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Pulse Energy Control Through Dual Loop Electronic Feedback

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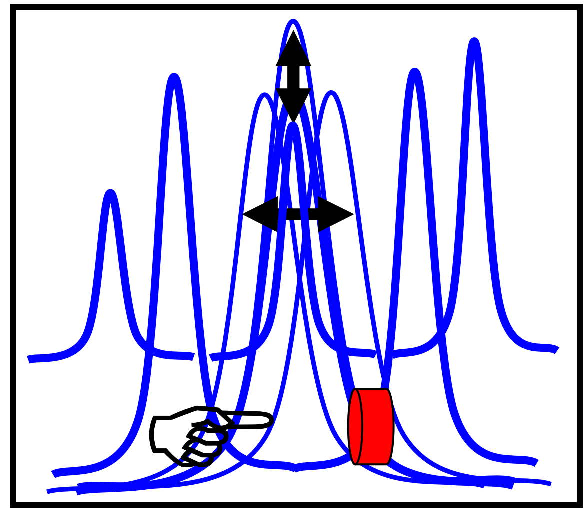
Overview

- What is Laser Pulse Energy Control?
- Why do we need it?
- How do we get it?
- Simulation
- Experimental Setup
- Results

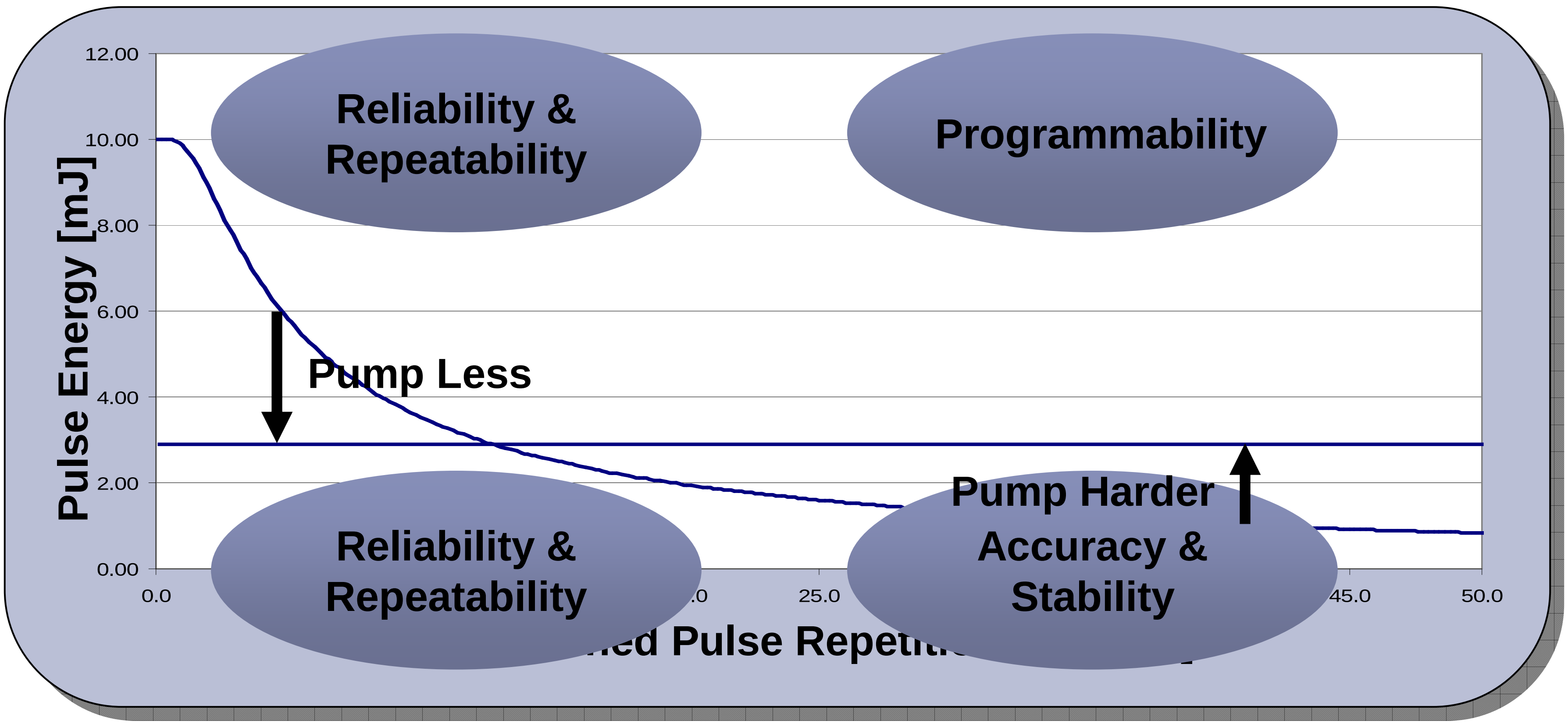
Pulse Energy Control



- What is Pulse Energy Control:
  - Reliability & Repeatability
  - Accuracy & Stability
  - Programmability
- Why do we need it:
  - Protection against component & subject damage
  - Micromachining with irregular pulse rate
  - Safer/improved laser surgery
  - Better accuracy in laser-based scientific measurements

