Weaving Undergraduate Research into the Laboratory Curriculum

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A variety of student independent study projects have been modified and woven into laboratory curriculum.

Straightforward commercial hardware and software integration lead to some interesting variations of the laboratory activities.

I) Science Workshop interface/software coupled with a soundcard/freeware

→ *<u>Universal</u> Nature of Oscillations*

II) Science Workshop interface/software coupled with a regulated power supply

→ *<u>Generalized</u> Photoeffect*

I) Universal Nature of Oscillations

Mechanical Oscillator

LRC circuit

Universal Nature of Oscillations

The universal nature of harmonically driven oscillations involve what might be assumed to the uninitiated observer as disparate phenomena–

- the translational mechanical oscillator
- the torsional mechanical oscillator
- the series RLC circuit
- the parallel RLC circuit
- the response of dielectric materials to electromagnetic fields (Lorentz model)

Note: natural frequencies range from 10^0 Hz to 10^{16} Hz

1 Hz (mechanical oscillators) ⟷ 10^{16} Hz (optical frequencies)

Universal Nature of Oscillations

The equation of motion of any damped oscillator subject to a harmonic driving force and viscous damping can be modeled with the following differential equation

$$\ddot{\eta} + 2\gamma\,\dot{\eta} + {\omega_0}^2\eta = \alpha\, e^{i\omega t}$$

η --generalized coordinate

γ --damping parameter

ω_0 --is the natural frequency

α --generalized acceleration term

ω --the driving frequency.

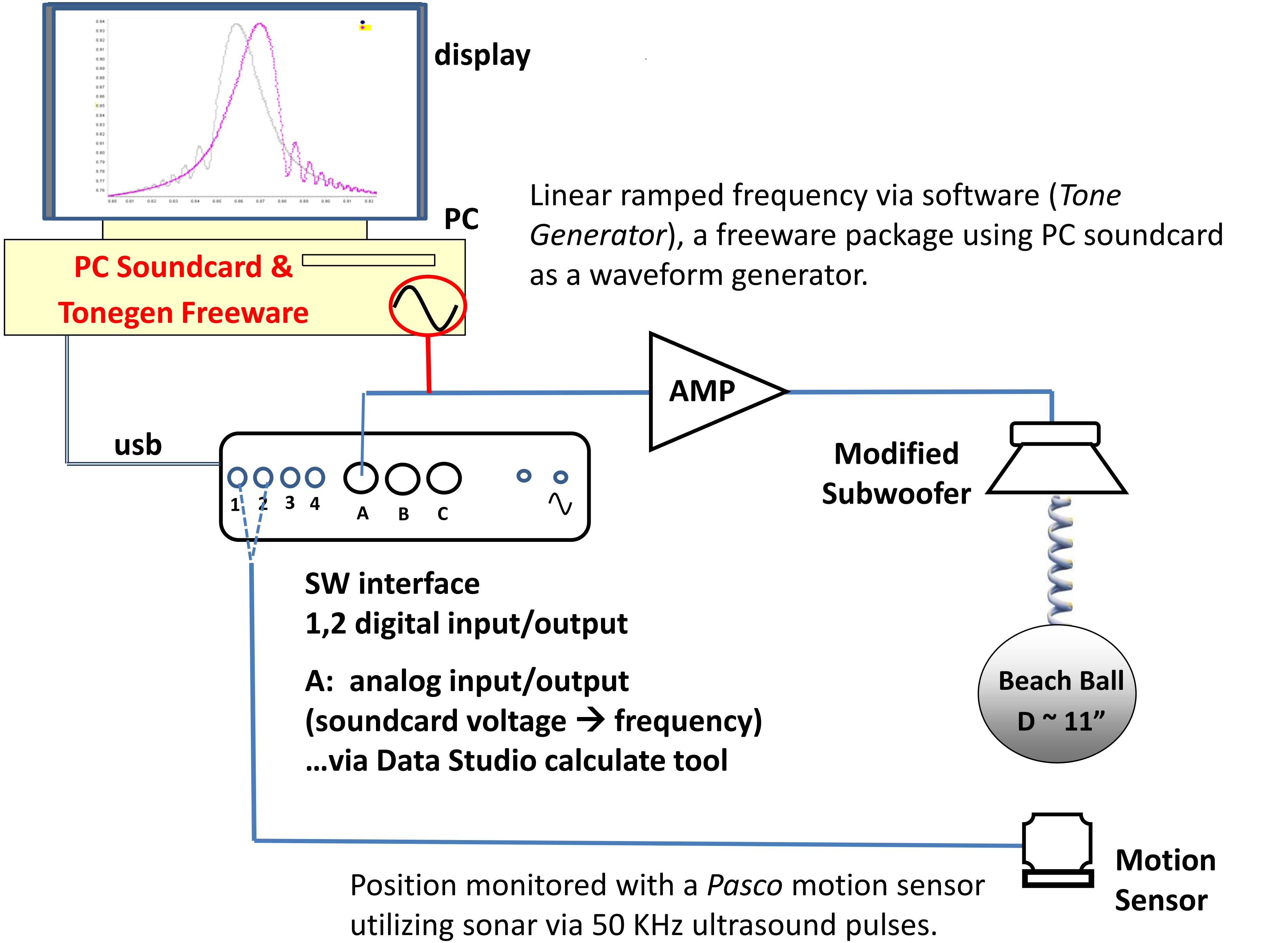
$$\ddot{\eta} + 2\gamma\,\dot{\eta} + {\omega_0}^2\eta = \alpha\, e^{i\omega t}$$

