# LCGT Detector Configuration

LCGT F2F meeting @ ICRR
Feb. 2011

*Waseda Inst for Advanced Study*
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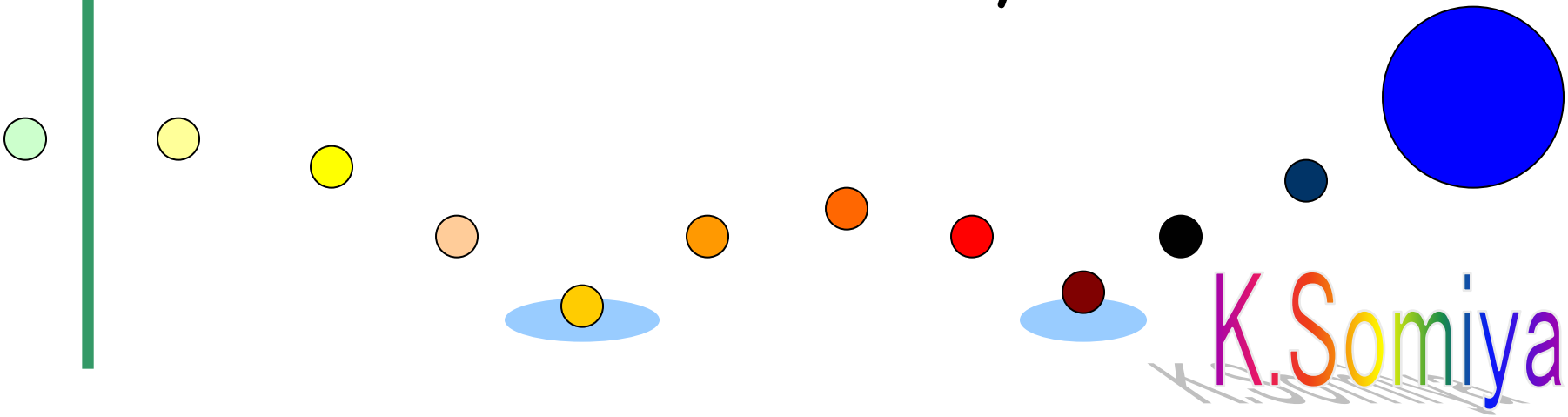


# LCGT Goal


"Detecting GW a few times per year"

(1) NS-NS binary inspirals
SN=8@190Mpc; ~1 event per year
SN=8@240~270Mpc; 2-3 events per year
(Duty cycle=90%, detection probability=90%)

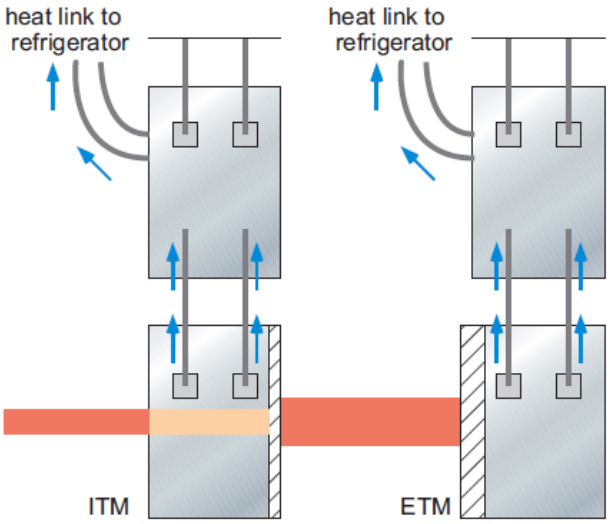
(2) Cooling mirrors to 20K and circulating 400kW light in 3km arms, we can realize the sensitivity.

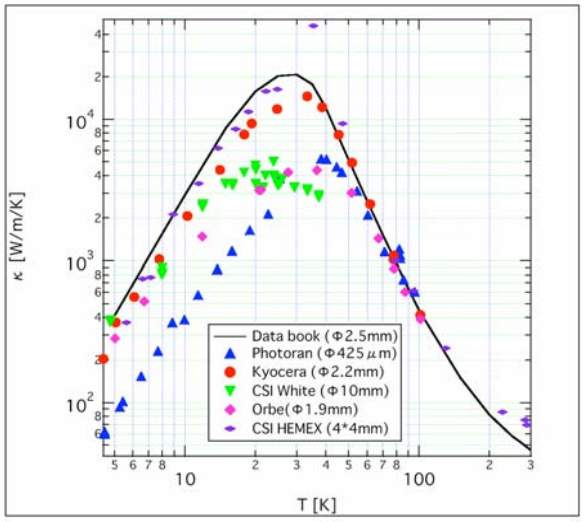
IFO Design

# Detector Configuration Group

1. Design the detector according to the noise analysis
2. Set requirements to realize the sensitivity
3. Risk management

# Cryogenic system




Thermal conductivity of Sapphire fiber

(1) Use Sapphire substrate that is good with 1064nm laser, has high thermal conductivity, and has high Q