Sources of Instability

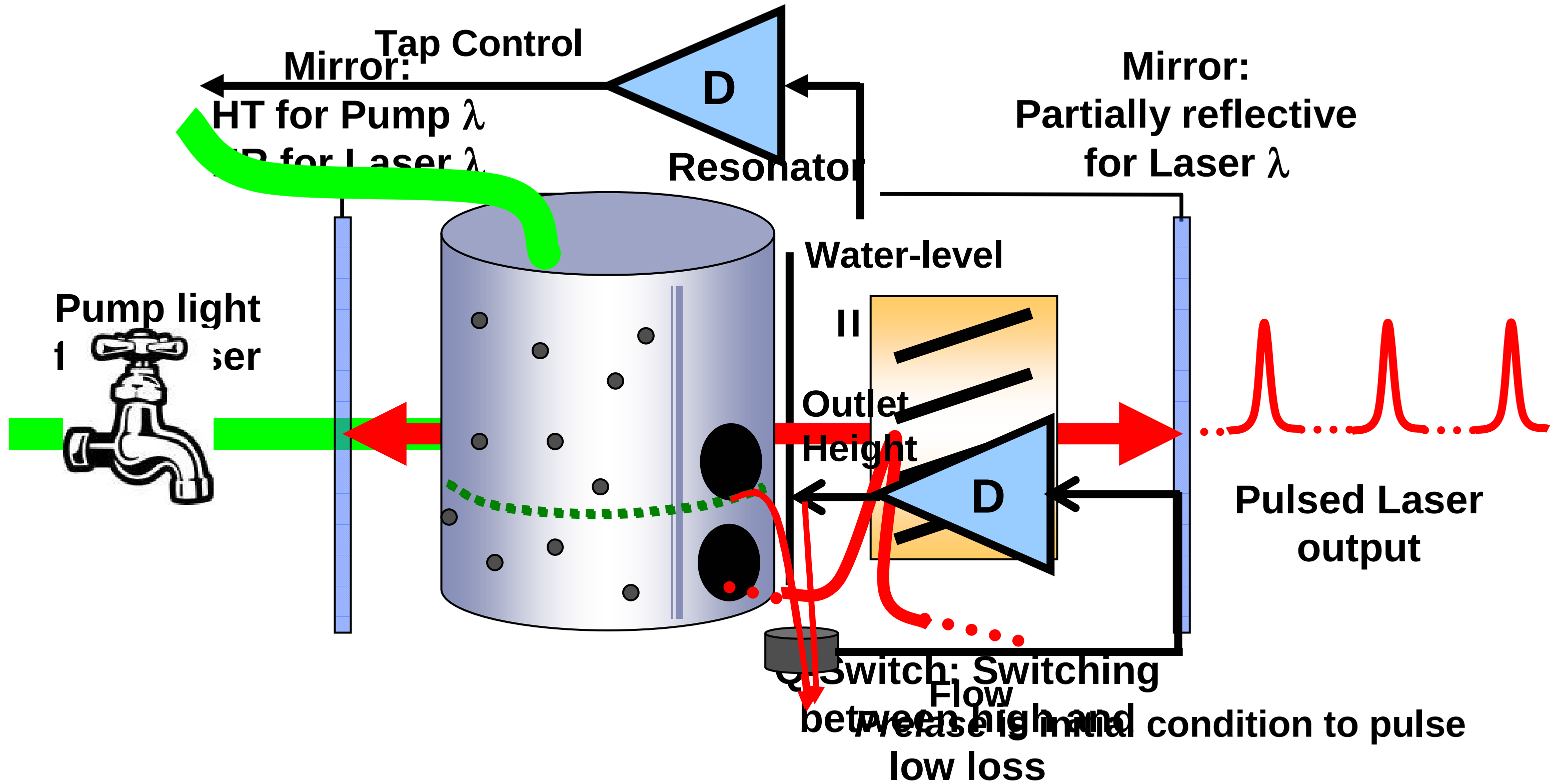
- Pump/Gain



Pulse Energy Control: How?

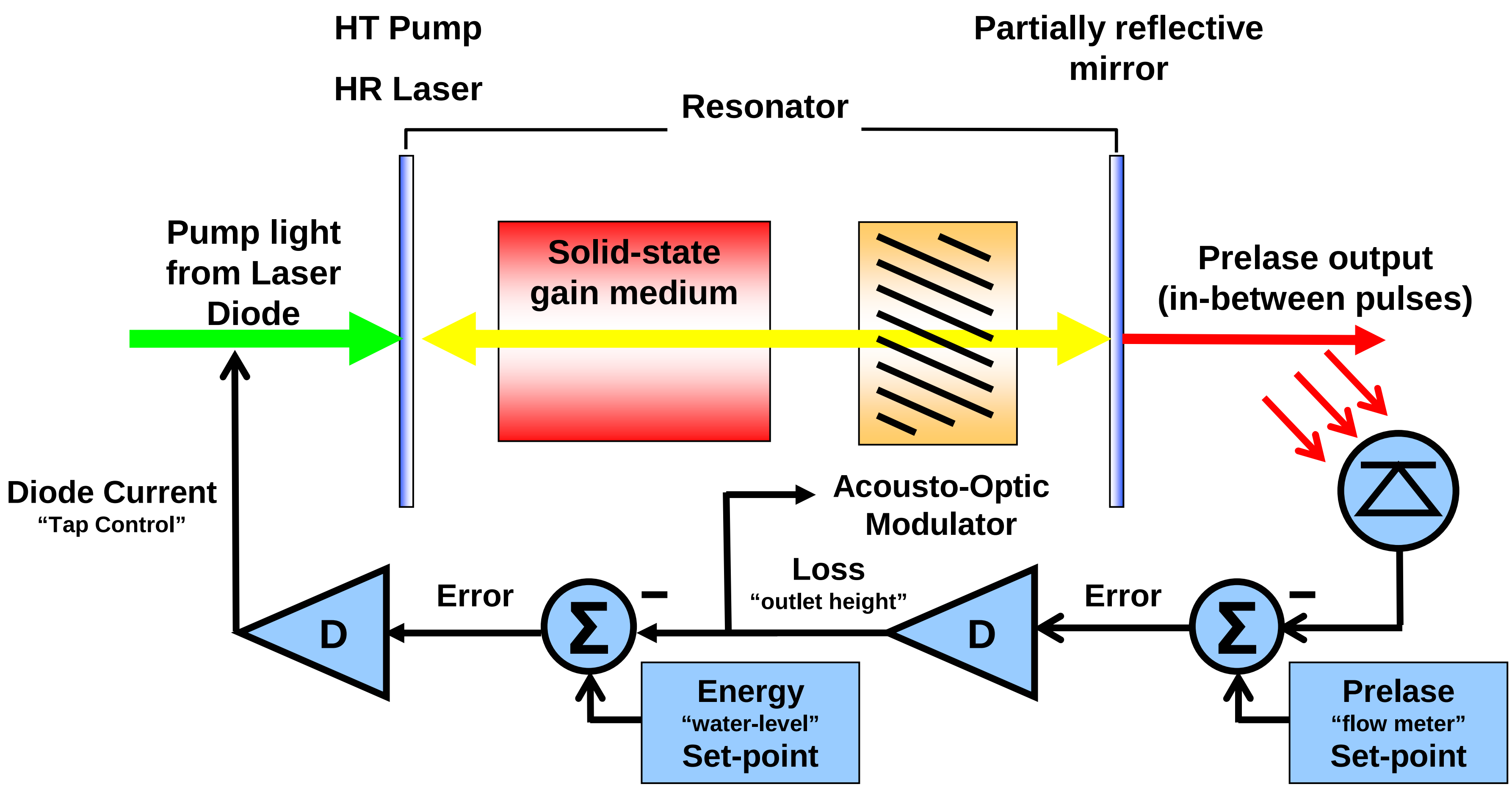
- Electronic Feedback
  - Inexpensive, efficient & highly flexible
  - Reported prelase technique with feedback to internal Q-switch for reducing **cavity** instabilities at SAIP2004 & 5
  - Now add 2nd feedback loop to **pump** for bulk energy/gain control
    - Problem: Need to measure stored energy in medium
    - Answer: Cascaded "dual" loop system
Gain control taps of the prelase loop

Bucket Analogy



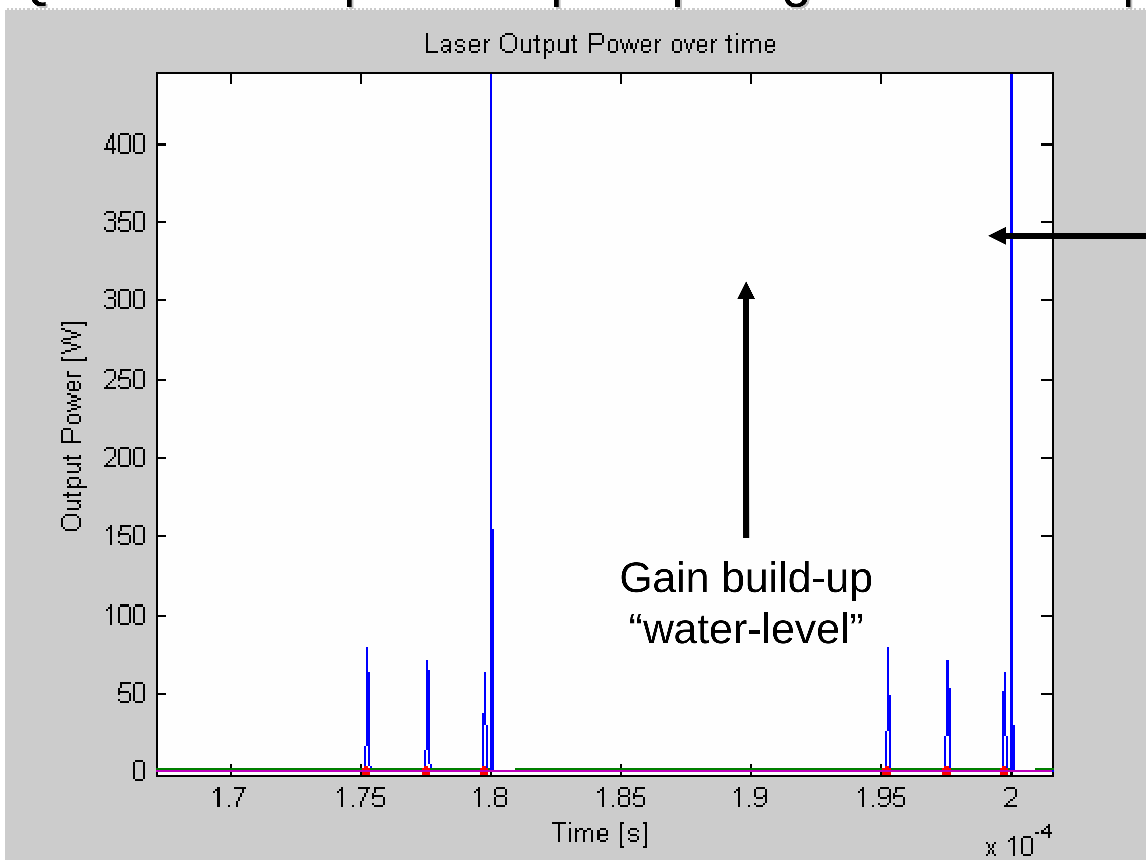
- Medium = bucket, water-level = stored energy available to pulse

