Faraday Isolator Performance at High Laser Power

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Motivation

LIGO upgrade from **Initial LIGO** to **Advanced LIGO**

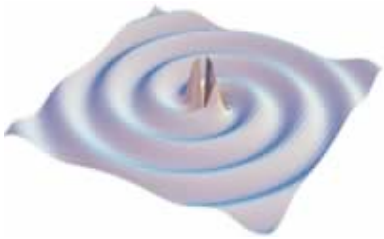
Change from **10 W** to **180 W** in the laser power

- Consequences due to light absorption in the optical components:
  - Thermal lensing
  - Thermally induced birefringence
  - Beam steering
- Some of the most affected: **EOM** and **Faraday isolator** (significant absorption in the transmissive elements)

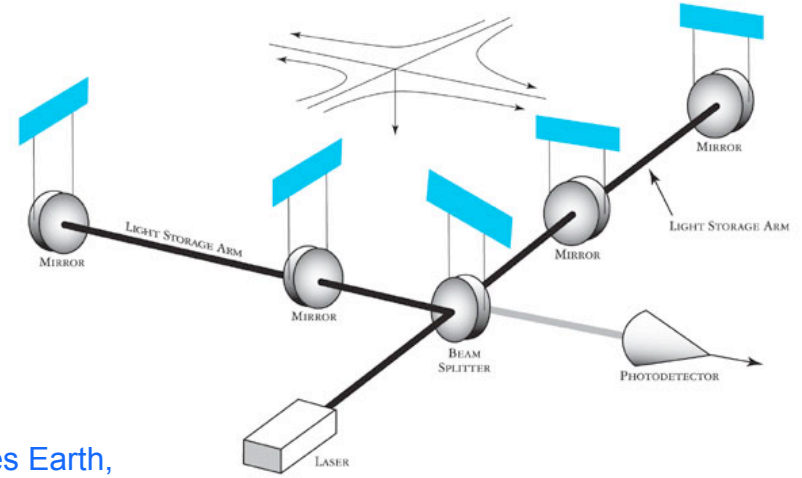
The Science of LIGO

(*Laser Interferometer Gravitational-Wave Observatory*)

- LIGO mission - to observe gravitational waves from strong cosmic sources:
  - » Inspiral of neutron stars or formation of black holes

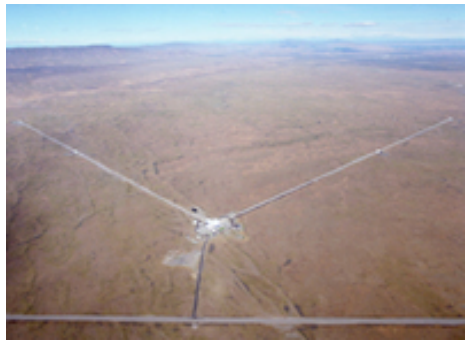


Two neutron stars orbiting each other will create ripples when they collide.



- Detection system - based on a Michaelson interferometer
  - » Hanford, WA: **2 km and 4 km**
  - » Livingston, LA: **4 km**

When the GW reaches Earth, it will be simultaneously detected at the two observatories

