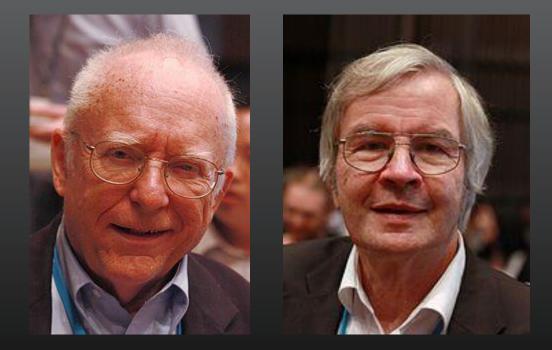
STABILIZING AN OPTICAL COMB WITH A DIGITAL PHASE LOCK LOOP

ANTHONY OCEGUERA



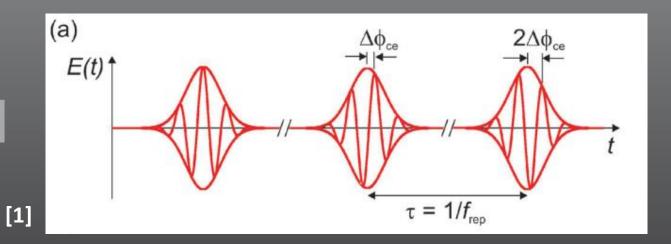
NOBEL PRIZE AWARDED FOR DEVELOPMENT OF OPTICAL COMBS

- DEVELOPED BY JOHN HALL AND THEODORE HANSCH (AWARDED NOBEL PRIZE IN 2005)
- OPTICAL COMBS ALLOW FOR A DIRECT LINK BETWEEN RADIO FREQUENCIES AND OPTICAL FREQUENCIES
- CAN BE USED IN PRECSION OPTICAL METROLOGY AND DUAL COMB SPECTROSCOPY
- MORE PRECSICE GPS AND OPTICAL CLOCK TECHNOLOGY



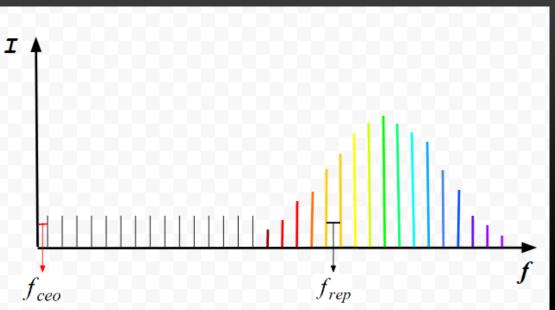
JOHN HALL

THEODORE HANSCH

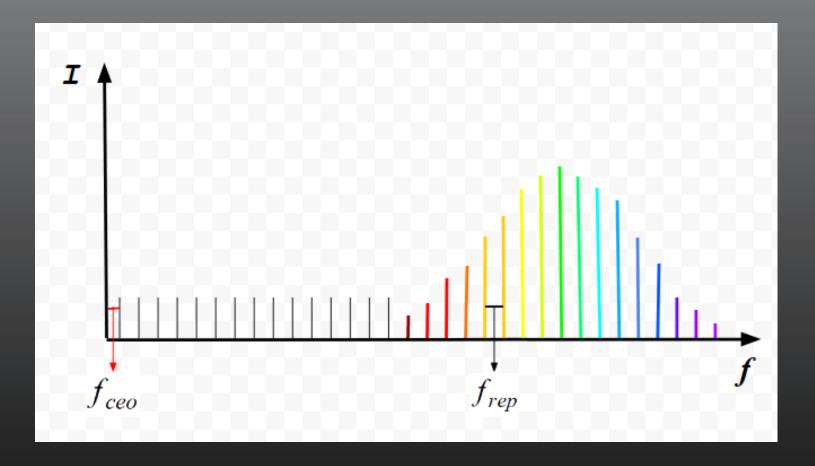


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FOURIER TRANSFORM
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OPTICAL COMB



AN OPTICAL COMB IS THE SPECTRAL CONTENT OF A PULSE WAVE TRAIN



$$f_n = n \cdot f_{rep} + f_{ceo}$$

OPTICAL COMB EQUATION



...........