SYSTEM	translational mechanical	torsional mechanical	series RLC	parallel RLC	Lorentz
coordinate: η	position: x	angle: θ	charge: q	voltage: V	position: x
coordinate evolution	velocity:	angular velocity:	current:	voltage:	velocity:
inertia	mass: m	moment of inertia: I	inductance: L	capacitance: C	electron mass: m
restoration	spring const: k	torsion const: μ	elastance: $1/C$	susceptance: $1/L$	restoration const: k
friction	linear friction: b	rotational friction: b	resistance: R	conductance: $1/R$	collisional damping: b
drive term	drive force: $F(t)$	drive torque: $\tau(t)$	drive voltage: $V(t)$	radiative drive: $i(t)$	E-field drive: $eE(t)$
natural frequency	$\omega_0 = \sqrt{k/m}$	$\omega_0 = \sqrt{\mu/I}$	$\omega_0 = \sqrt{1/LC}$	$\omega_0 = \sqrt{1/LC}$	$\omega_0 = \sqrt{k_{eff}/m_e}$

I) Universal Nature of Oscillations

Mechanical Oscillator

LRC circuit


display
PC
PC Soundcard &
Tonegen Freeware
Linear ramped frequency via software (*Tone Generator*), a freeware package using PC soundcard as a waveform generator.
AMP
usb
1
2
3
4
A
B
C
Modified
Subwoofer
SW interface
1,2 digital input/output
A: analog input/output
(soundcard voltage → frequency)
…via Data Studio calculate tool
Beach Ball
D ~ 11”
Motion
Sensor
Position monitored with a *Pasco* motion sensor utilizing sonar via 50 KHz ultrasound pulses.

Discussion:

Investigate the effect of various sweep times on the behavior of the oscillator.

1) What effect does a continuously swept driver frequency have on the motion of the ball as the sweep rate is varied?
2) How fast can one scan through resonance and still obtain the classic (textbook) Lorentzian-like amplitude associated with the pure steady state motion (no distortion or modulation)?
3) What effect does the sweep rate have on the amplitude profile?
4) Does it make any difference if one performs a linearly increasing sweep or a linearly decreasing sweep? If so explain why!

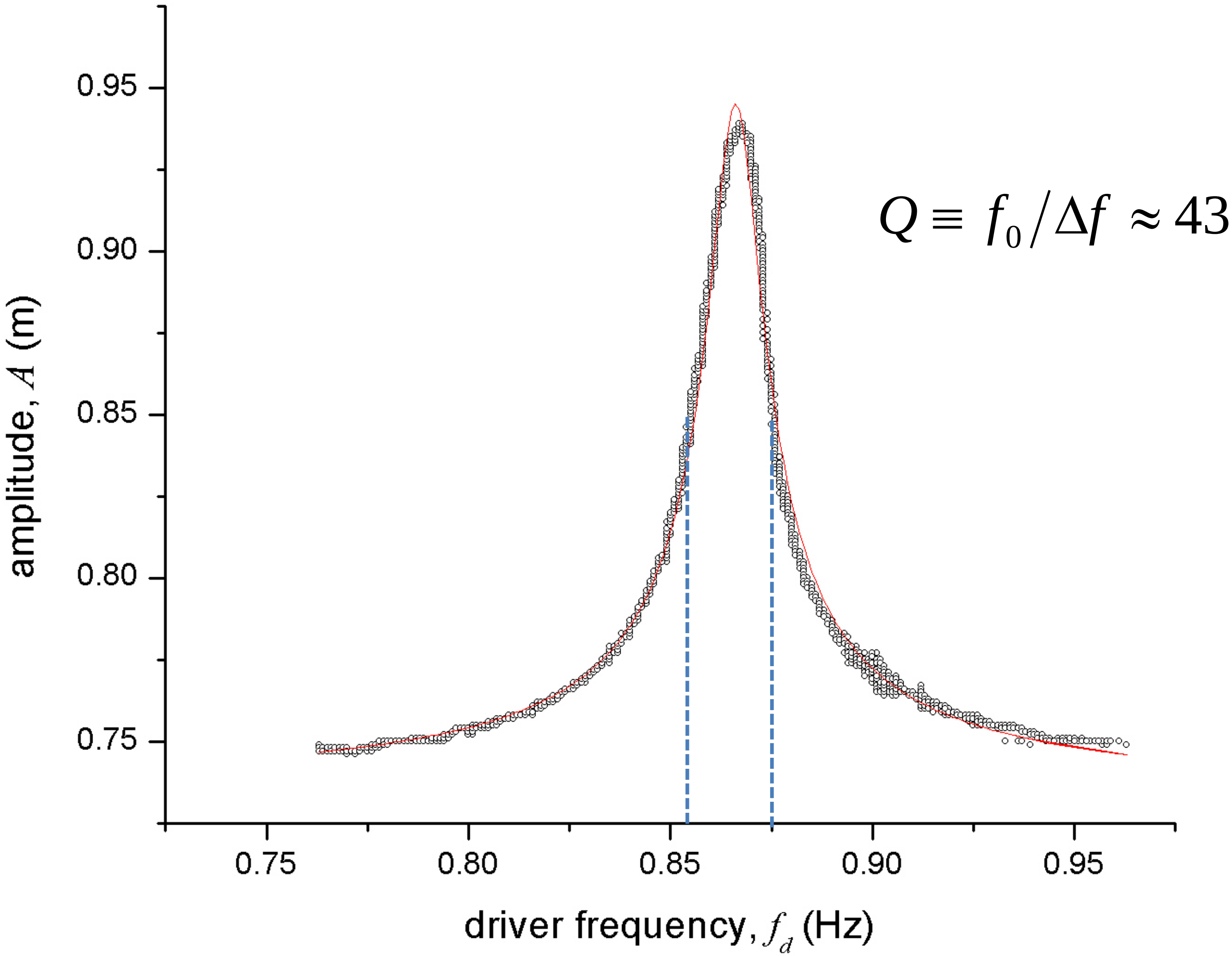
One natural consequence arising from this activity approach is a deeper understanding of how transient behavior effects steady state behavior.