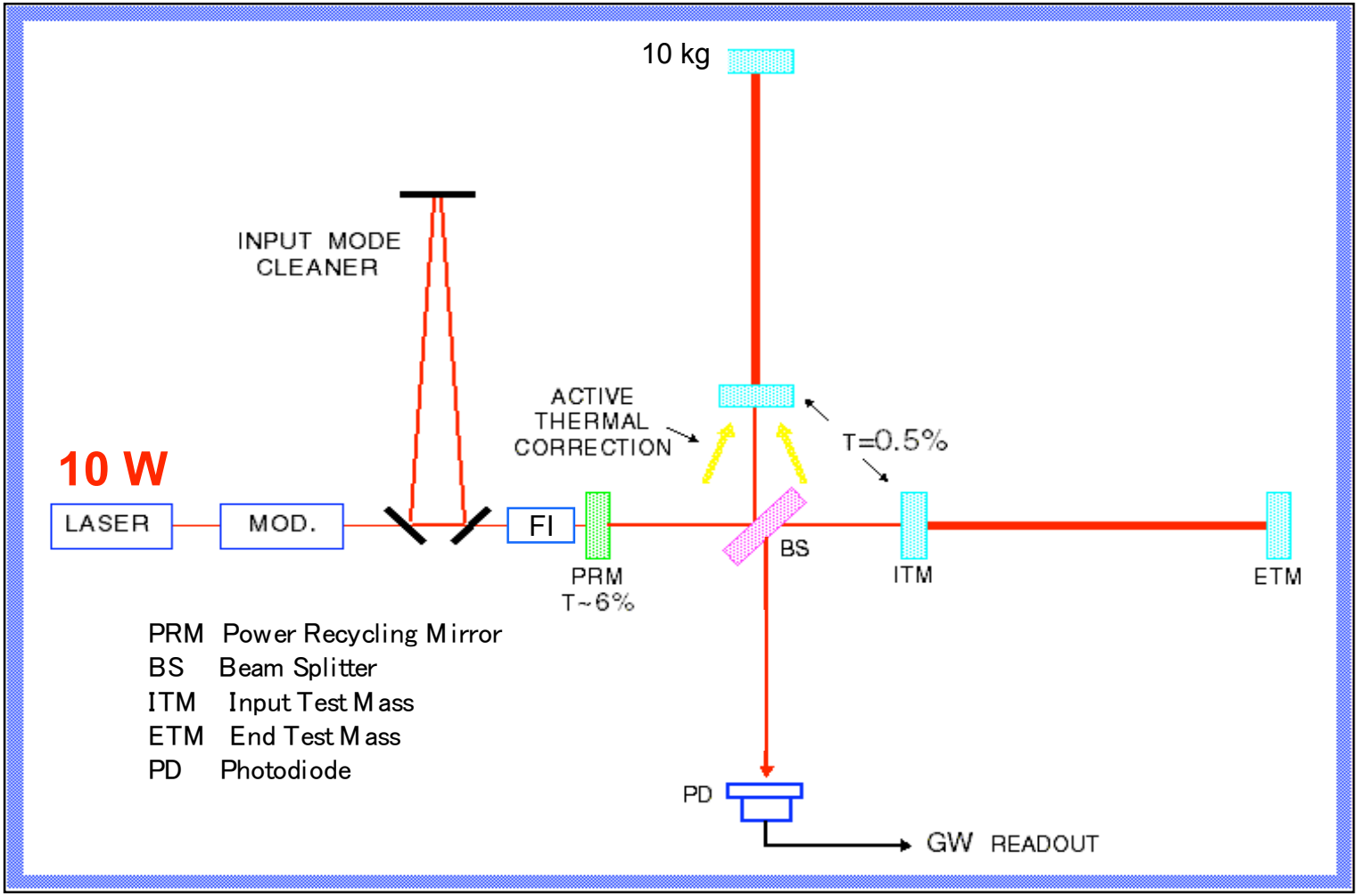


Hanford, WA

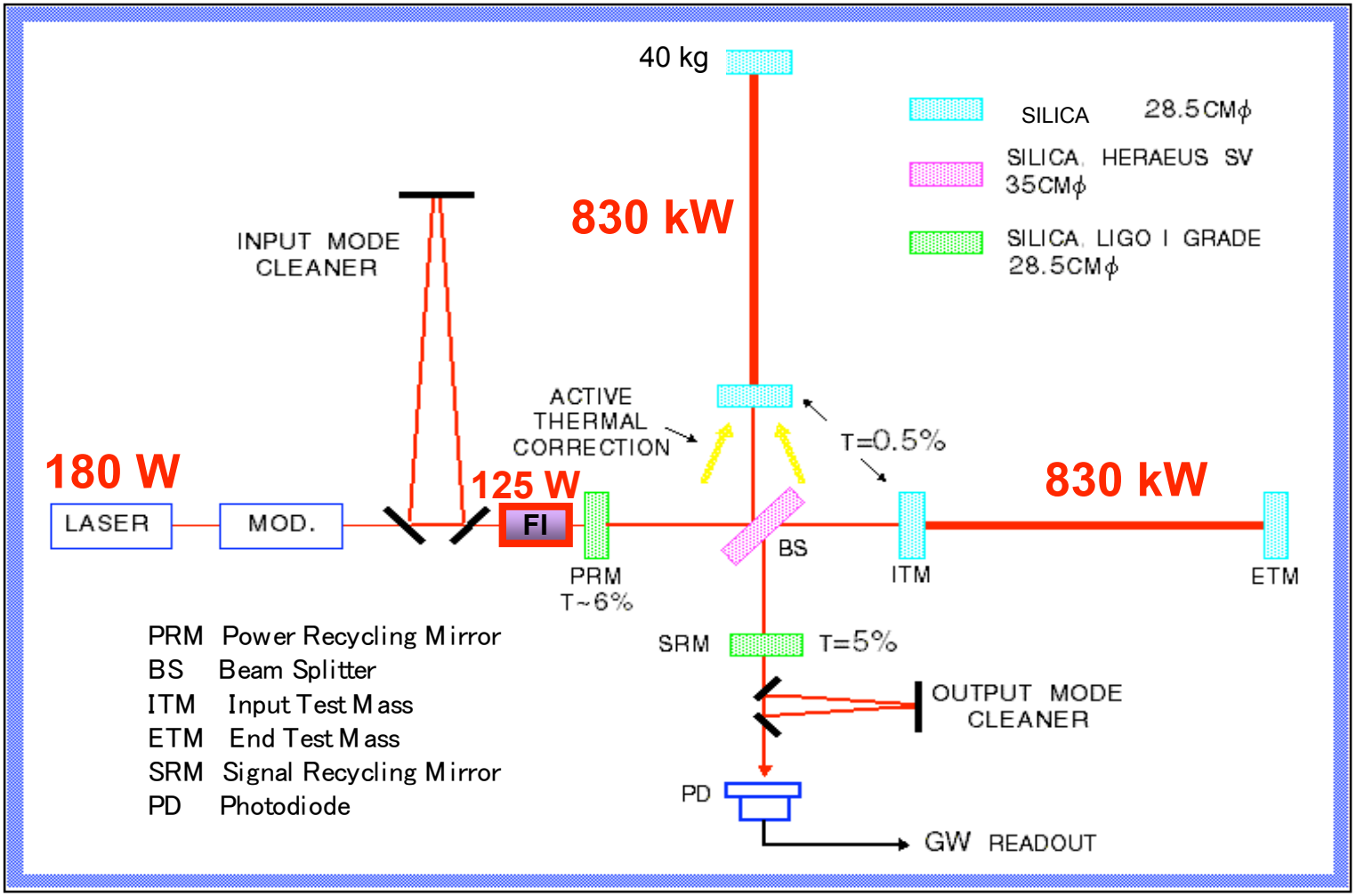
Livingston, LA

Operated by the California Institute of Technology and Massachusetts Institute of Technology for the National Science Foundation

Initial LIGO



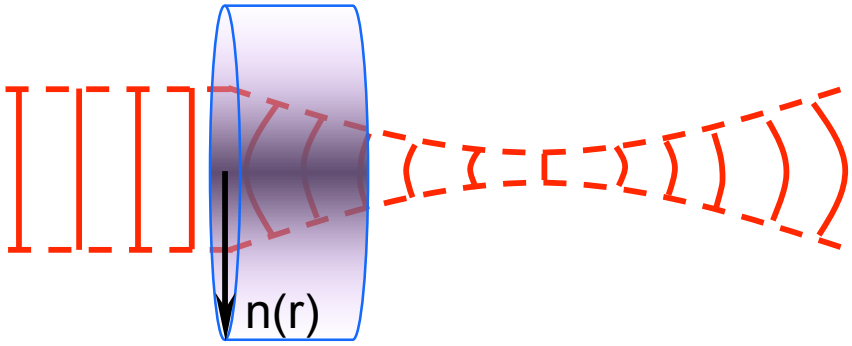
Enhancements to Advanced LIGO



Absorption in transmissive elements (TGG)