Dual loop system



Simulation: Prelase

- Look at typical response on detector (still without feedback)
- Too low Q-switch loss produce pre-spiking before each pulse



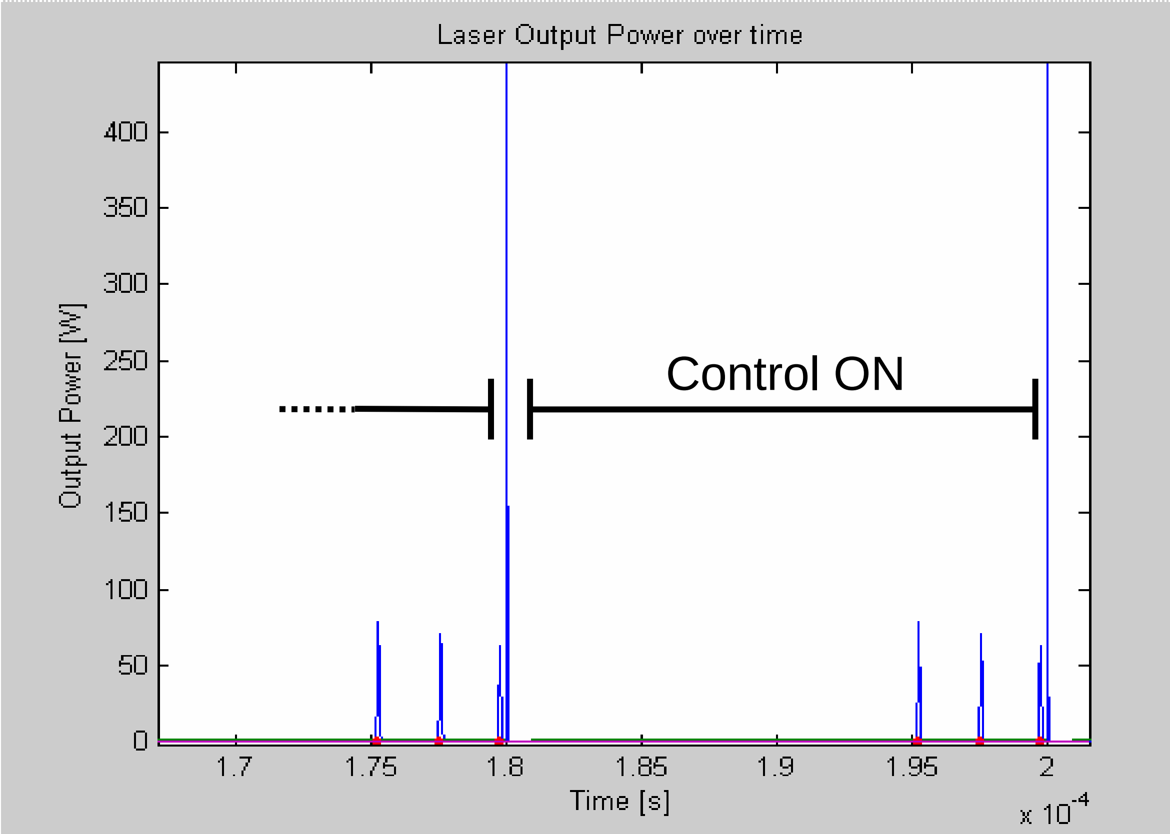
Switched loss

“outlet height”

- Observe lasing if “gain equals the losses”

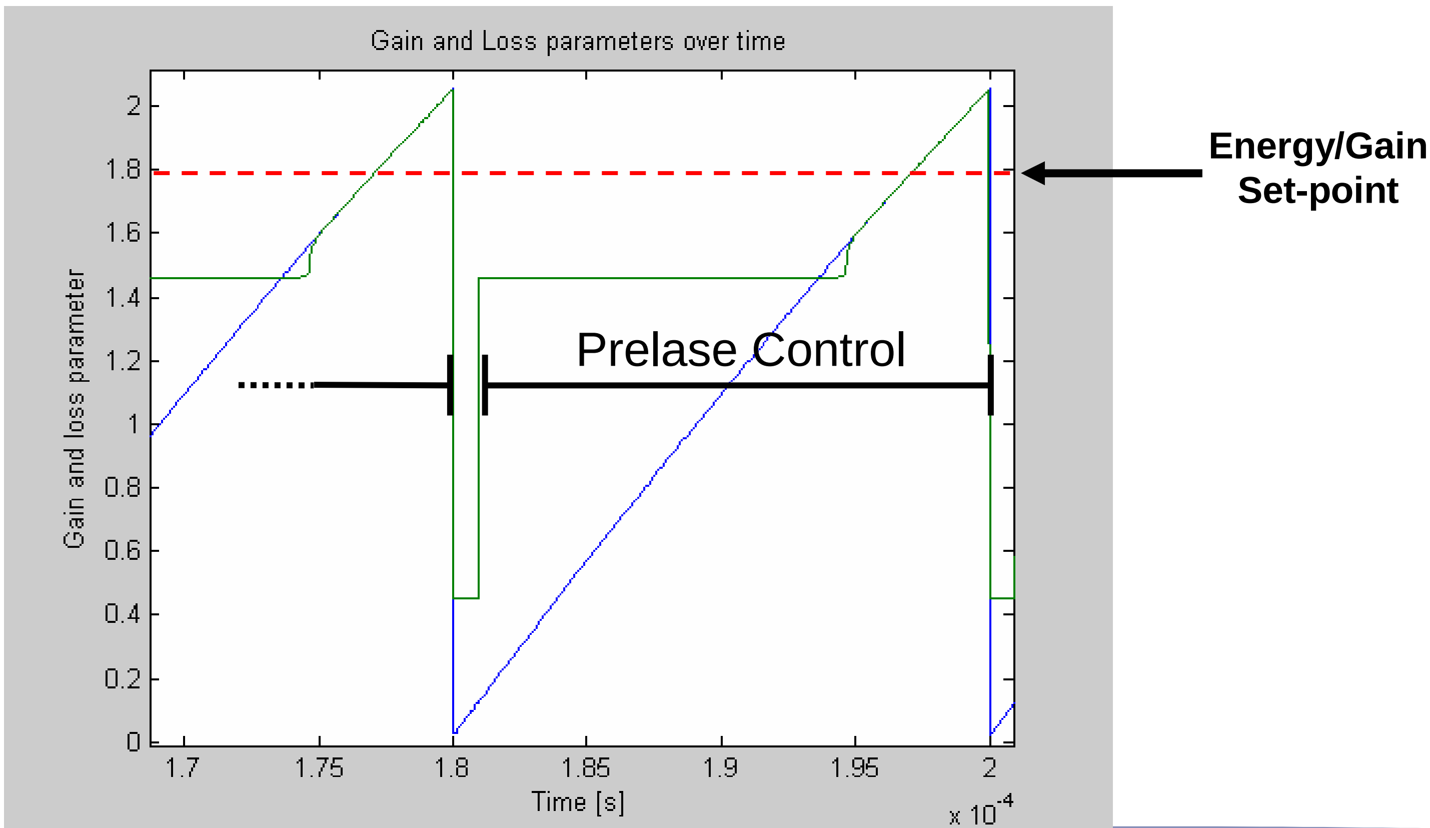
Simulation: Prelase Control

- As before, allow pre-spiking but add *control* between pulses
- Rejected as noise and formed into stable, low power CW ***prelase***