Raw data consists of ball position vs. time

Convert to amplitude vs. frequency plots using Pasco's *Data Studio* software.

Open "mech osc exhibit"

"Textbook" Lorentzian-like distribution requires ~ 2 hour scan time for this system



$$A(f) = A_{offset} + \frac{A}{\sqrt{\left((2\pi f)^2 - (2\pi f_0)^2\right)^2 + 4\gamma^2 (2\pi f)^2}}$$

A_{offset} = distanceof themotion detectorfrom equilibrium

$A_{offset} = 0.732\, m$

$A = F_0/m$

$A = 0.0969\ m/s^2$

$$f_0 = \frac{\omega_0}{2\pi}$$

$f_0 = 0.866\ Hz$

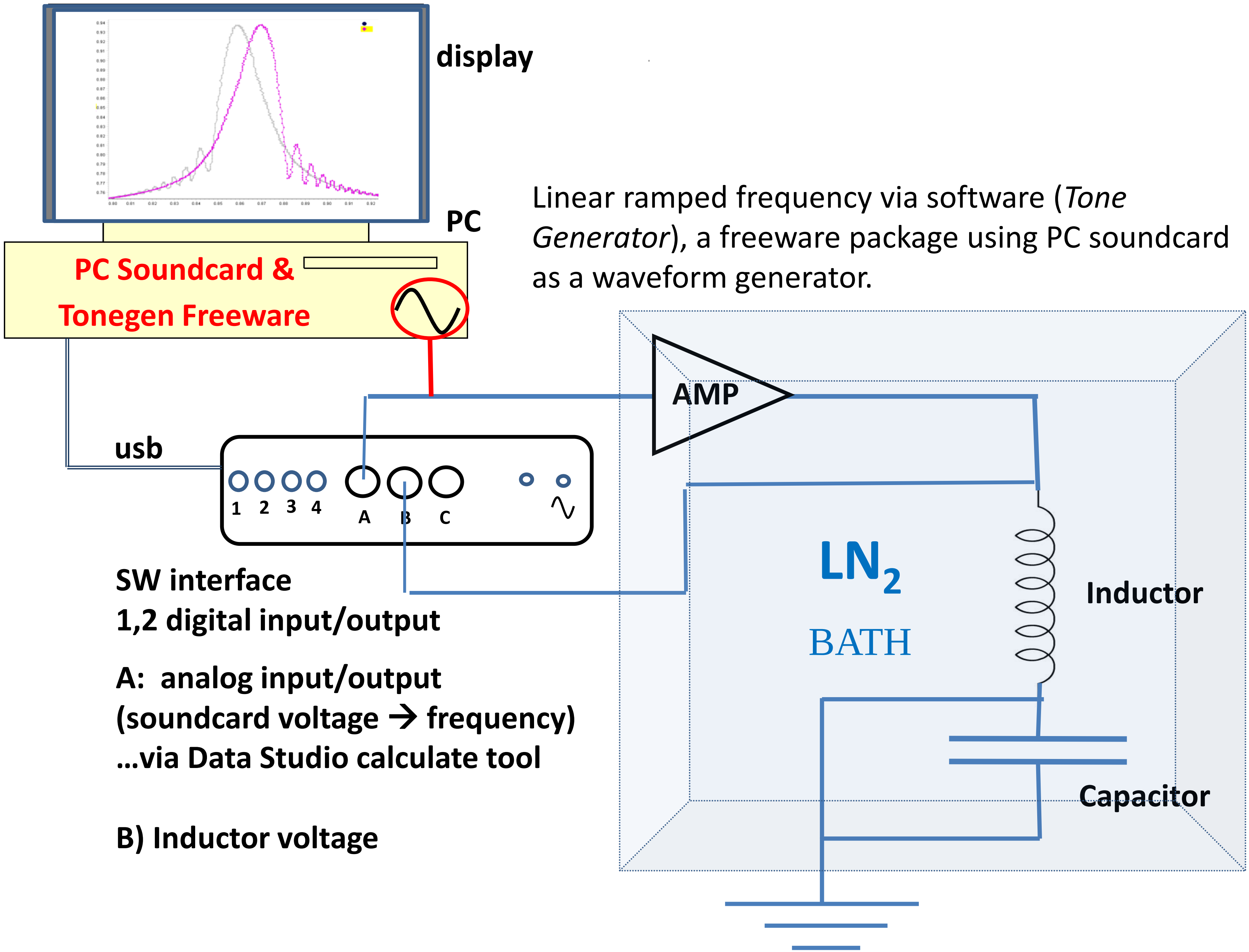
$\gamma = b/2m$

$\gamma = 0.0068\ s^{-1}$

I) Universal Nature of Oscillations

Mechanical Oscillator

LRC circuit


display
PC
PC Soundcard &
Tonegen Freeware
Linear ramped frequency via software (Tone Generator), a freeware package using PC soundcard as a waveform generator.
usb
1
2
3
4
A
B
C
AMP
LN2
BATH
Inductor
Capacitor
SW interface
1,2 digital input/output
A: analog input/output
(soundcard voltage → frequency)
…via Data Studio calculate tool
B) Inductor voltage