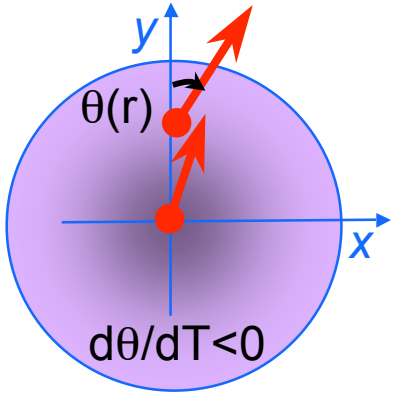
1. Thermal lensing:

due to wavefront distortion of light passing through a medium with nonuniform distribution of the refractive index



2. Nonuniform distribution of the rotation angle

due to the temperature dependence of the Verdet constant

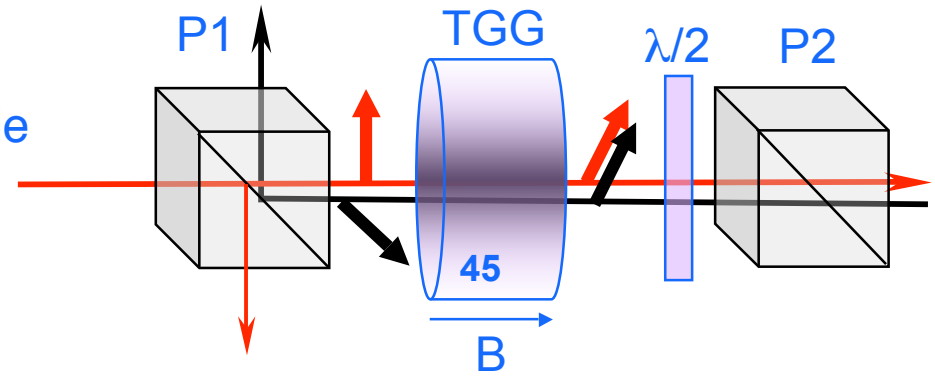


3. Photoelastic effect:

due to strain induced by the temperature gradient causing localized birefringence

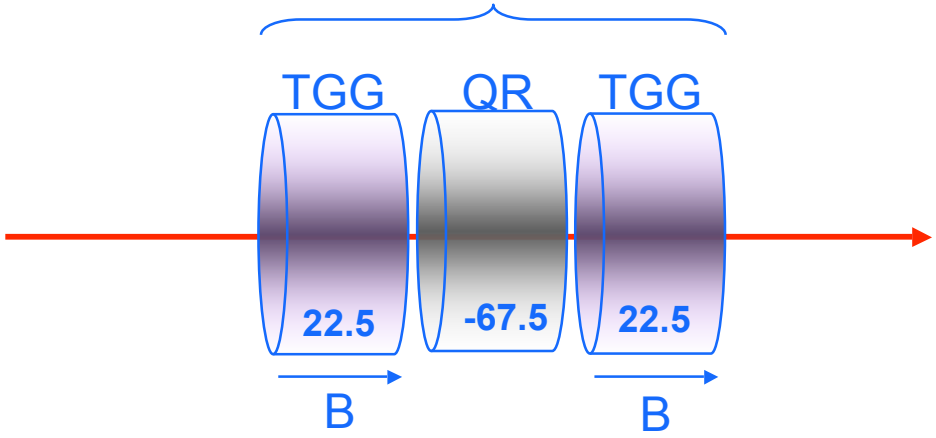
Depolarization in Faraday isolators

- A **Faraday isolator** consists of a **Faraday rotator** (TGG crystal inside magnet) + **pair of polarizers**



