Photodiodes for Initial and Advanced LIGO

LIGO Science Collaboration Meeting

LHO, Hanford, Washington

March 12-14, 1998

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Outline

- Requirements (M. Zucker):

  What does LIGO want from a photodiode?
- Existing LIGO I devices Part I (A. Marin):

  Power handling, RF characteristics, spatial uniformity
- Existing LIGO I devices Part II (P. Csatorday):

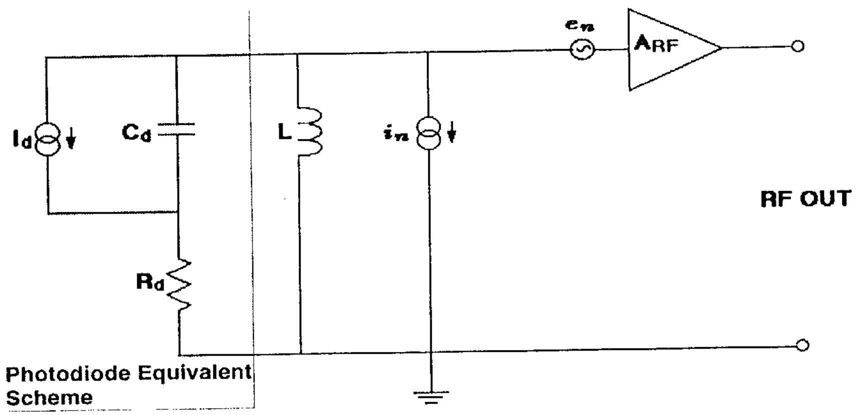
  Thermal dissipation, surface reflectance, backscatter
- Summary: Future directions for advanced LIGO

LIGO Photodetector Requirements

- Quantum efficiency
- SNR
- Linearity
- Spatial uniformity
- Backscatter
- Power handling: Steady-state
- Power handling: Transient

Front-End SNR

- LIGO I: $f_0 = 25$ - 32 MHz



- $10 < \frac{S_{shot}}{S_{elec}} \propto \frac{Z_D\sqrt{2eI_{DC}}}{e_n}$
- $Z_D = \frac{1}{R_D(\omega_0 C_D)^2}$
- need low R_D, C_D

- Both R_D and C_D depend on device area, which affects...
  - Power handling (at least in principle)
  - Backscatter (through area*solid angle conservation)

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Linearity

- Gain compression at level which affects SNR (~ few dB ?)
- Noise: mechanisms poorly defined ; "zoo" of possible effects which might induce signals at f_0 , including
  - Two-tone intermodulation, $(2f_0 \; +/- f_{GW}) \; X \; (2f_0 \; +/- f'_{GW})$
  - Hysteretic down conversion from $2f_0 \; - f_0 \;\; X$ intensity fluctuation
  - ???
- Need better models, testing with "realistic" photocurrent waveforms & noise sensitivities

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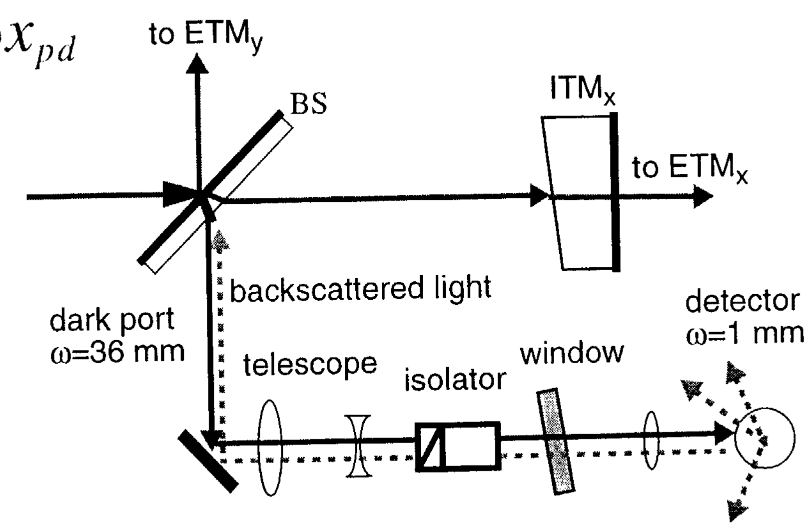
Spatial Uniformity and Backscatter