Raw data consists of voltage across the inductor vs. time

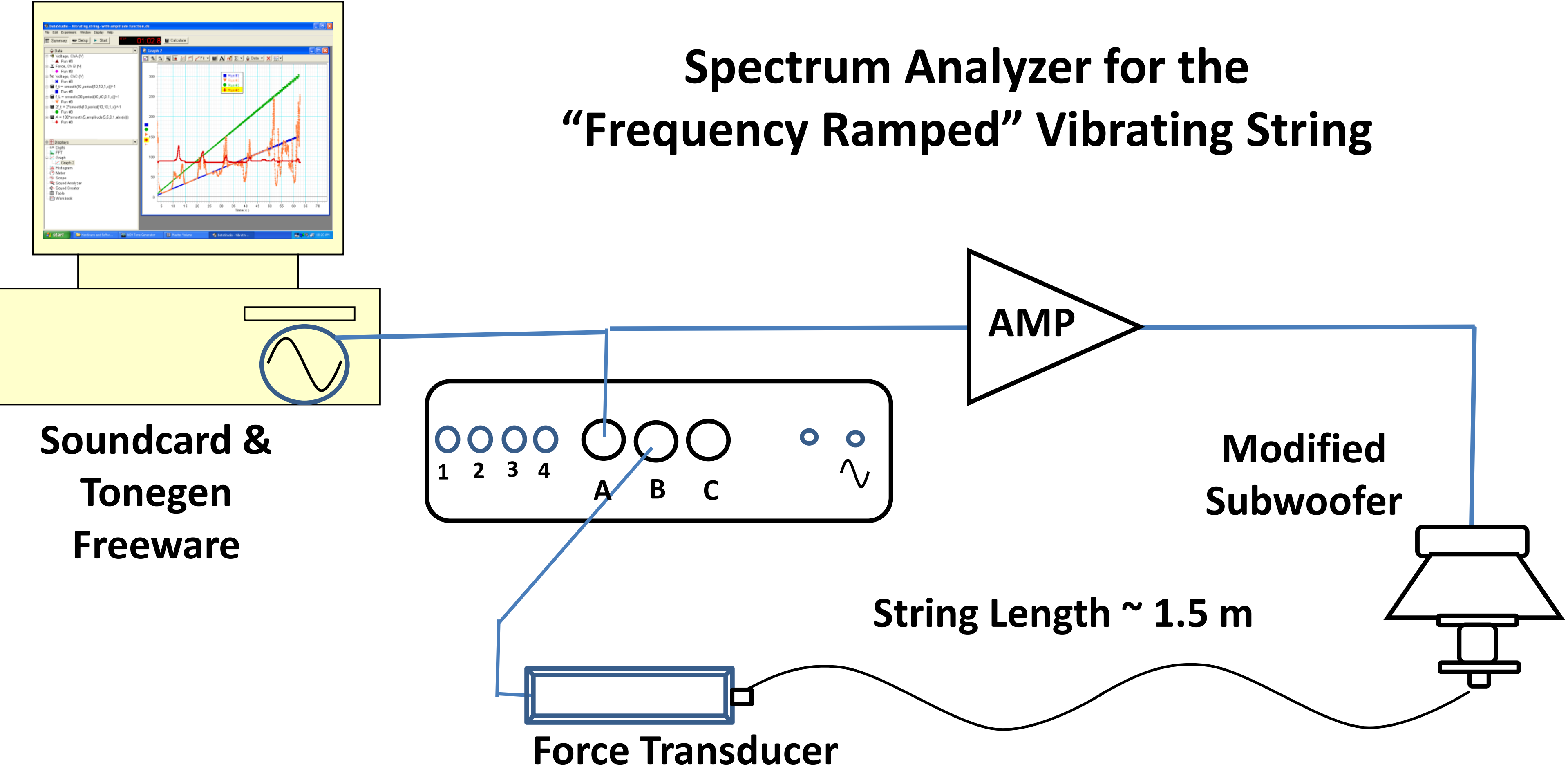
Convert to voltage vs. frequency plots using Pasco's *Data Studio* software.

Open "LRC exhibit"