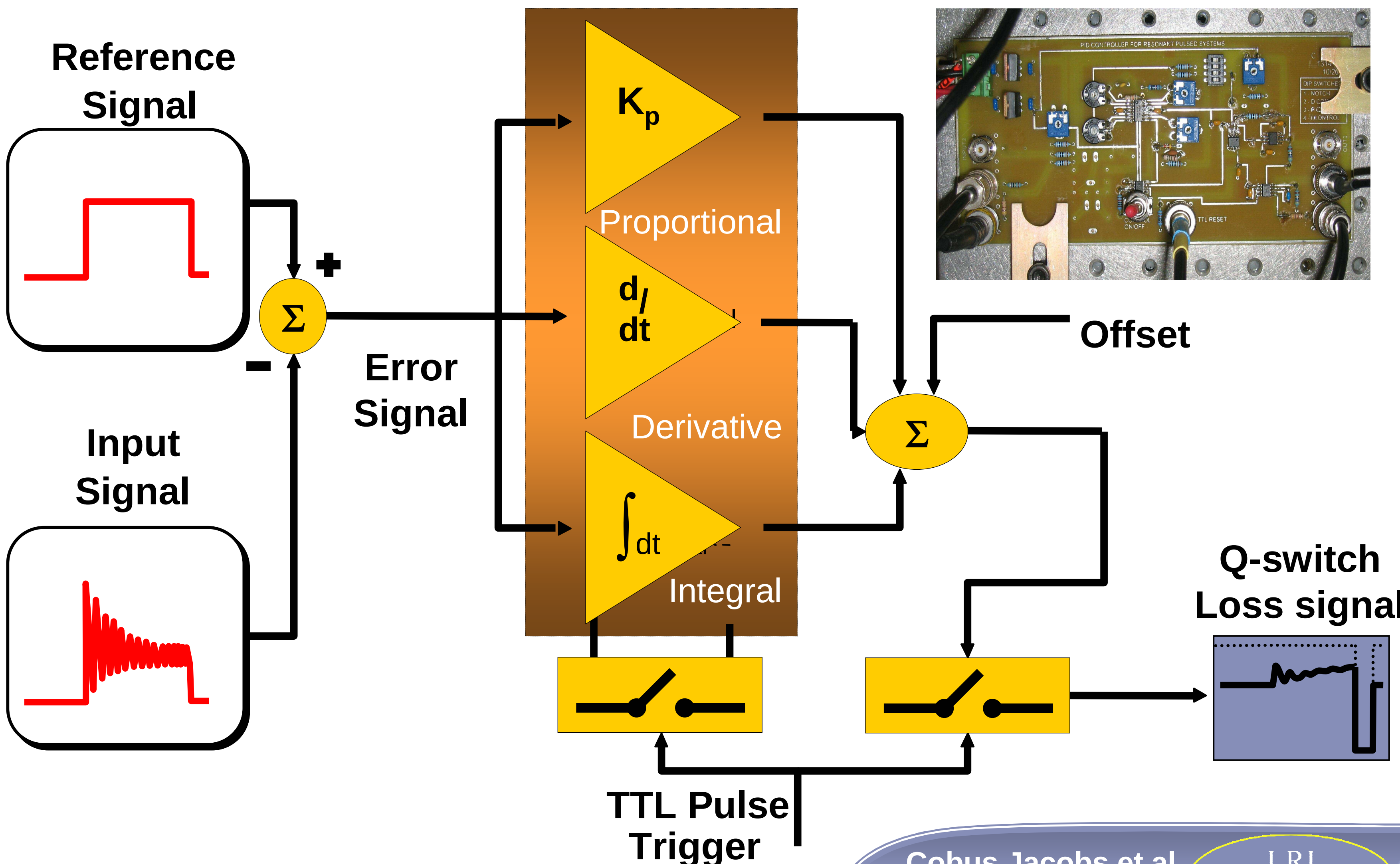


Dual Loop

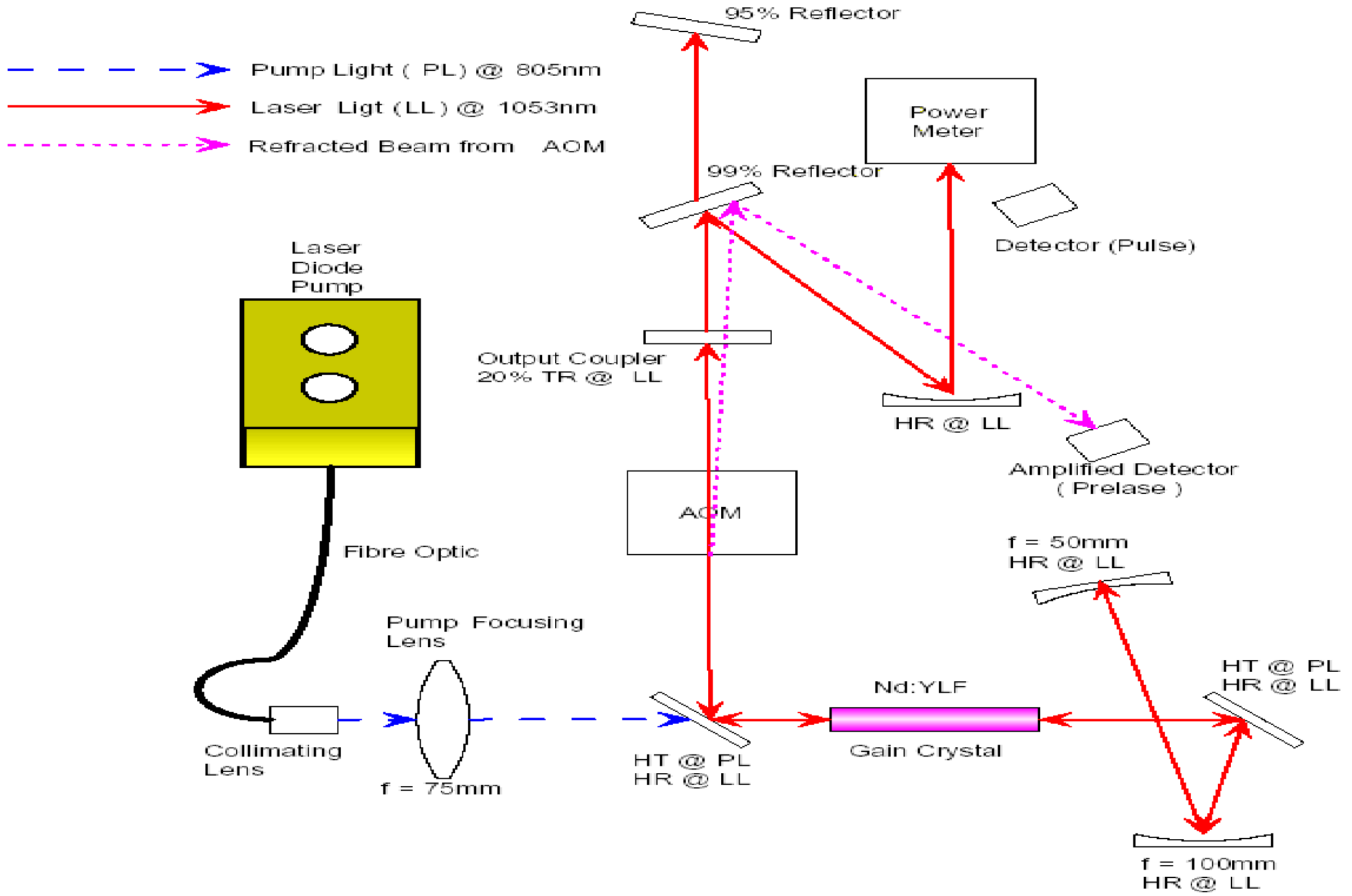
- Most cases pump will already be running at full power
- Gain-loop reduces pump power and keep energy/gain constant in the presence of other losses (natural decay, heat…)