- Spatial uniformity:
  - Defeats modal orthogonality, enhancing effect of beam tube scattering recombination
  - Requirement can be relaxed with output mode cleaner
- PD Surface Backscatter

$$h_n^2 \sim P_{dp} \cdot BRDF \cdot \Delta\Omega \cdot \frac{\omega_0^2}{\omega_{pd}^2} \cdot \delta x_{pd}$$

  - optical isolation (costs efficiency)
  - seismic /acoustic isolation (costs $)
  - improved BRDF
  - larger detector area



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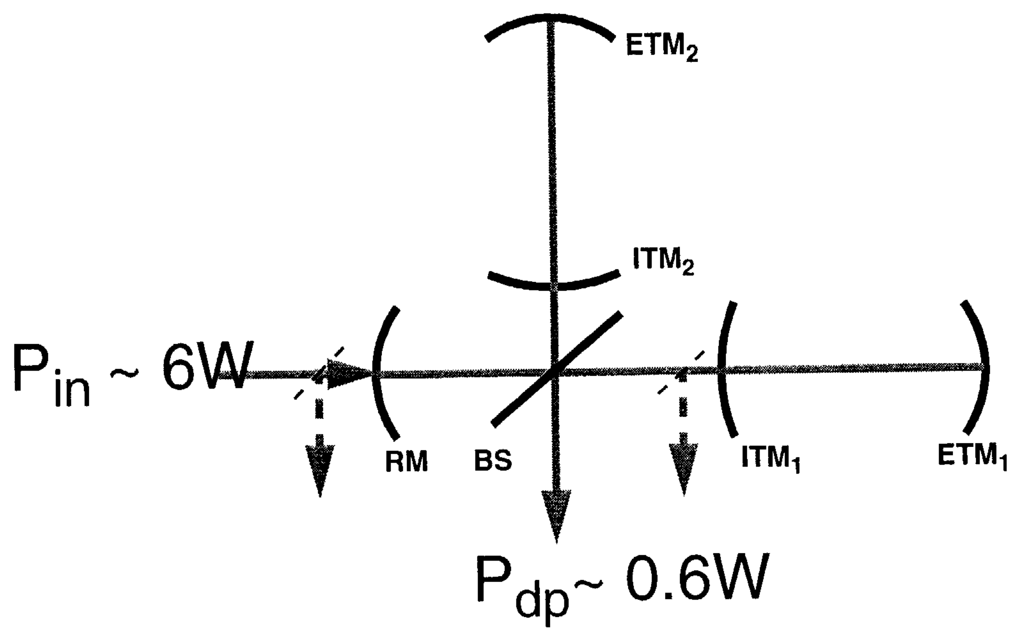
Power handling (steady-state)



- $N_{pd} \geq P_{dp}/P_{MAX} \approx 4$; the fewer the better (SNR, $, scatter,...)
- tradeoff against linearity