…More Oscillations

The Vibrating String

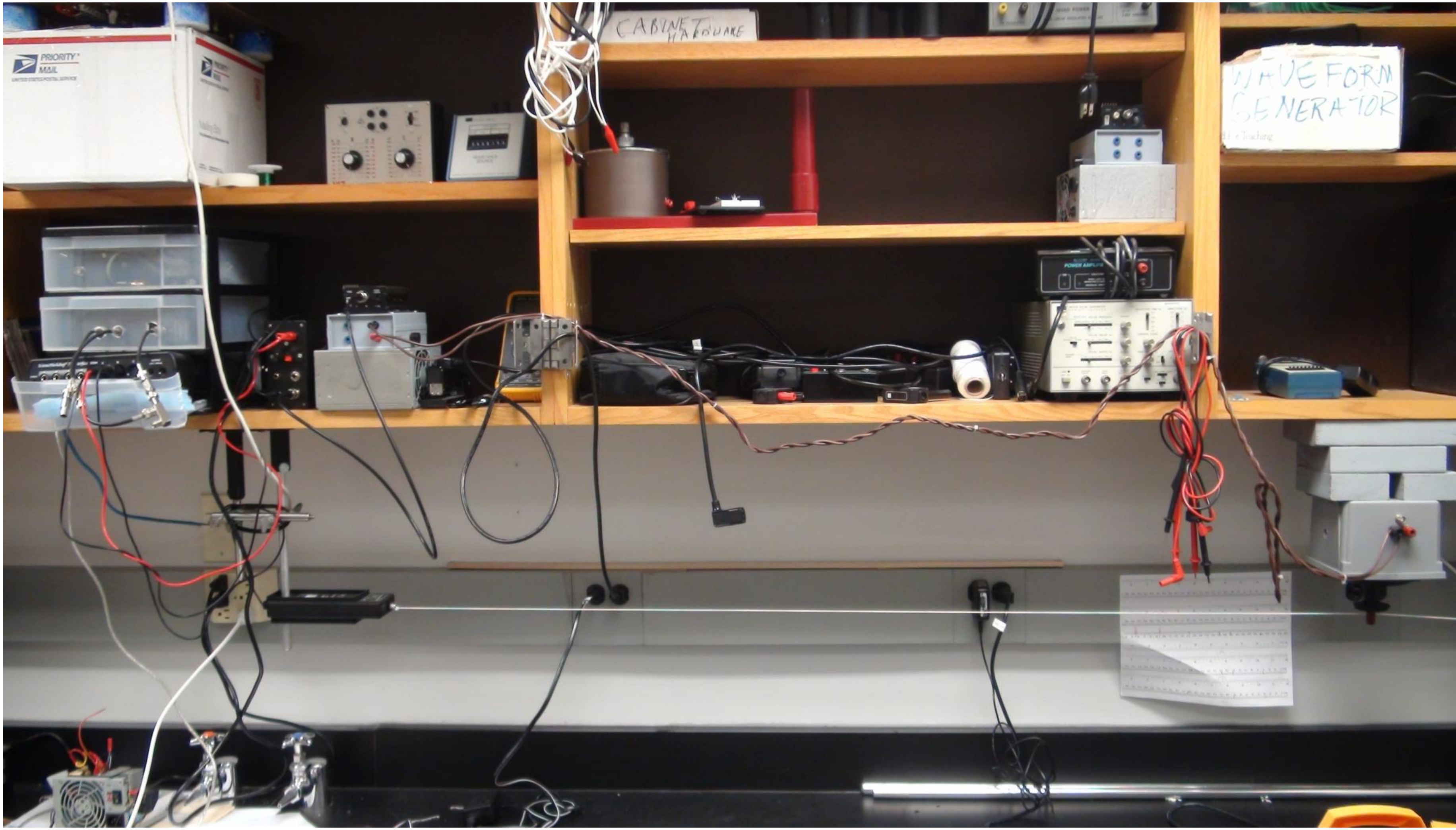
Spectrum Analyzer for the “Frequency Ramped” Vibrating String



A: analog input/output
(soundcard voltage → frequency)

B: analog input/output
(force transducer voltage & frequency)

Data Studio calculate tool


PRIORITY MAIL
CABINET
WAVE FORM GENERATOR

Raw data consists of strain gauge voltage (force probe) vs. time

Convert to voltage vs. frequency plots using Pasco's *Data Studio* software.

Open "string exhibit"

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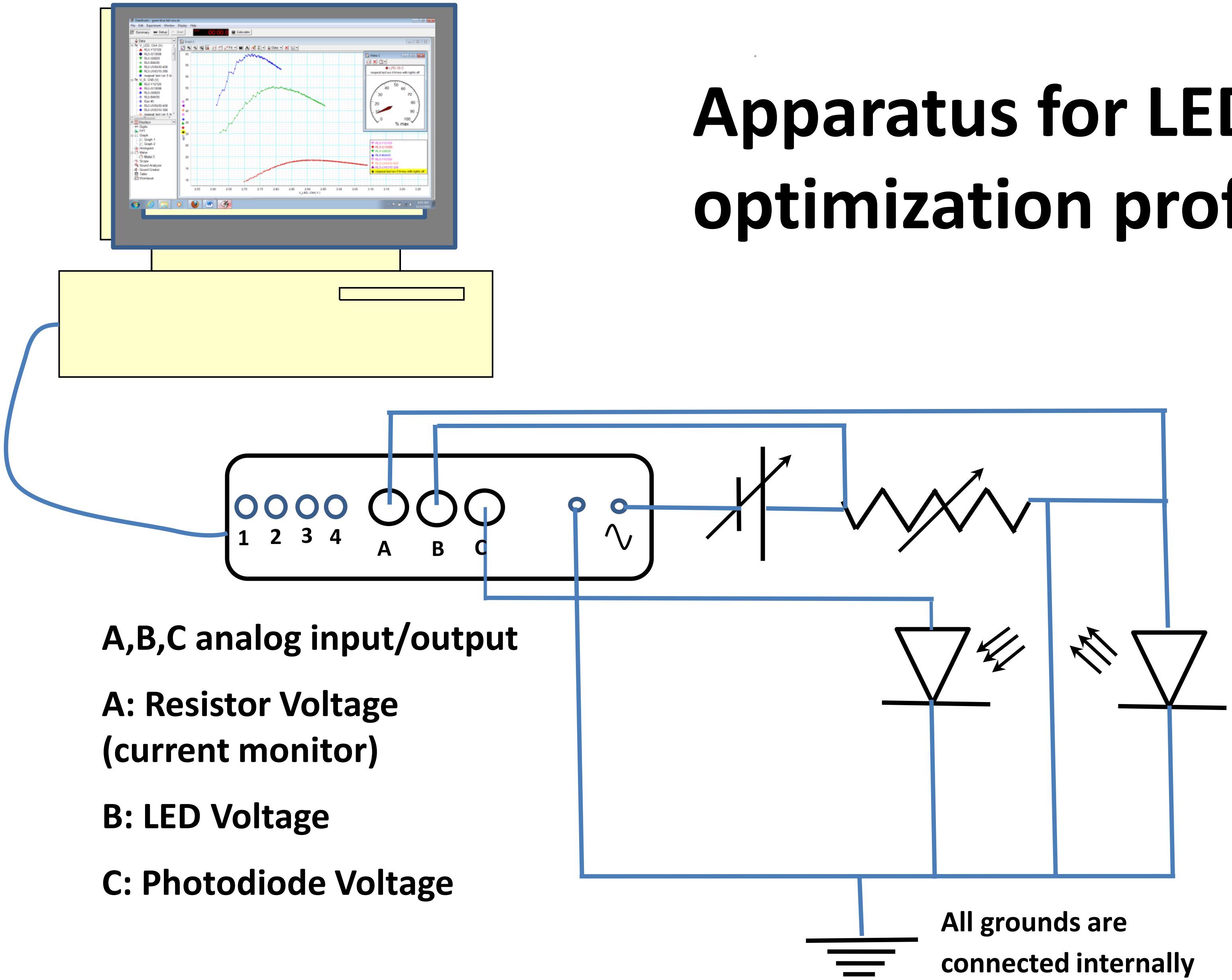
→ *<u>Universal</u> Nature of Oscillations*