<u>_____</u>

.....

Hardware Overview

Fast analog inputs (2 ch. @ 125 MS/s, 14 bits)

Fast analog outputs (2 ch. @ 125 MS/s, 14 bits)

Digital sig. extension connector 16 FPGA GPIOs

Remote access (Ethernet 1Gb/s)

USB port (USB OTG) Console (micro USB)

Power (micro USB)

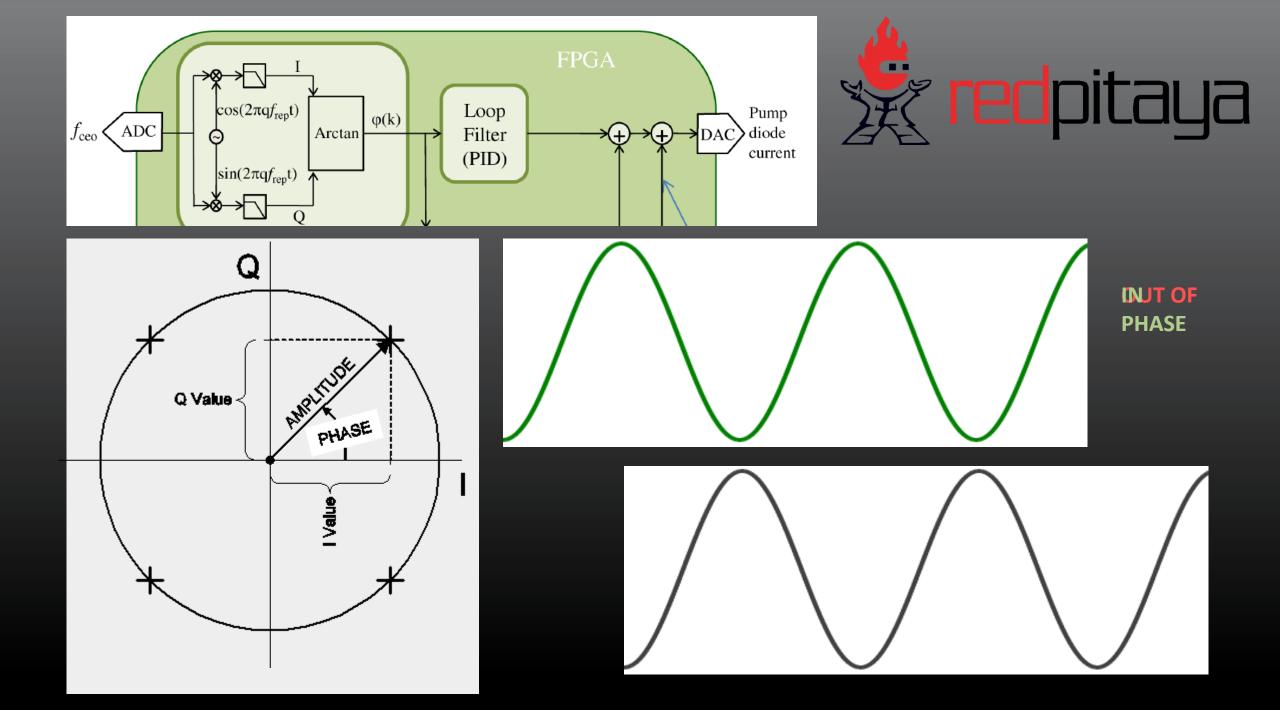
Analog Sig extension connector

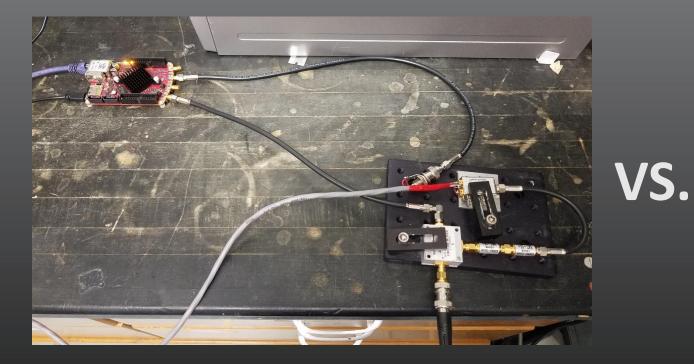