Analog PID Controller Design

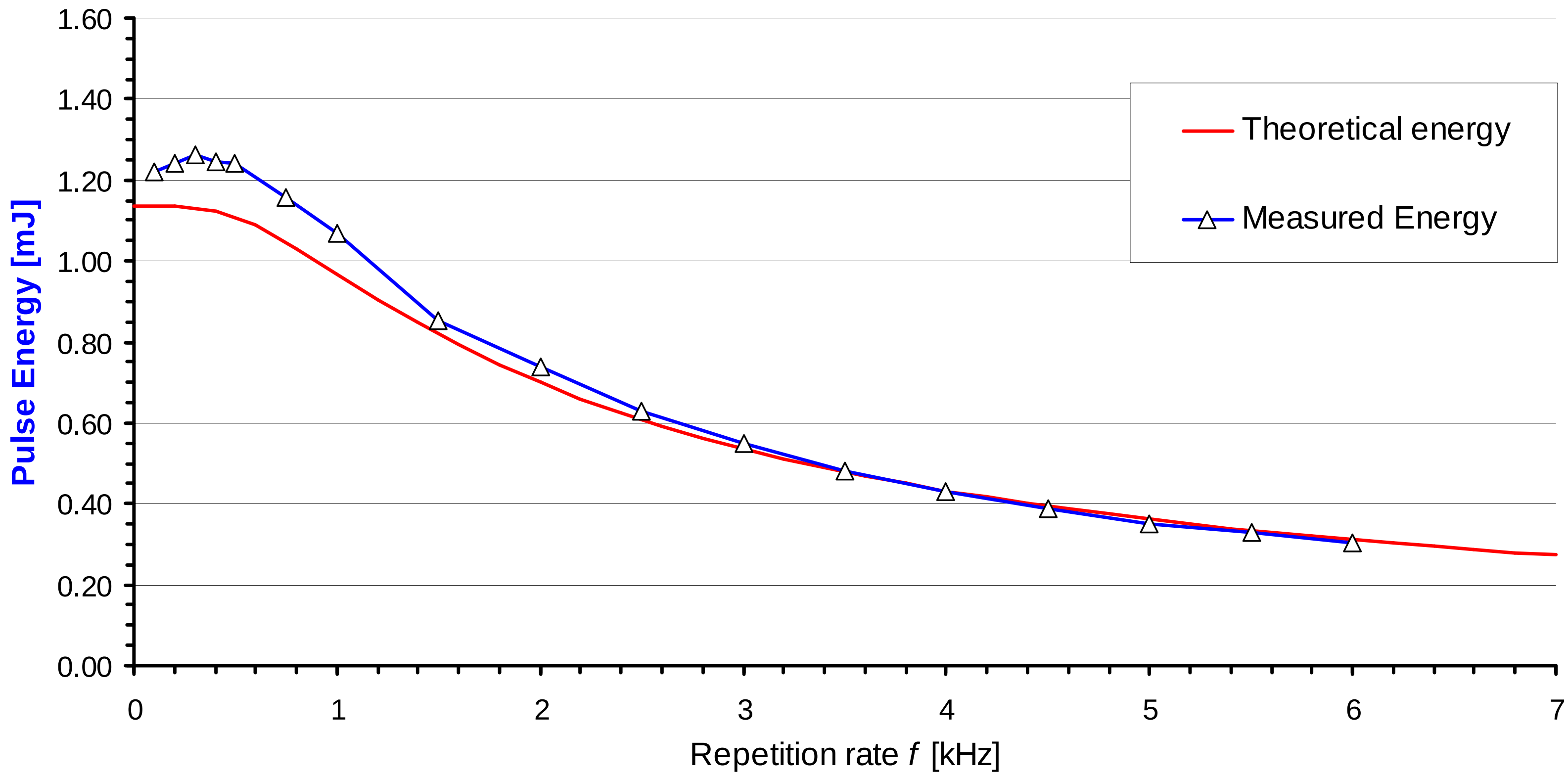


Experimental Setup

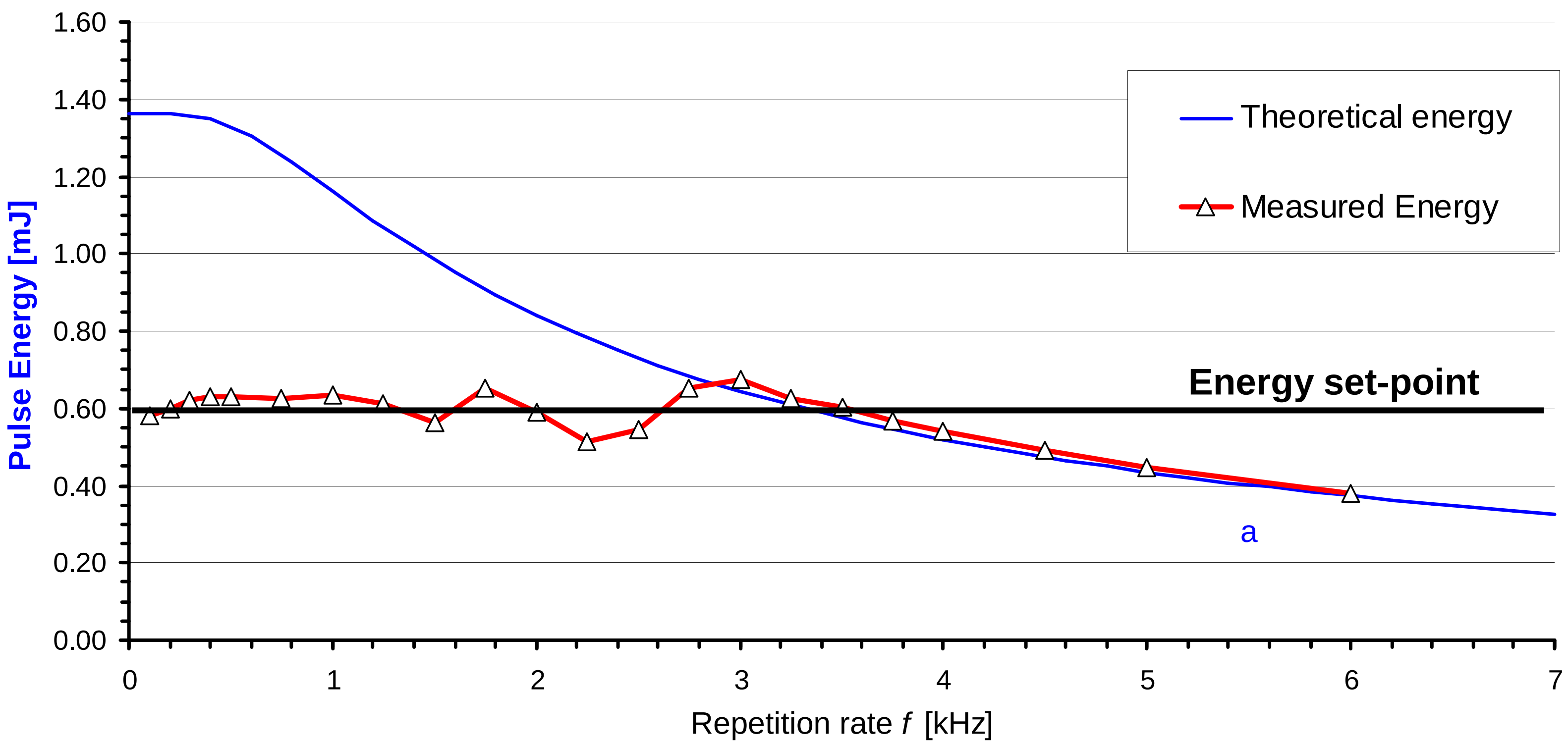


CW: Max Pump 28W, Output 5,6W, 20% eff.