II) Science Workshop interface/software coupled with a regulated power supply

→ *<u>Generalized</u> Photoeffect*

This work represents some simple yet novel measurements, summarizes the optimization scheme in defining the effective band gap potential, and makes two predictions – one of which will come to bear over the next five years.

Apparatus for LED optimization profiles



A,B,C analog input/output

A: Resistor Voltage (current monitor)

B: LED Voltage

C: Photodiode Voltage

All grounds are connected internally through the Pasco 750 interface


FUNCTION GENERATOR GFG-8219A
FUNCTION GENERATOR GFG-8219A
ScienceWorkshop® 750 Interface
DIGITAL CHANNELS
OUTPUT
Rx1
Rx10
Rx100
GINSBERG
RSR DC POWER SUPPLY HY3003
CURRENT
VOLTAGE

Raw data consists of

A) resistor current vs. time

→ actually voltage (*I* =*V*/*R*)

B) LED Voltage vs. time

C) PD Voltage vs. time

Convert to (PD Voltage)/(LED Voltage x Resistor Voltage) vs. LED Voltage Pasco's *Data Studio* software.

Define the Voltage via optimization:

$$\eta = \frac{P_\gamma}{P_{LED}} = \frac{\kappa N_\gamma}{I_{LED} V_{LED}}$$

Open "LED exhibit"

Part Number	wavelength	FWHM	U_gamma	V_P	Error Sum	Agree?
RL5-R2415	649	22	1.910	1.87	3.780	Y
RL5-R12120	629	19	1.971	1.96	3.931	Y
RL5-O5015	608	18	2.039	1.866	3.905	N
RL5-Y5615	594	15	2.087	1.96	4.047	N
RL5-Y10008	590	18	2.101	2.09	4.191	Y
RL5-Y12120	589	15	2.105	2.19	4.295	Y
RL5-G8020	531	31	2.335	2.8	5.135	N
RL5-G13008	528	30	2.348	2.91	5.258	N
RL5-B4630	470	29	2.638	2.71	5.348	Y
RL5-UV0430-400	402	16	3.084	3.21	6.294	Y
RL5-UV0315-380	383	11	3.237	3.23	6.467	Y

Is Bulk Quantum Behavior Exhibited in LED Optimization?

→Patterns emerge in the characterization of LED efficiencies spanning the spectrum from near ultraviolet, across the visible and into the near infrared.

Is Bulk Quantum Behavior Exhibited in LED Optimization?

→Direct use of the simplest electro-optical quantum relation, $eV = hf$, to characterize such LEDs is typically only alluded to in the technical literature as a rule of thumb.

Is Bulk Quantum Behavior Exhibited in LED Optimization?