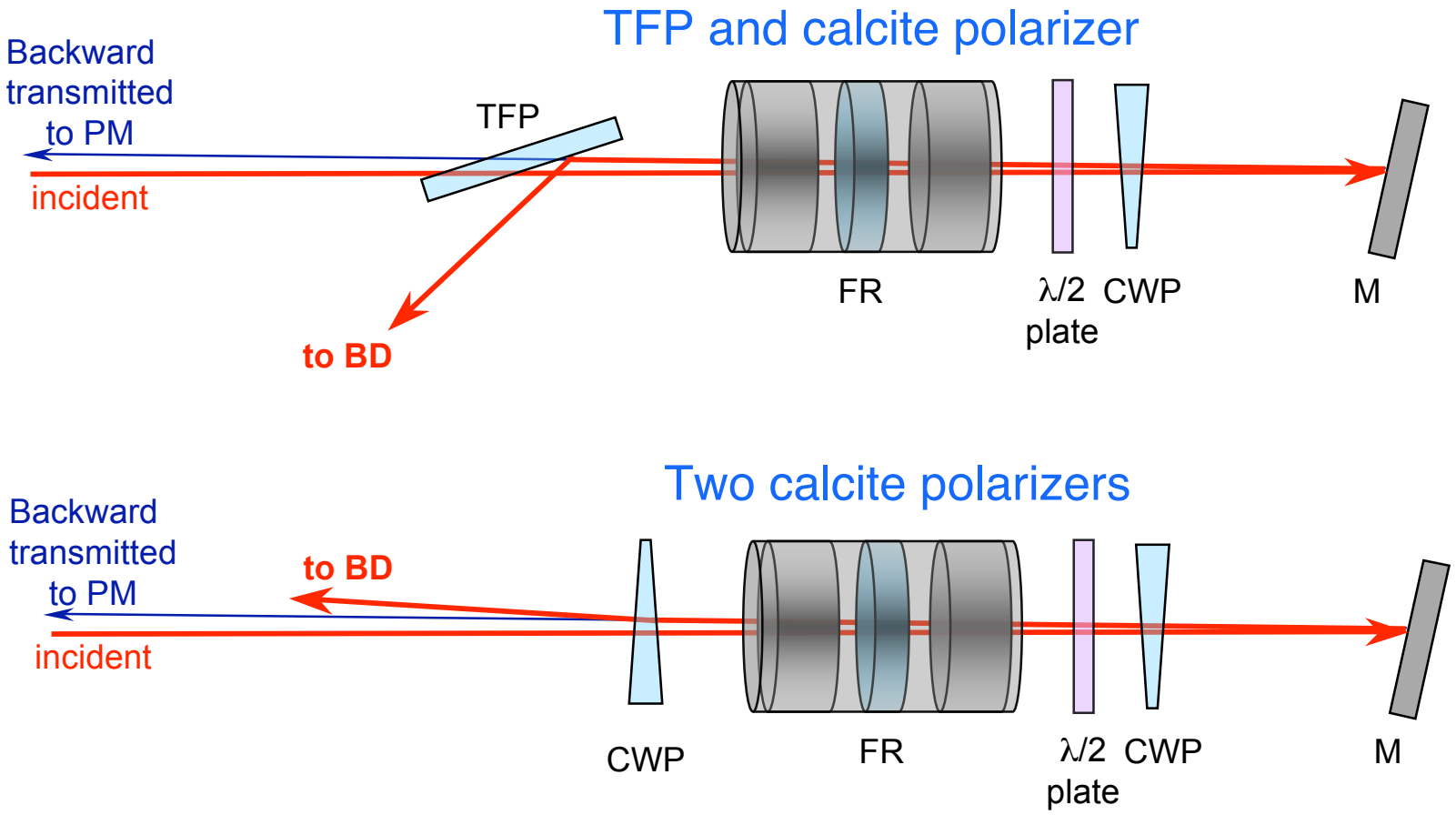
- New design compensates for thermally induced depolarization effects in the TGG crystals:

TGG + QR + TGG

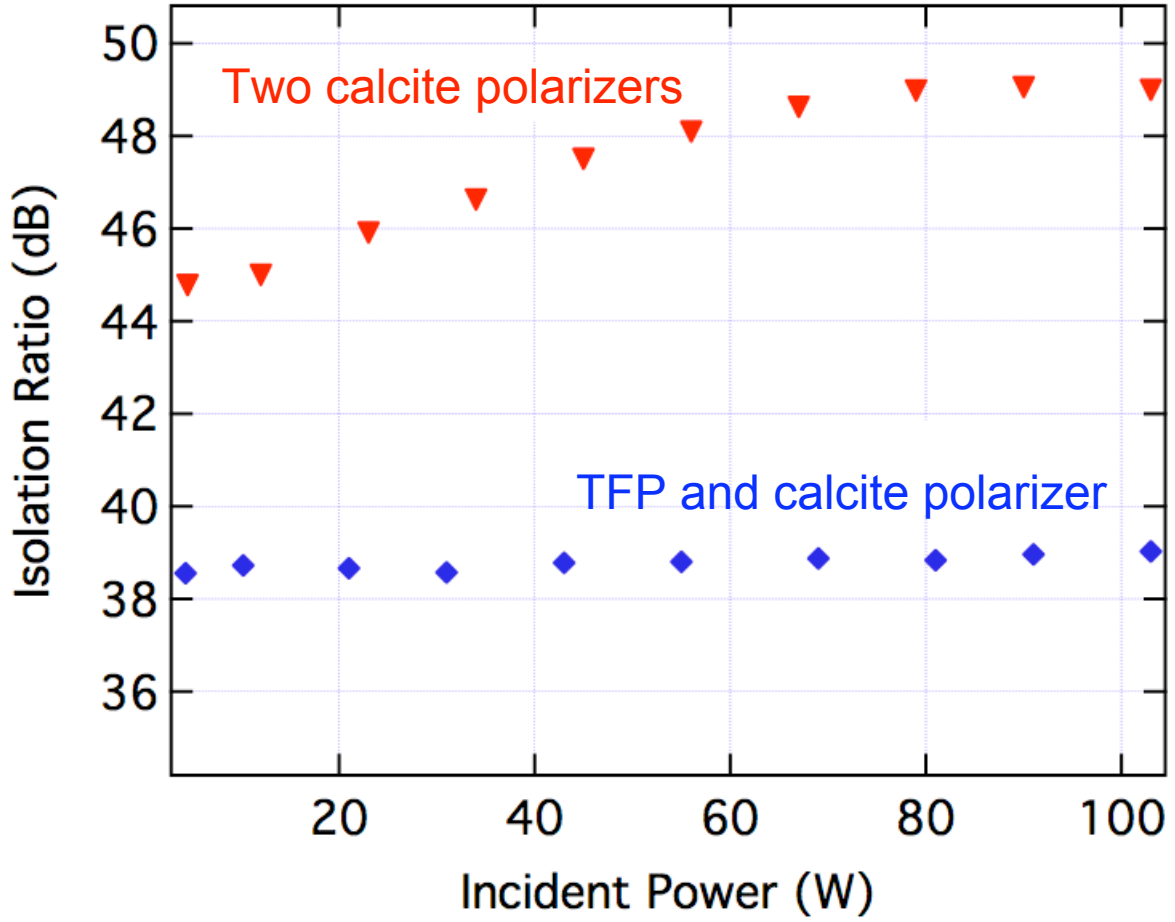


Khazanov et al., IEEE J. Quantum Electron., 40, 1500-1510 (2004).

Isolation measurements



Isolation results



Results Summary

FI performance in TFP + CWP and CWP + CWP configurations at 103 W incident power

Performance at 103 W		TFP + CWP	CWP + CWP	Comments
Isolation Ratio:		**39 dB**	**49 dB**	Good optical isolation in both setups. **39 dB** is limited by the extinction of the TFP.
Back-transmitted:		12.9 mW	1.3 mW	Better suppression for the CWP + CWP setup.
Transmitted: *(in the right polarization)*		94 %	95 %	The FI was optimized for max. isolation (min. back reflection).
Losses:		6 W	5 W	Of which ~ 3 W are lost in the second polarization after the second CWP.
Thermal Drift: *(±20μrad)*	*Transmission:*	**30 μrad** *(0.3 μrad/W)*	**50 μrad** *(0.5 μrad/W)*	Larger drift for CWP + CWP setup (2 CWPs), both in reflection and in transmission.
	Reflection:	**50 μrad** *(0.25 μrad/W)*	**80 μrad** *(0.4 μrad/W)*	

Conclusions and future work

FI for Advanced LIGO:

- **High isolation:**
  - Use calcite polarizers
  - Self-compensating Faraday rotator
- **Beam drift:**
  - Less beam drift for TFP + CWP
  - Investigate new configurations: insert a TFP between the two CWP.
- **Thermal lensing:**
  - Can be corrected with a DKDP crystal (negative dn/dT)
  - Compensation to up to 70 W (UF/IAP)
  - ongoing work
- **UHV tests :**
  - underway

Thank you!