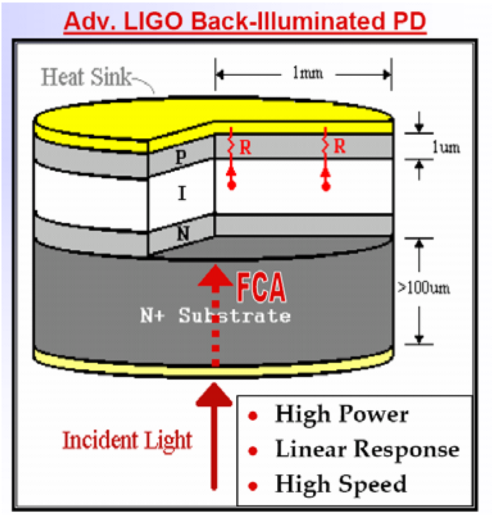
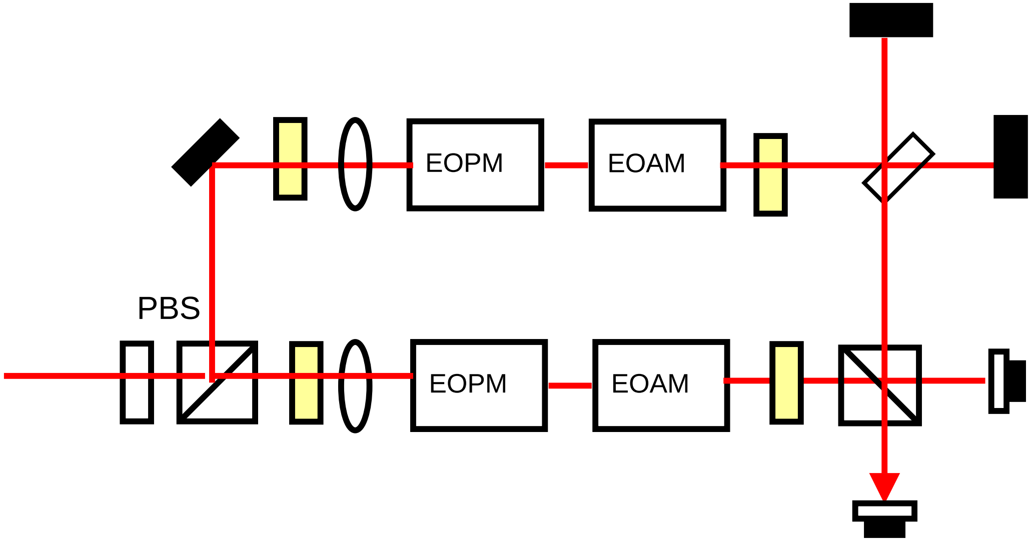
LIGO Photodiode Development and Optical Platform for LIGO Photodetectors Testing





Ke-Xun Sun

Photodiodes --- with Rana Adhikari, Peter Fritschel, Osamu Miyakawa, Allan Weinstein, David Jackrel, Brian Lantz

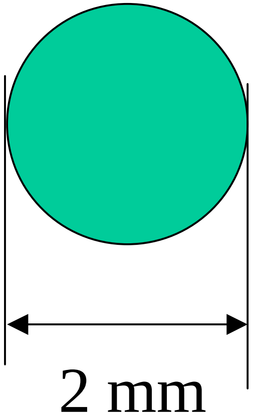
Optical Platform --- with Vern Sandberg, Fred Raab, Dick Gustafson

LSC March Meeting

LIGO Hanford Observatory, March 22, 2006

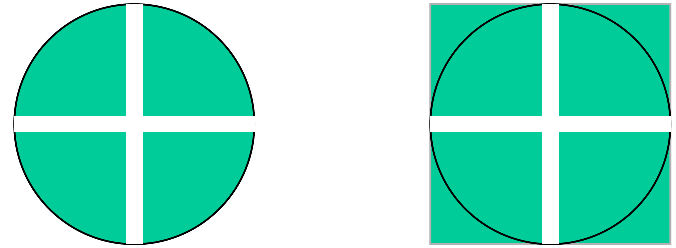
RF Singlet Detector for LIGO+ and Adv. LIGO

