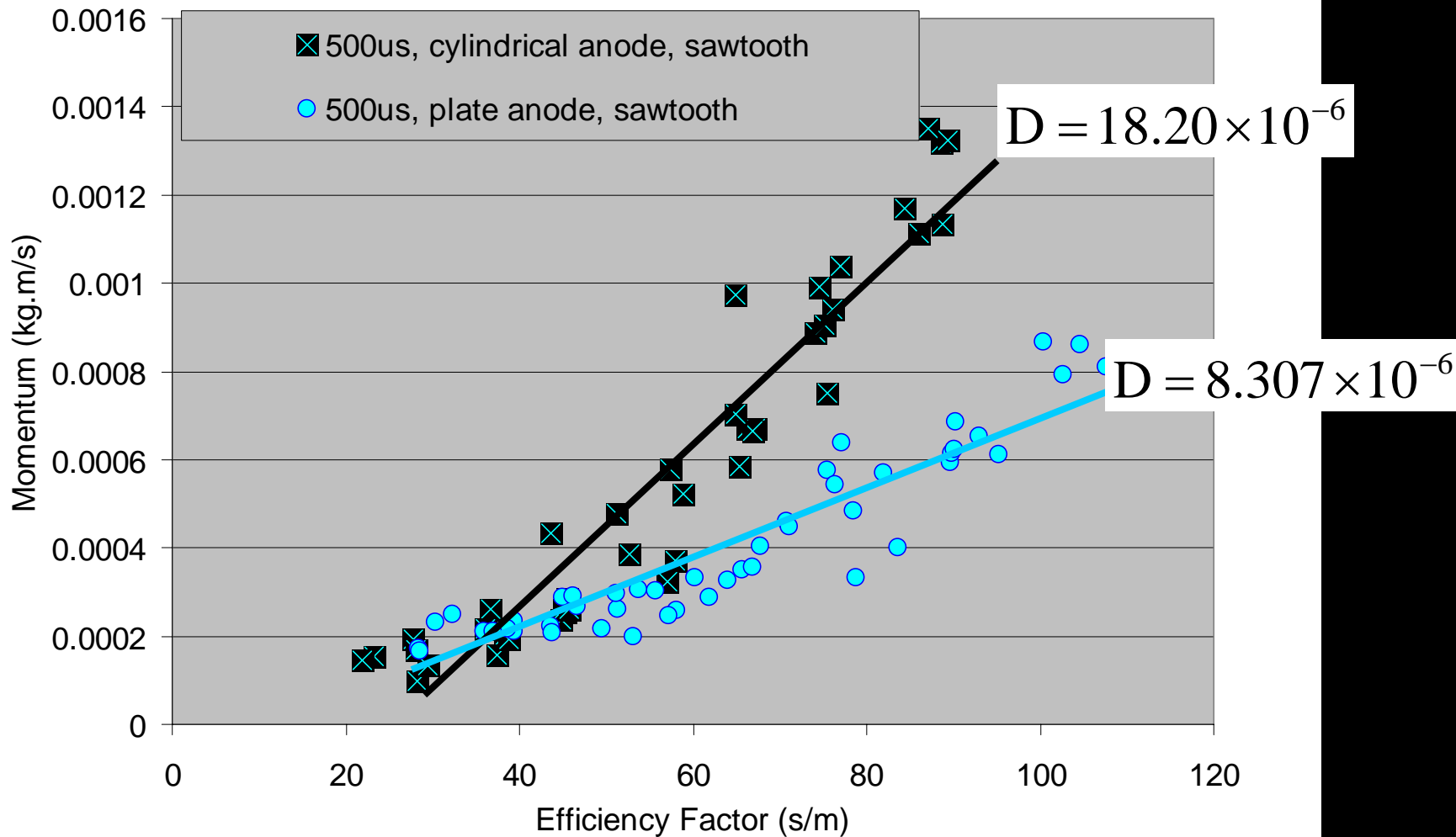
Results – Pulse Shape



Results – Anode Geometry



Results – Anode Geometry



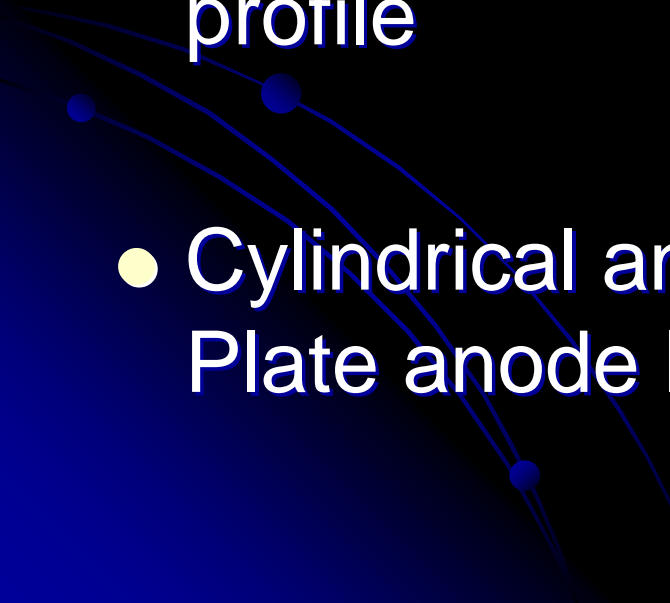
Analysis of a Representative High-Yield Pulse

- Pulse 27343 – 500us Cylindrical anode with speedup caps – average pendulum speed of 0.225m/s
- Pendulum mass of 6.476g gives momentum of 1.454 mN.s
- Over 500us pulse duration, equates to a net average force of 2.91N

Discussion of a Representative High-Yield Pulse

- For a 50mm diameter cathode, this yields a thrust density of $1481\text{N}\cdot\text{m}^{-2}$
- Thrust densities of $20\text{-}30\text{N}\cdot\text{m}^{-2}$ are considered high for current generation ion thrusters
- Requires high duty cycle of ~ 80 pulses per second to be competitive with SNECMA Moteurs PPS-1350
- Current power supply has max duty cycle of 10Hz

Conclusions

- Long pulse durations appear better for thrust, may degrade efficiency
 - Square current profile superior to ramped profile
 - Cylindrical anode superior to Bell, with Plate anode least effective
- 

Questions?