Results: Uncontrolled



Results: Dual Loop



Summary

- Previous results for single *prelase* loop
  - CW noise reduction by a factor of 20
  - Reduced timing jitter 13% → < 1% @ 5kHz (uncontrolled 87%)
  - Reduced amplitude jitter 5% → < 1% @ 5kHz (uncontrolled 21%)
- Successful bulk pulse energy control
  - Improvements possible
    Faster power supply, control hardware, optimal control (not cascade, but integrated) – ideal for a digital controller
  - A fast optimised pump setup can replace prelase loop, but with less jitter stability

Acknowledgements

- Steven Kriel
- Stellenbosch University
  - Laser Research Institute, Physics Department
  - Department of Electrical & Electronic Engineering
- CSIR - National Laser Centre
- Supervisors
  - Christoph Bollig (NLC)
  - Thomas Jones (Engineering)

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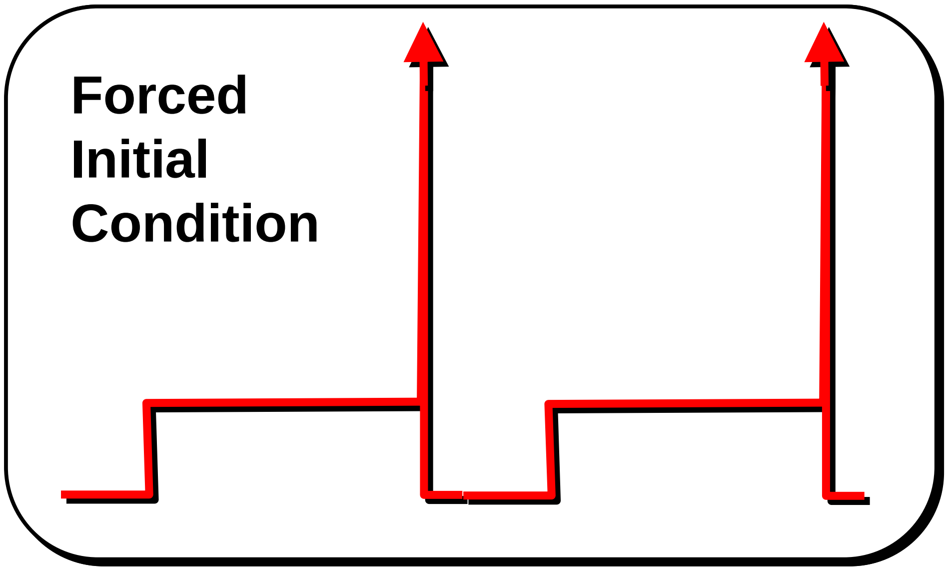
Proposing a solution

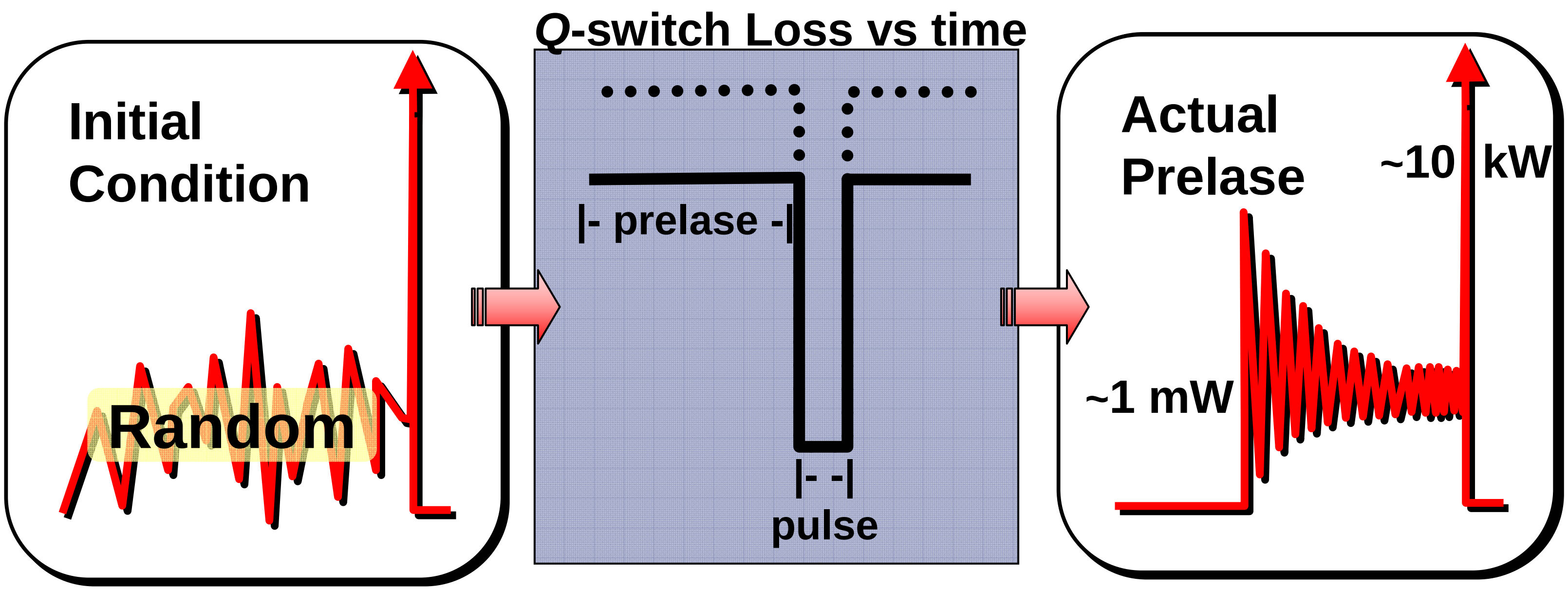
- Can not stabilize pulses directly
- Look at initial condition before each pulse



- Pulses are triggered from spontaneous emission
  => pulse to pulse variations
- Force a repeatable, stable initial condition
  => pulses will be stable as well