- Material: InGaAs based family
- Pattern: Single element
- Diameter > 2 mm
- Frequency response: ~100 MHz
- Packaging: rf operable
- Cooling: Possible TEC
- Optical power: ~1 W
- Quantum efficiency target: 70%

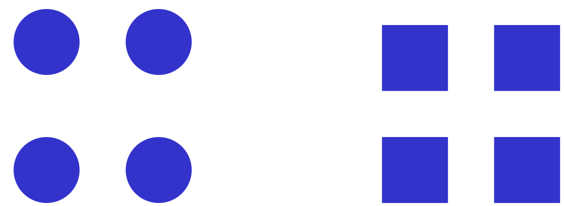


RF Quad Detectors for LIGO+ and Advanced LIGO

- Material: InGaAs based family
- Pattern: Quad (see options right)
- Gap size > 100 μm
- Active receiving area: 1 cm^2 span
- Frequency response: >100 MHz
- Cross talk: 6 dB Better than minimum SNR
  - Neighbor: -20dB @ 100 MHz
  - Diagonal: -23 dB @ 100 MHz
- Packaging: Multi pin rf operable
- Optical power: ~100 mW total
- Quantum efficiency target: 70%
- Other ideas (see right)

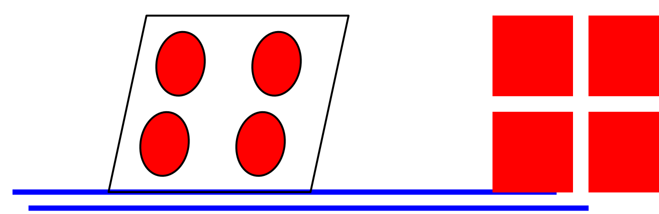


Large gap quad photodiodes



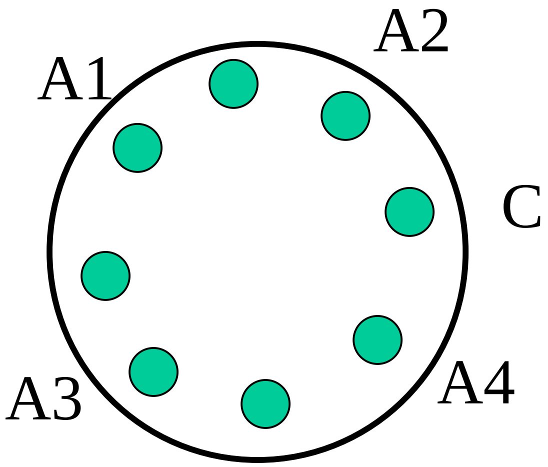
Arrayed single detectors

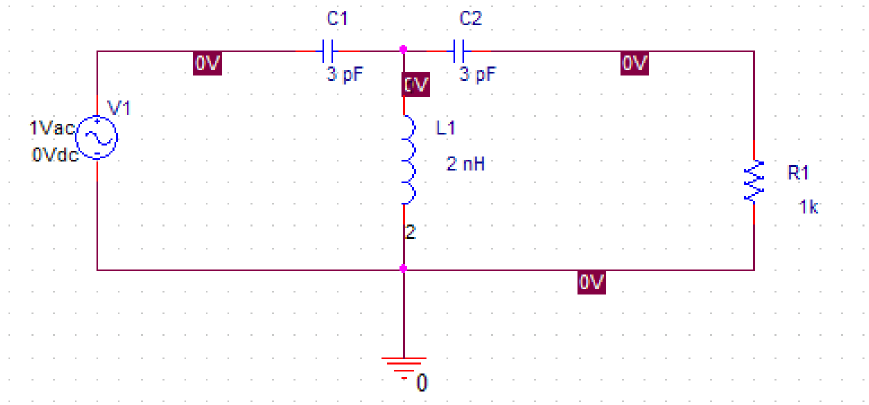
Use with lens arrays (commercially available)