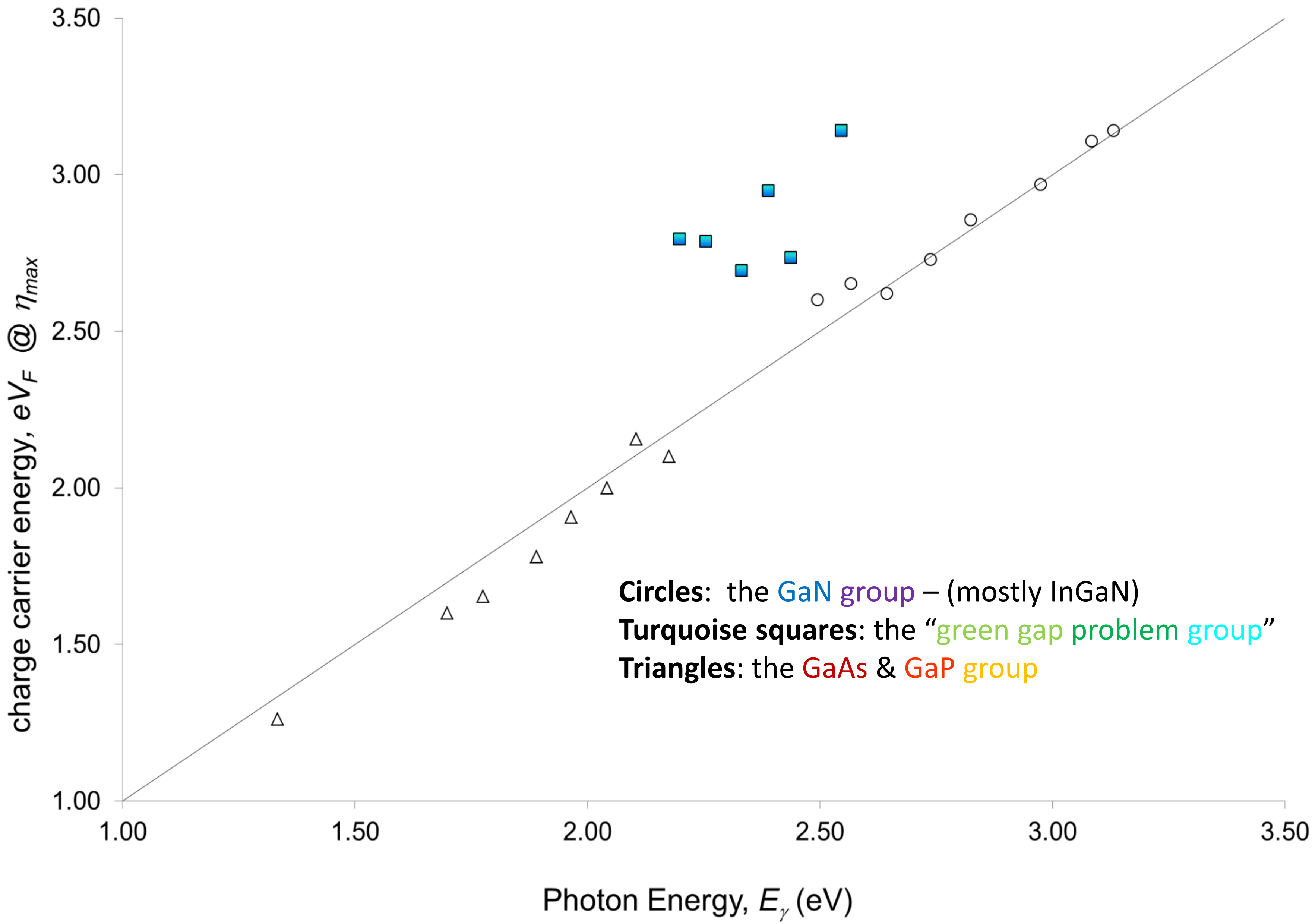
→ In spite of serious objections concerning the theoretical validity of the relation to accurately characterize LEDs, it appears that an effective band gap potential, *V*, in this quantum relation may be defined as the voltage at which the LED is "optimized".

Is Bulk Quantum Behavior Exhibited in LED Optimization?