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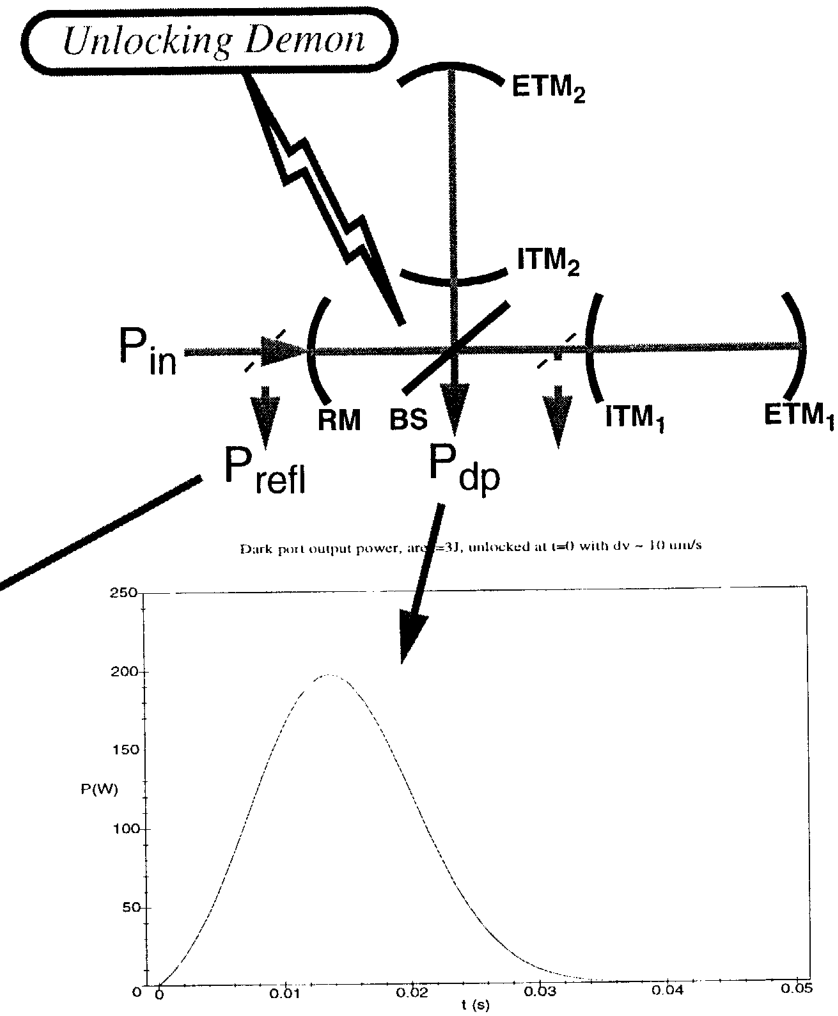
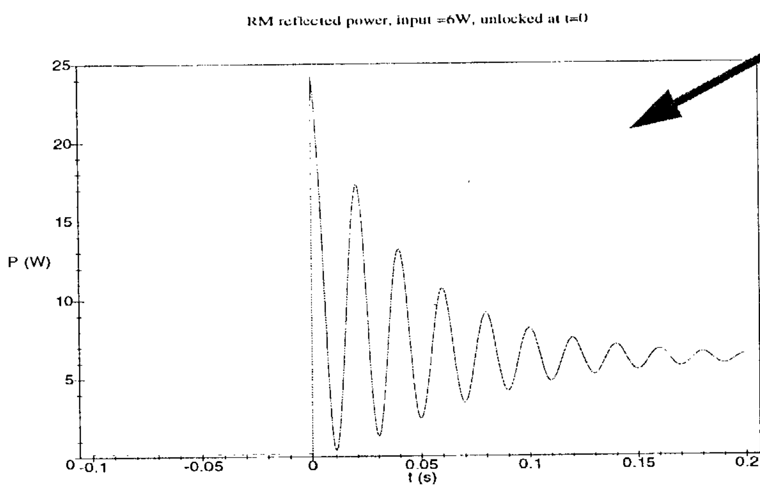
Power handling (transient)

- Sudden loss of lock releases stored energy U~3J thru dark port
- P_{refl} rises briefly to 4 P_{in}
- EO shutter required (costs efficiency)





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PD Specs Scaled to LIGO II Power and Sensitivity

Parameter	*LIGO I*	*LIGO II*	*Current design*
Steady-state power	0.6 W	3.0 W[a]	0.75 W
Transient damage	3 J / 10 ms	30 J / 10 ms	3 J / 10 ms
Signal/Noise	1.4×10^{10} $Hz^{1/2}$	3.1×10^{10} $Hz^{1/2}$	1.5×10^{10} $Hz^{1/2}$
Quantum efficiency	80%	90%	83%
Spatial uniformity	1% RMS	0.1% RMS	1% RMS
Surface backscatter	10^{-4} /sr	10^{-5} /sr[b]	$< 10^{-4}$/sr

a. Assuming a factor of two improvement in contrast defect
b. Assuming comparable active detector area.

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Note 1, Linda Turner, 04/21/98 09:01:43 AM
LIGO-G980049-25-M