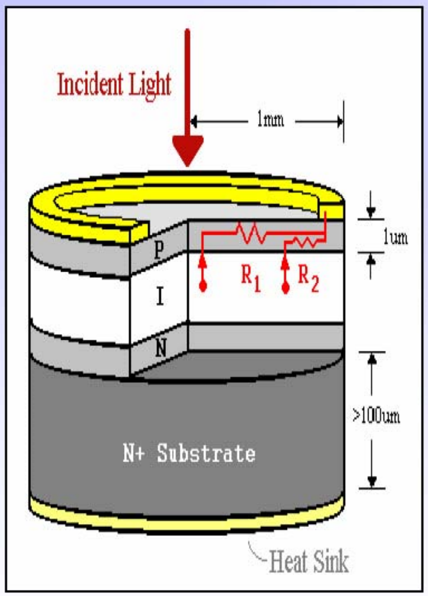
Commercial InGaAs Quad Photodiodes

- Hamamatsu
  - 6849-01
    - 1 mm, 80 MHz
  - 6849
    - 2 mm, 30 MHz
  - Cross coupling via the single cathode pin connection



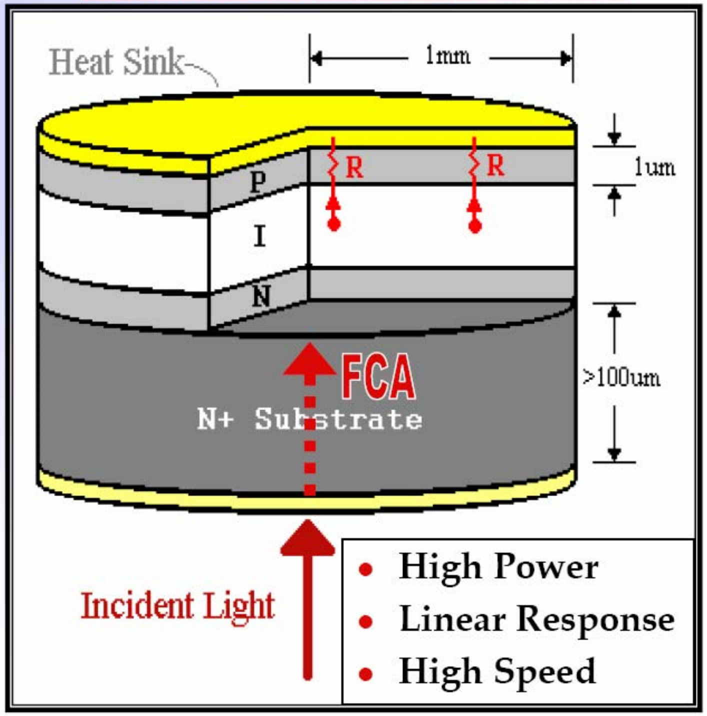


Back Illuminated Photodiodes for High Power Optical Detection



Conventional PD

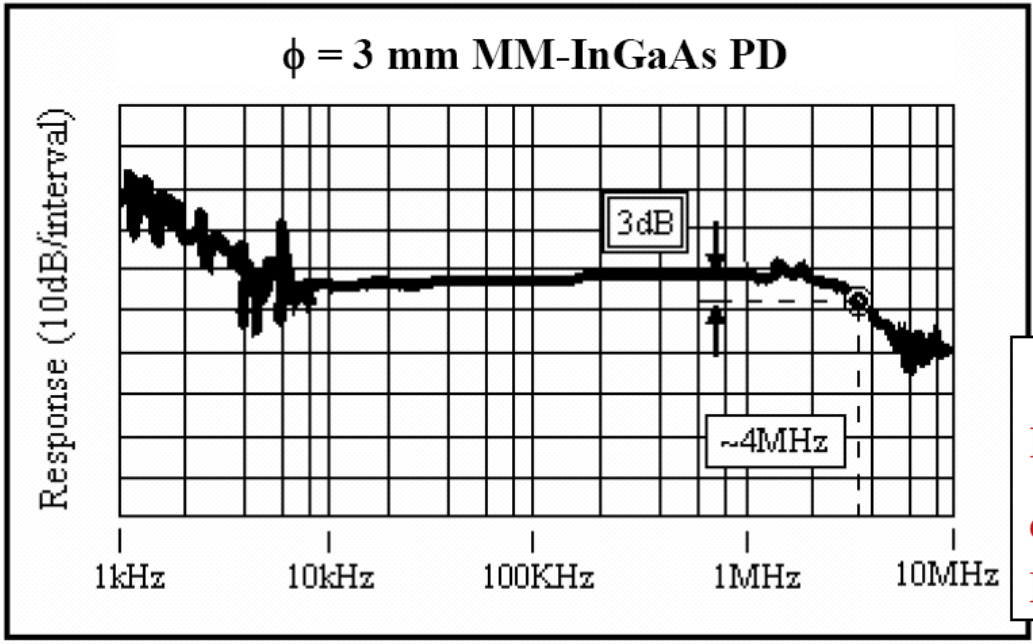
Adv. LIGO Back-Illuminated PD



- "Flip over" to facilitate heat dissipation
- Improved transmittance in the "new front"
- Power level raised
- Need device packaging
- Need RF packaging
- Need systematic testing

Probe Testing Results

The new 2006 strategy: Packaging and testing needs to be improved for high frequency applications



BW ~ 1/RC

BW > 200 MHz

ϕ = 400 μm

P_{sat} ~ 10 mW

AdLIGO PD Specifications:

3-dB Bandwidth	Sat. Power