Low speed ADCs (4 ch. @ 100 kS/s, 12 bits) Low speed DACs (4 ch. @ 100 kS/s, 12 bits)

Dual core ARM Cortex A9+ FPGA (Zyng SoC)

..... Daisy chain connector

System & FPGA image (micro SD card)

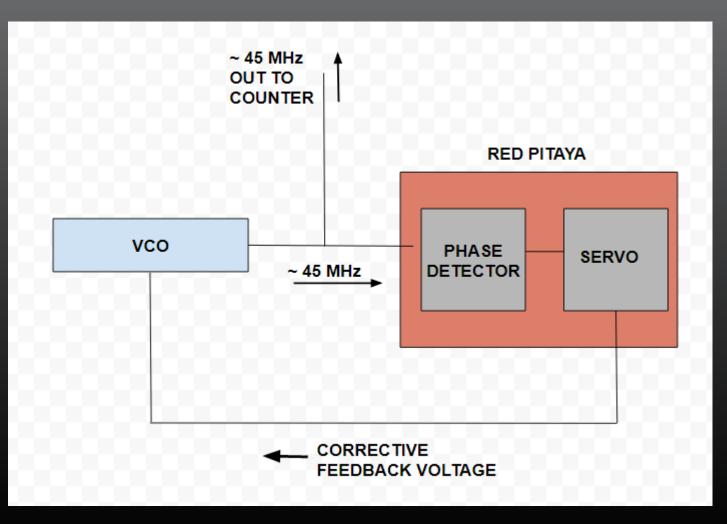


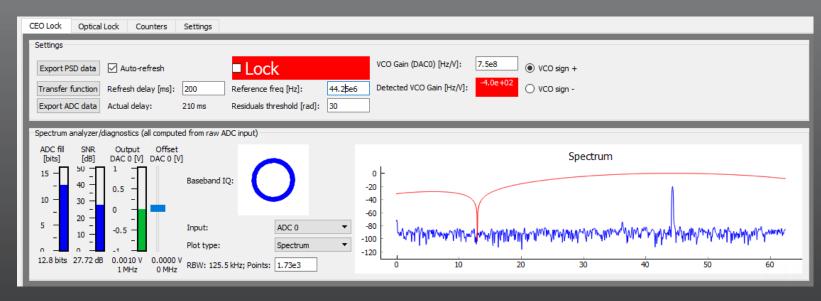


- COMPACT
- TENS OF THOUSANDS OF DOLLARS CHEAPER
- MUCH LESS POWER COMPSUMPTION
- MOBILE AND EASILY DEPLOYABLE
- CAN BE CONTROLLED REMOTELY