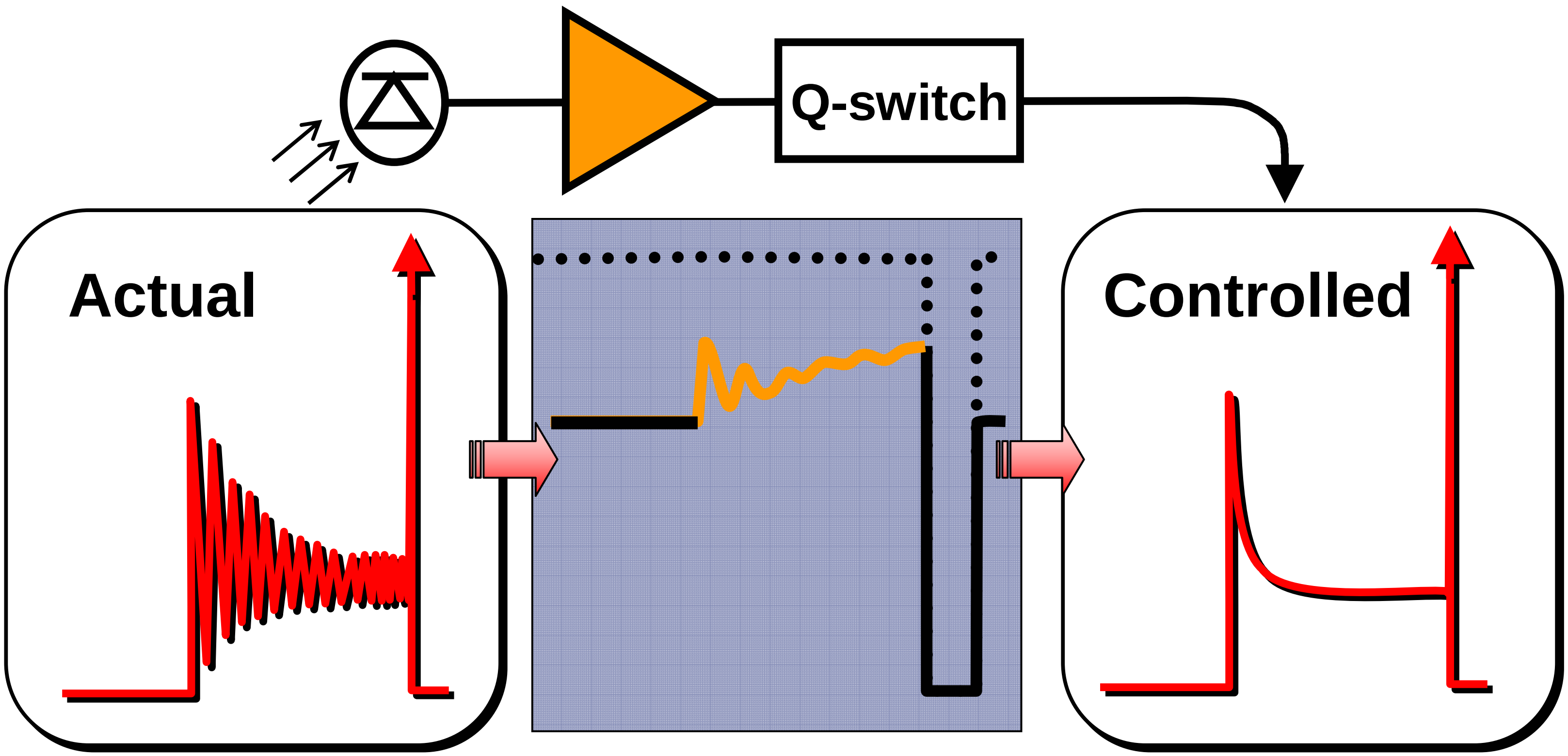
Forced Initial Condition

- Lower *Q*-switch *high*-loss slightly
  => slight lasing occurs before pulse (~1 mW vs ~10 kW)
- This forced initial condition is called the ***prelase***
- After short build-up time, prelase starts with **spiking**
- Stability worse because pulse triggered by spikes



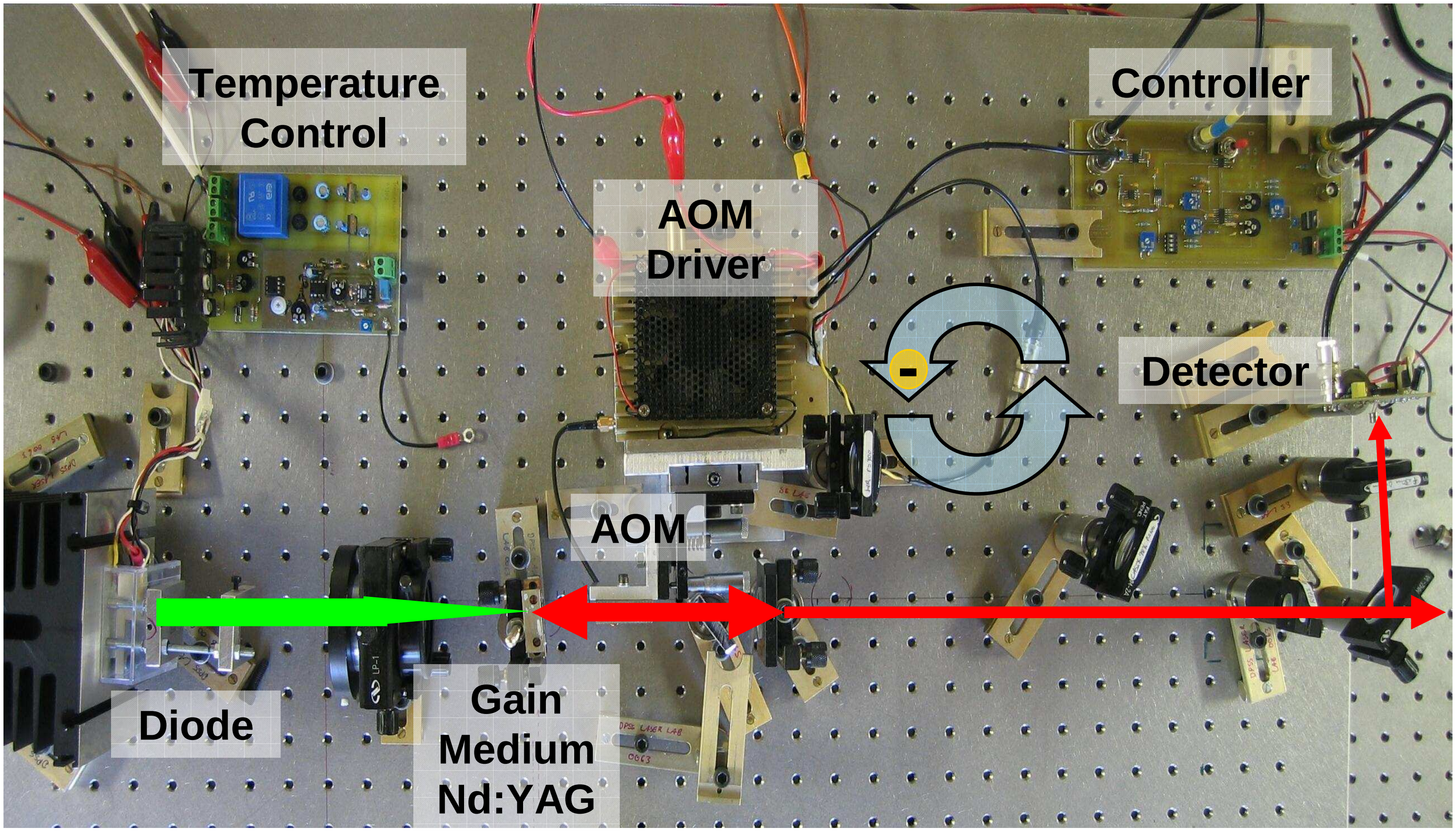
A Feedback Solution

- Stabilize the prelase by controlling the *Q*-switch loss through negative feedback of prelase signal