DC-Scheme: 100 kHz	30 – 100 mW
RF-Scheme: 200 MHz	

AdLIGO RF-Readout Challenging for PDs!

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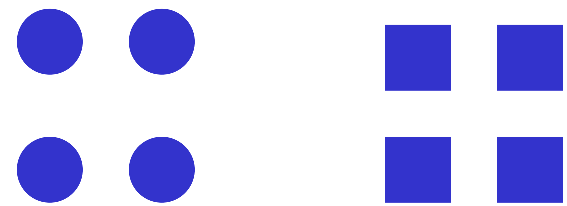
Data shown from D. Jackrel LSC 2005

Detector Work at Stanford

- Catalog existing chips from David
- Ordered 30 InGaAs chips
- Negotiating wire bonding
- RF packaging comparison
- External resonant elements
- Structure design to allow TEC cooling
- Look for a grad student
- Or an interactive commercial sensor

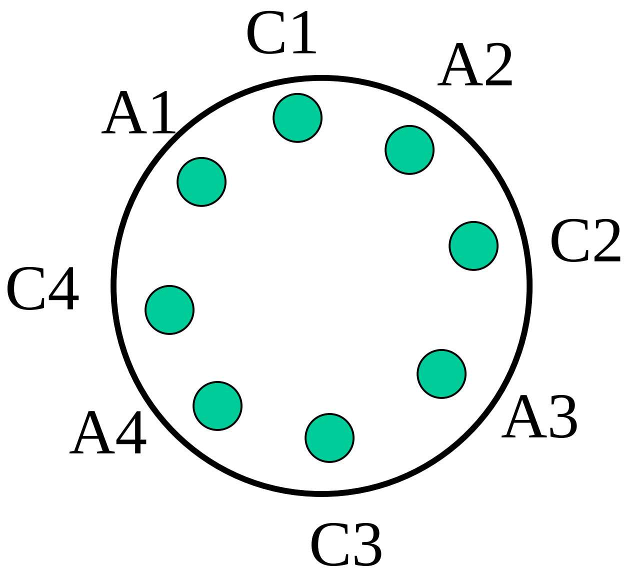
- (Commercial products?)

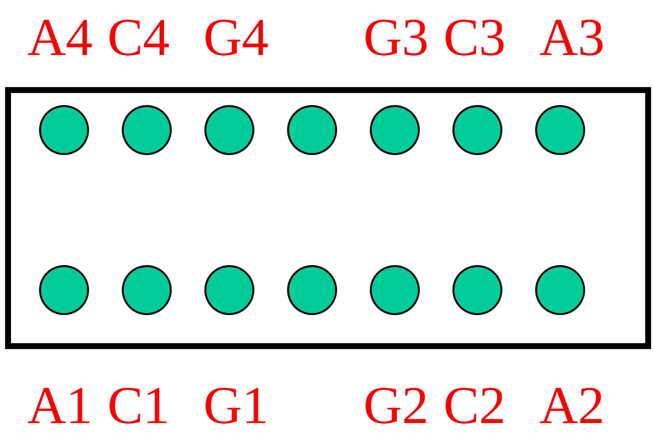


Verify the design first

RF Packaging of Quad Detector Options

- Use separate cathode pins
- Add grounding ring and grounding for
  - Better isolation
  - External resonant circuits
- Use BGA pin fan out
- Allow heat sink and TEC cooling