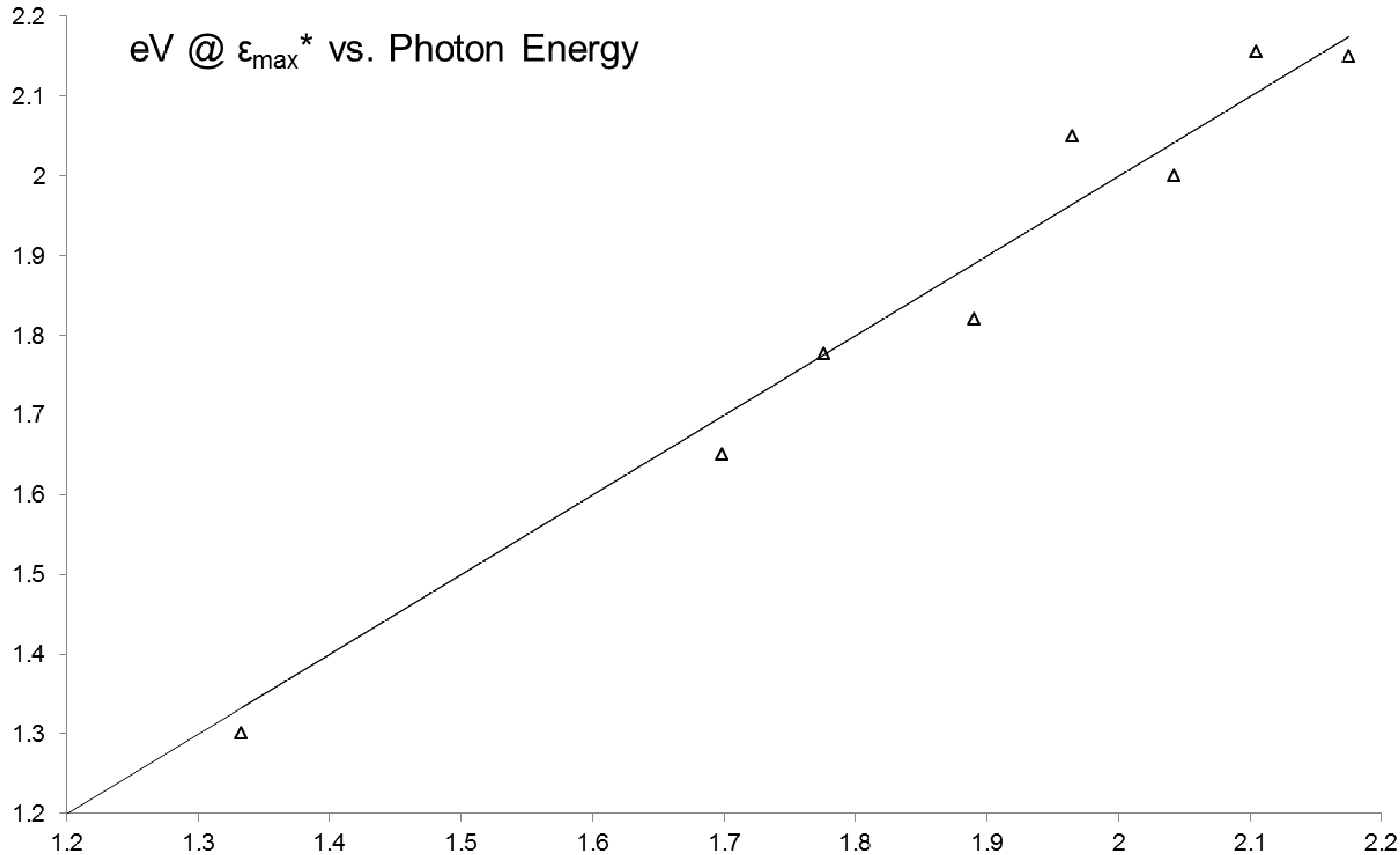
→ PREDICTIONS

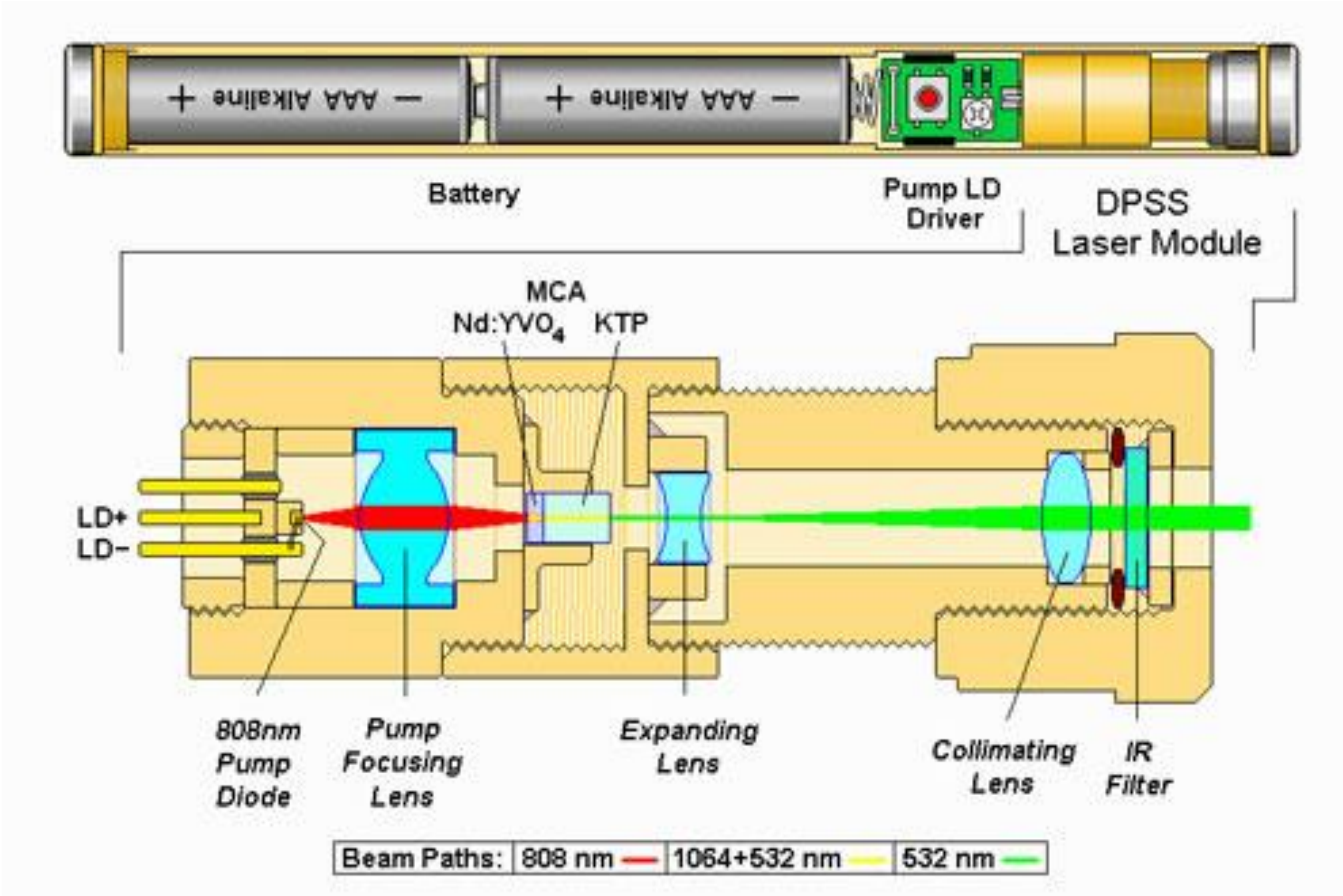
1) All things considered, any LED which does fall satisfy this scheme will last longer than those that do not.

2) The Green Gap will eventually "behave" as the LED industry tweaks the doping ratios based on emerging direct gap lasers come to market



charge carrier energy, eV_F @ η_{max}
3.50
3.00
2.50
2.00
1.50
1.00
1.00
1.50
2.00
2.50
3.00
3.50
Photon Energy, E_γ (eV)
Circles: the GaN group – (mostly InGaN)
Turquoise squares: the “green gap problem group”
Triangles: the GaAs & GaP group


eV @ ε_{max}* vs. Photon Energy
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
2.1
2.2



Neodymium-doped yttrium orthovanadate

Potassium Titanium Oxide Phosphate (KTiOPO4), or *KTP*

Major Collaborators

Mechanical Oscillator

Don Maloy
PHY 4200

Austin Griffin
“hanging around”

Major Collaborators

STRING

Nick Pilot
PHY 2210

Major Collaborators

LEDs: Generalized Photoeffect

Billy Dudding
PHY 4200

Austin Griffin
still "hanging around"

Acknowledgements

UNCP - Department of Chemistry and Physics

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THANK YOU !