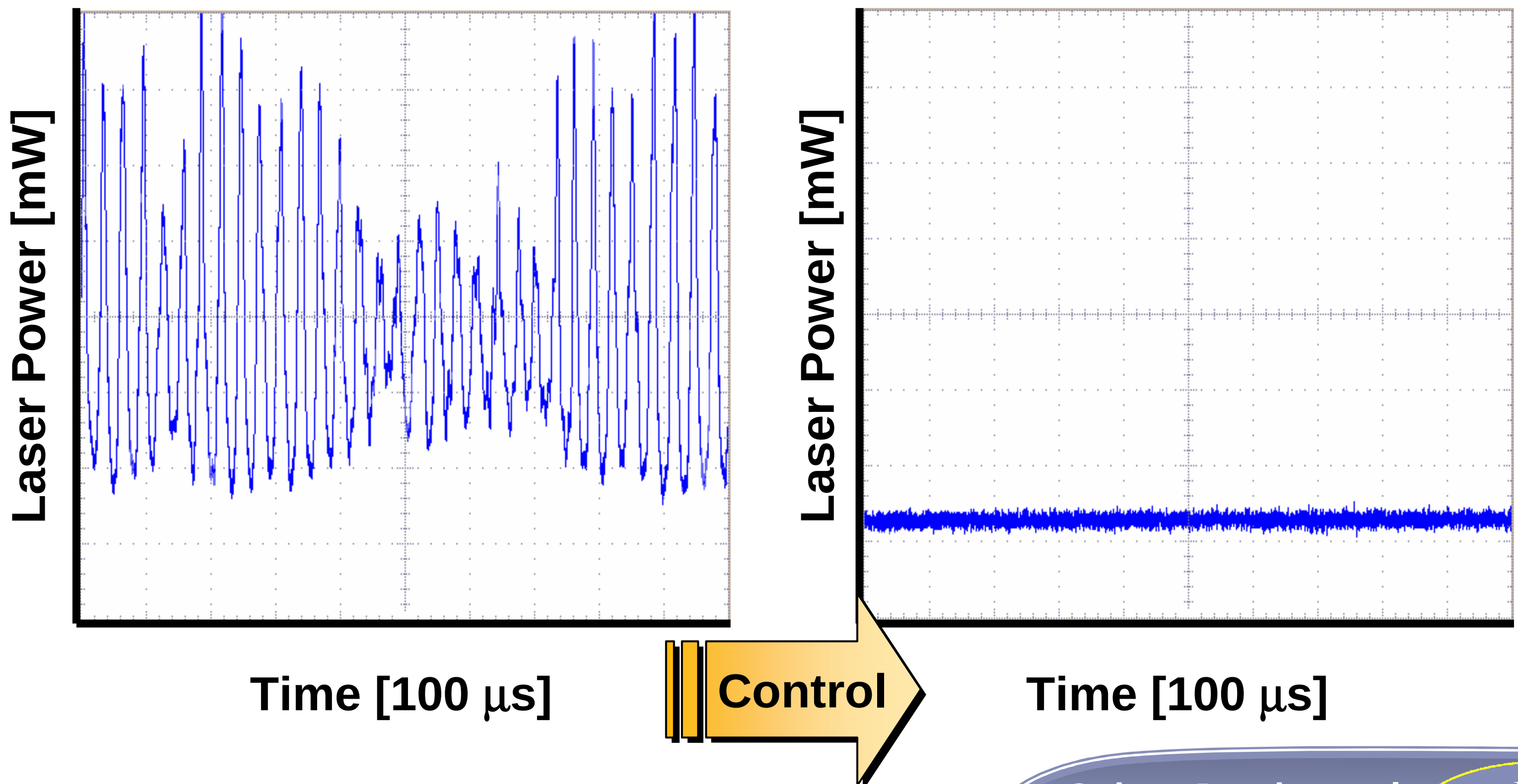
***Q*-switch Loss**

Low-power Stabilized YAG laser



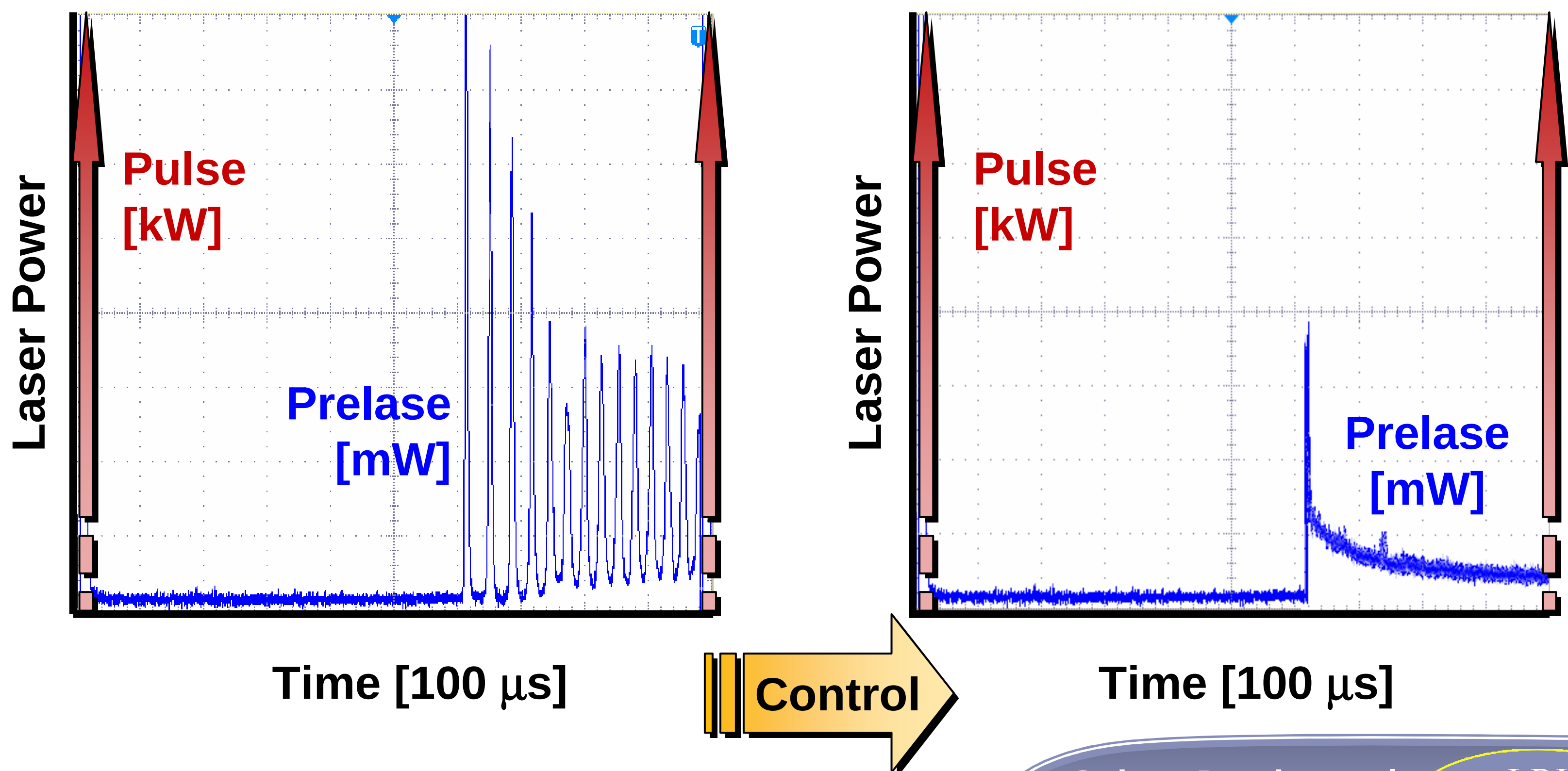
Continuous Wave Results

- As a runner up to pulsed testing
- At low power, signal consists mostly out of noise
- Suppression of noise by factor of 20



Pulsed Results

- Reduced timing jitter 13% → < 1% @ 5kHz (uncontrolled 87%)
- Reduced amplitude jitter 5% → < 1% @ 5kHz (uncontrolled 21%)
- Successful prelase damping allowing higher PRR



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