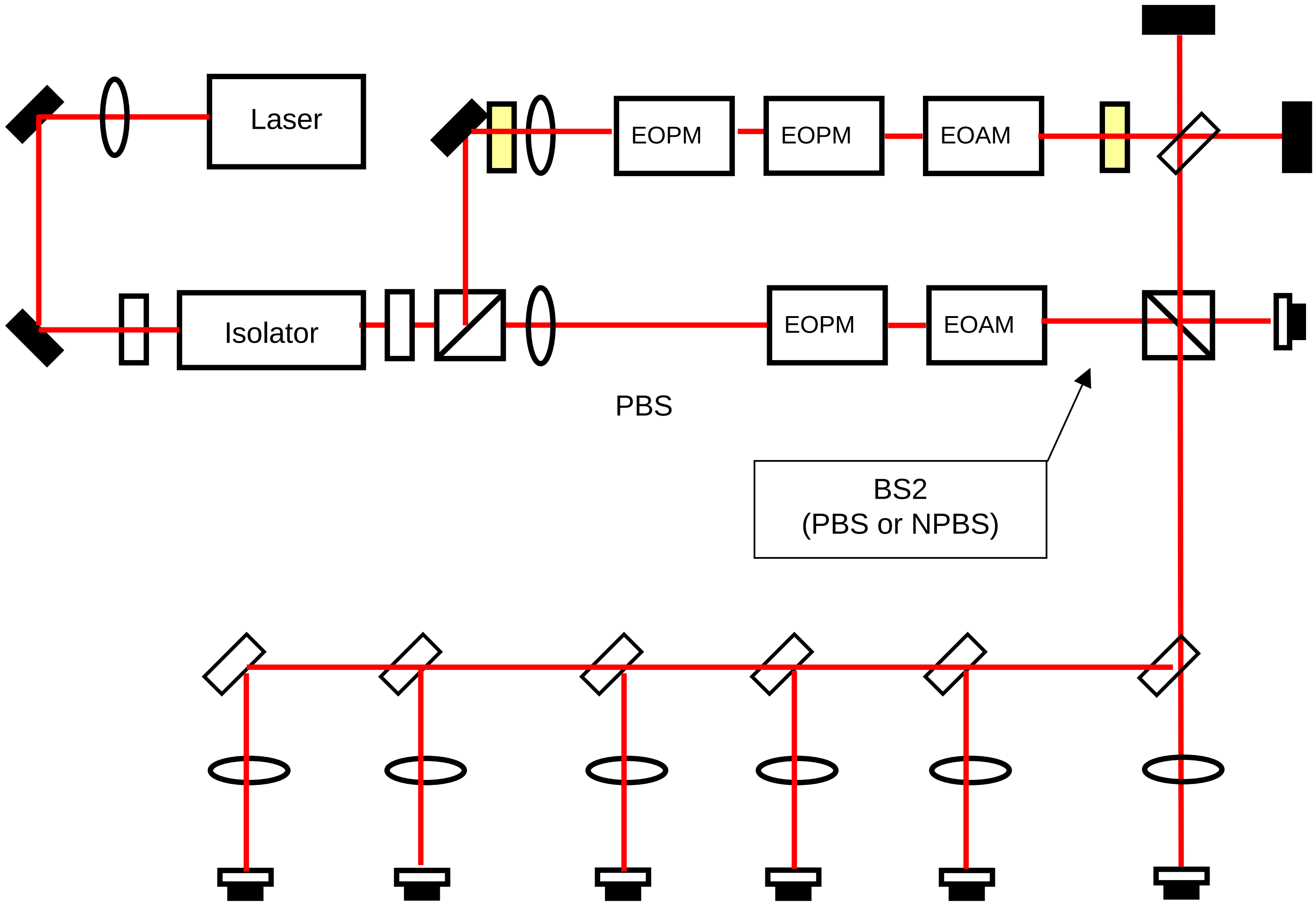




Optical Test Platform at LIGO Hanford

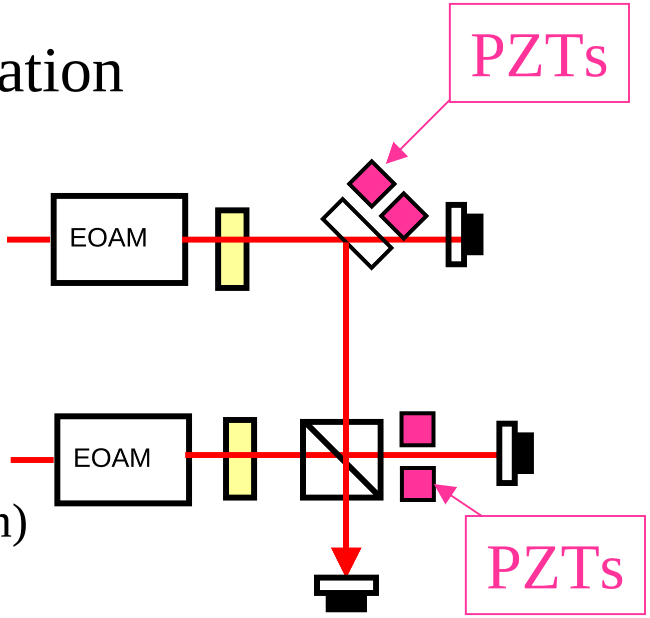
Simulates all field components at all frequencies

Can be built step-by-by step to reduce cost shock



Wavefront and Alignment Sensing

LIGO beam pointing simulation



Wavefront sensor

- RF modulation
  - Phase
  - Amplitude
- Overlap modulation
  - Beam displacement (~4x10^{3}x(30/2)x10^{-17}~ 0.6 pm)
  - Coherent (co-polarized fraction)
  - Incoherent (orthogonal polarized fraction)
  - Angular modulation