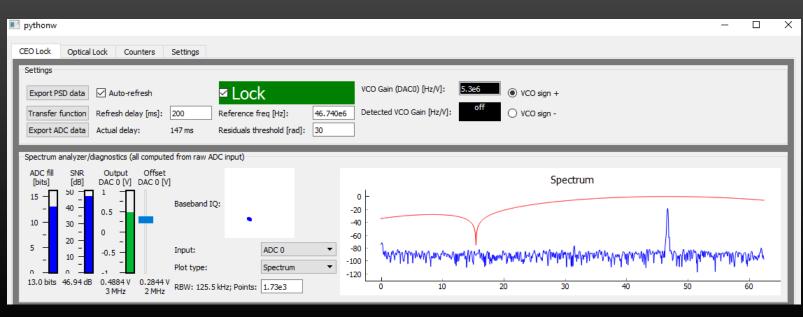


LOCKING A VOLTAGE CONTROLLED OSCILLATOR WITH RED PITAYA





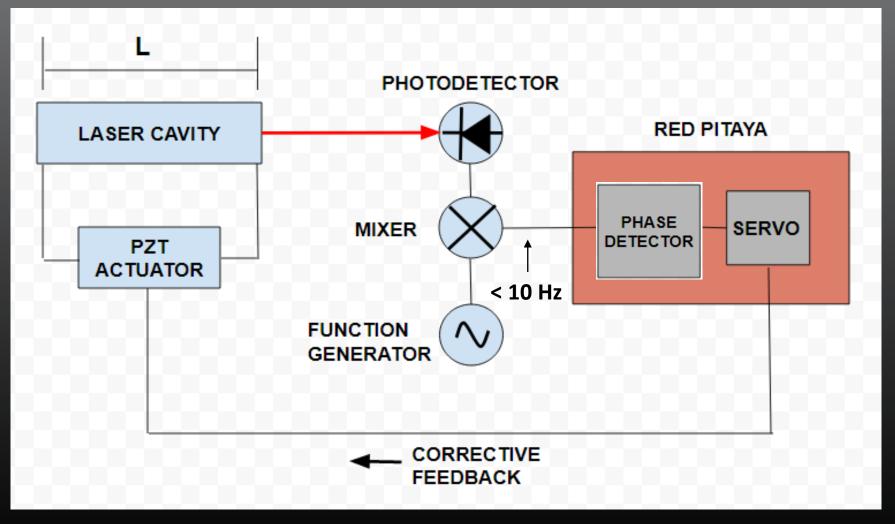




PRE-LOCK ERROR: <u>+</u> 100 Hz

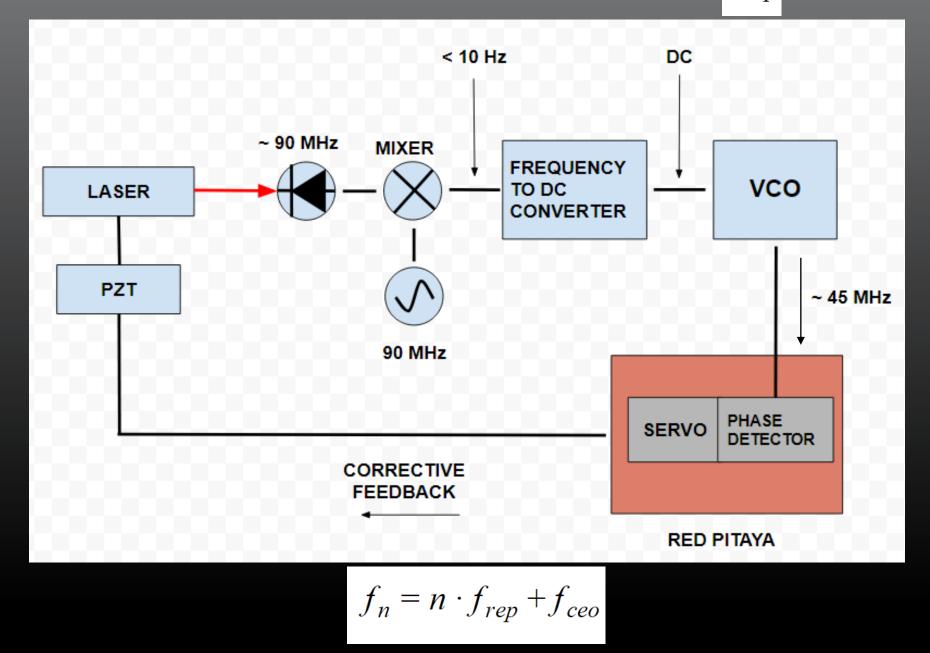
POST-LOCK ERROR: \pm .01 Hz

SCHEMATIC FOR REPETITION FREQUENCY LOCK f_{rep}



$$f_n = n \cdot f_{rep} + f_{ceo}$$

SCHEMATIC FOR REPETITION FREQUENCY LOCK f_{rep}

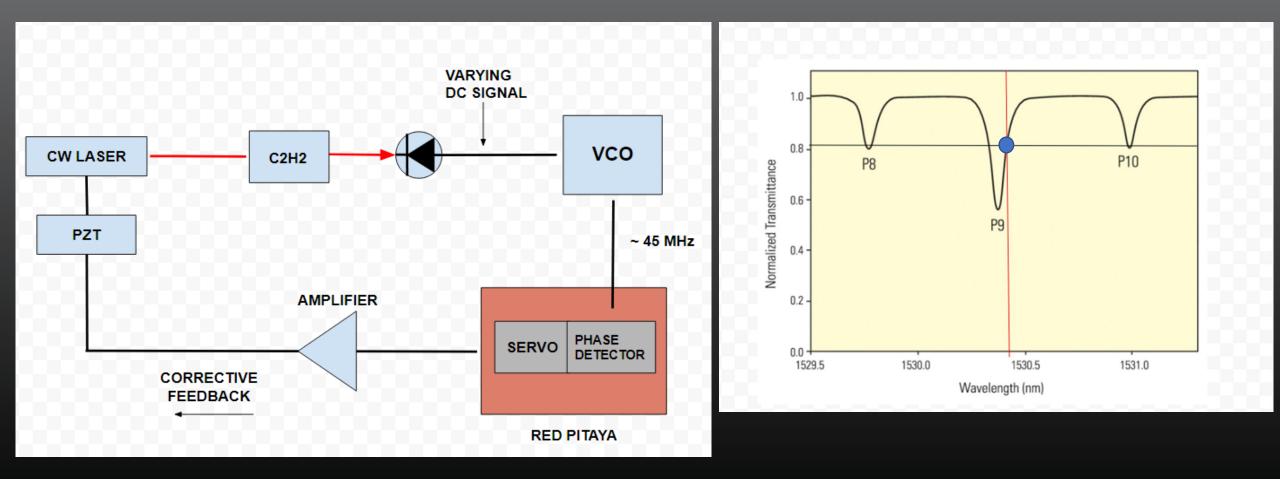


RESULTS OF PULSE REPETITION LOCK

CEO Lock Optical Lock Counters Settings	
Settings Export PSD data Image: Auto-refresh Transfer function Refresh delay [ms]: 200 Export ADC data Actual delay: 190 ms	Image: Construction of the second state of the second s
Spectrum analyzer/diagnostics (all computed from raw ADC fill SNR Output Offset [bits] [dB] DAC 1 [V] DAC 1 [V] 15 - - 0 10 - 0 - - - 0 - - - 0 - - - 0 - - - 0 - - - 0 - - - 0 - - - 0 - - - 0 - - - 0 - - - 0 - - - - - - - - - - - - - - - - - - - - - - - - -	ADC 1

PRE-LOCK ERROR: \pm 1 Hz POST-LOCK ERROR: \pm 0.1 Hz

SCHEMATIC FOR OPTICAL LOCK



SOURCES:

[1] Chem. Soc. Rev., 2012, 41, 5174–5184

[2] Brian Washburn. *Agro-combs: A mid-infrared dual-comb spectrometer for the detection of agriculturally significant gases*. (2017) Kansas State University

[3] National Physical Laboratory. *Self-Referencing of an Optical Frequency Comb*. (2007) Retrieved from http://www.npl.co.uk/science-technology/time-frequency/optical-frequency-standards-and-metrology/research/self-referencing-of-an-optical-frequency-comb

[4] Coddington. Newbury. Swann. *Dual Comb Spectroscopy* (April 14th, 2016) Optica. Vol 3. No 4.

[5] Coddington. Newbury. Swann. *Coherent Multiheterodyne Spectroscopy Using Stabilized Optical Frequency Combs* (January 2nd, 2008)

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