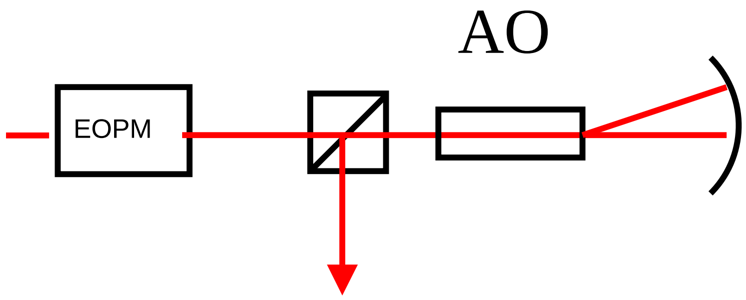
Alignment sensor

- DC or lock-in amplifier (~100 kHz) frequency

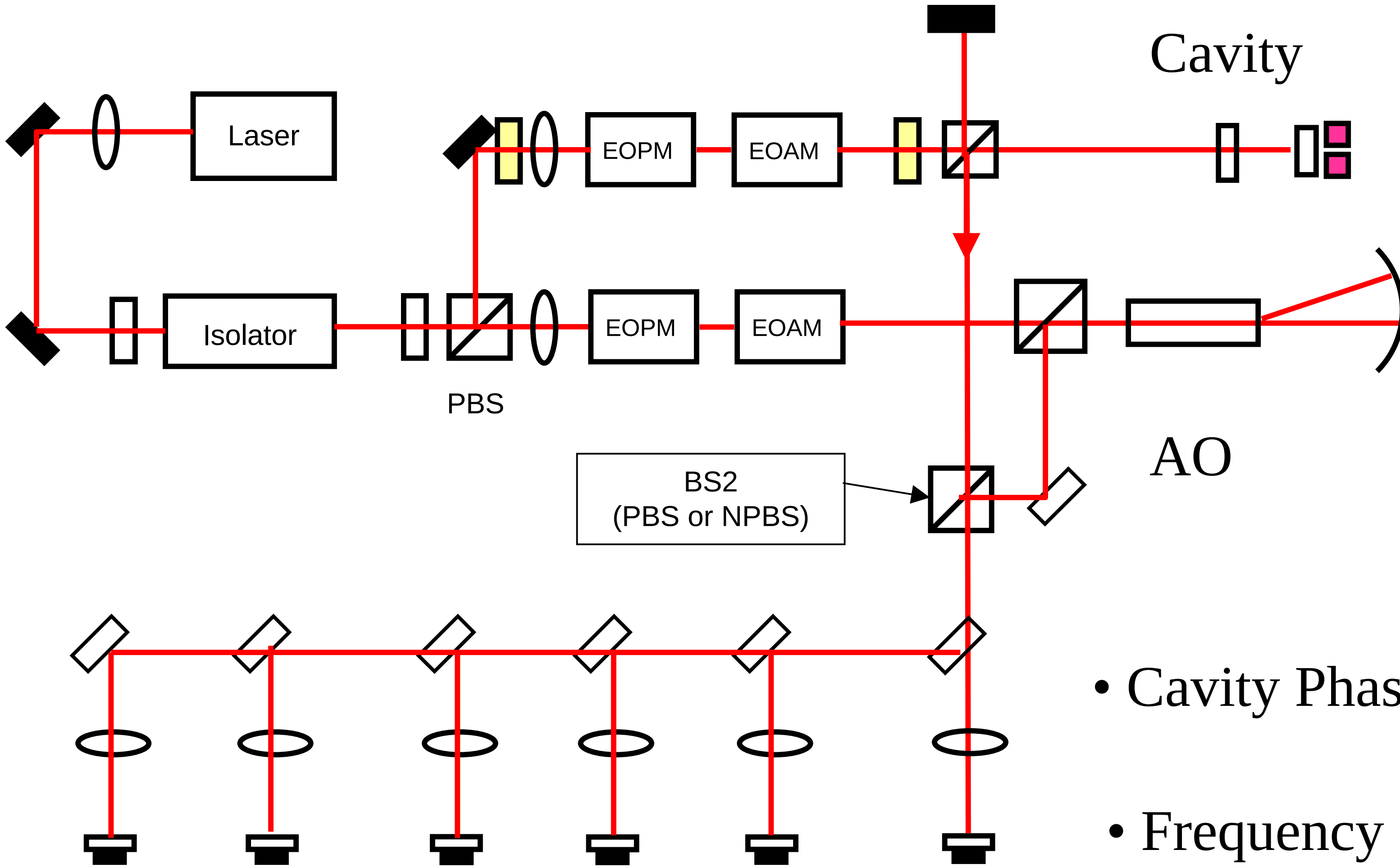
Single Side Band Frequency Shift

Single side band frequency

- Optical heterodyne frequency down shift for advanced LIGO wavefront sensor (Peter Fritschel)
  - Down shift from 200 MHz to below quad detector bandwidth
  - No beam movement
  - Tunable
- Double pass AO
  - Use an acoustic modulator (AO)
  - Curve mirror
  - Double pass for 2 ω modulation

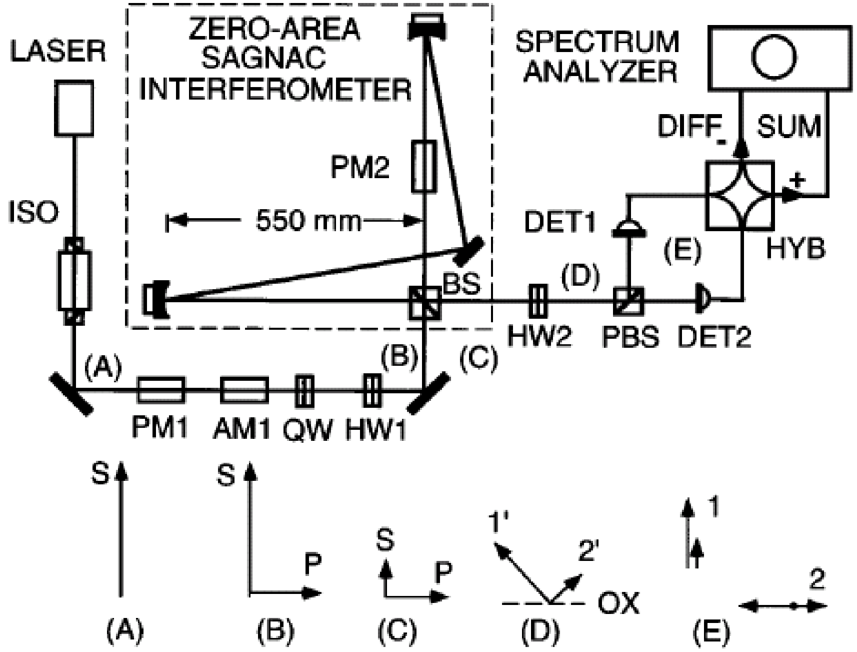


A More Complete Platform
Step by step implementation



- Cavity Phase Shifter
- Frequency Shifter

Orthogonally Polarized Local Oscillator



- Simulated amplitude noise by using Amplitude modulation
- CMRR >30 dB with adjustable gain amplifiers

Spectrum Measurement at 90.9 MHz
Amplitude Noise Suppression 32 dB
Good for AS_I Mitigation?

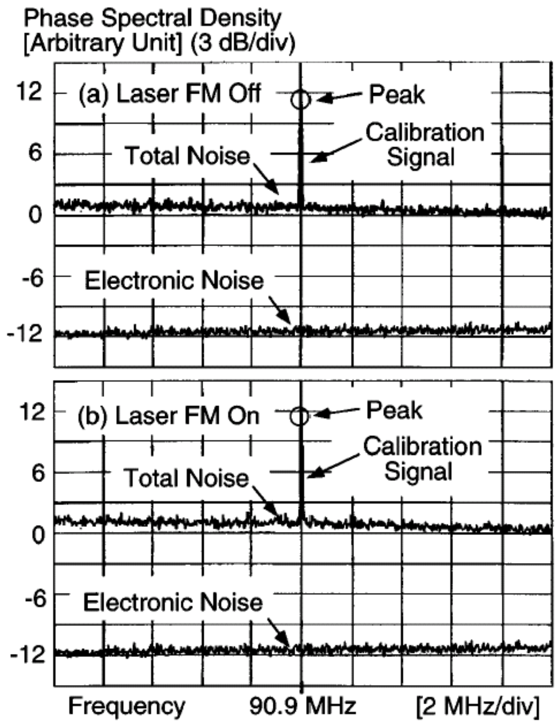


Fig. 3. Demonstration of the robustness of the detection system against laser frequency noise by comparison of phase measurements without (a) and with (b) laser frequency noise simulated by frequency modulation. No significant shift in the shot-noise-dominated noise floor was observed in response to frequency modulation applied to input laser beam.

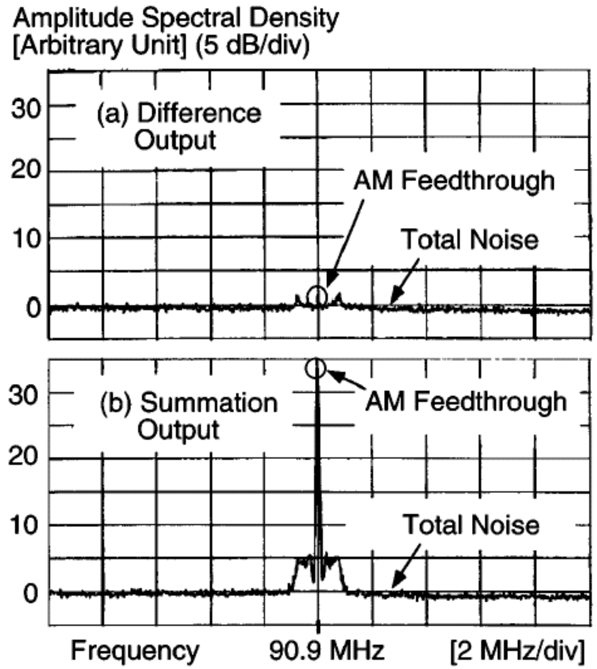


Fig. 4. Measurement of the system CMRR by comparison of difference (a) and summation (b) outputs from the hybrid junction. The signal peak that is due to laser amplitude modulation is 1 dB above the noise floor in (a) and 33 dB above the noise floor in (b), indicating a 32-dB CMRR of the balanced detection system to laser amplitude noise.

Summary
Iterative Steps of Detector Development

1. System requirement
2. Chipset configuration
3. Material science
4. RF packaging
5. External matching circuit
6. Device testing
7. System testing