(2) 20K fiber can transfer ~1W heat

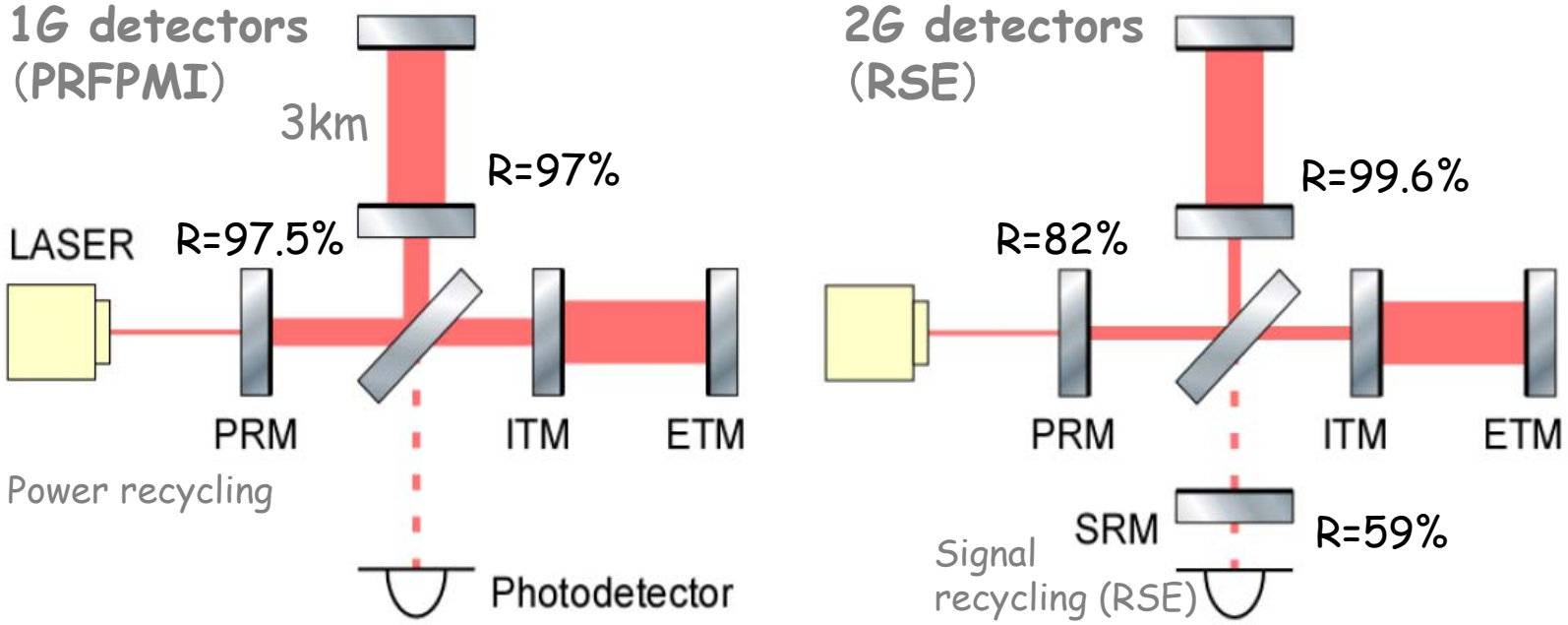
(3) Absorption of Sapphire substrate is not small

**High-finesse RSE (F=1550)**

- **825W in PRC, Arm power=400kW**
- **Absorption in ITM substrate=0.24W**
  **Absorption in coatings=0.20W**
- **Fiber diameter=1.6mm, length=30cm**

# RSE

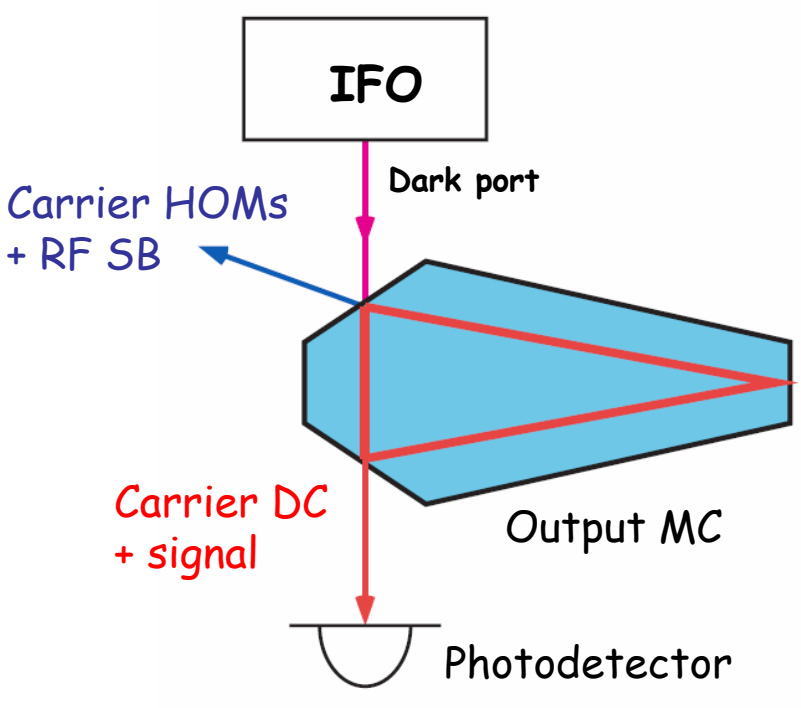
RSE=Resonant Sideband Extraction




Same shot-noise level but different power in ITMs

⇒ RSE is good for LCGT

# DC readout




## RF readout to DC readout

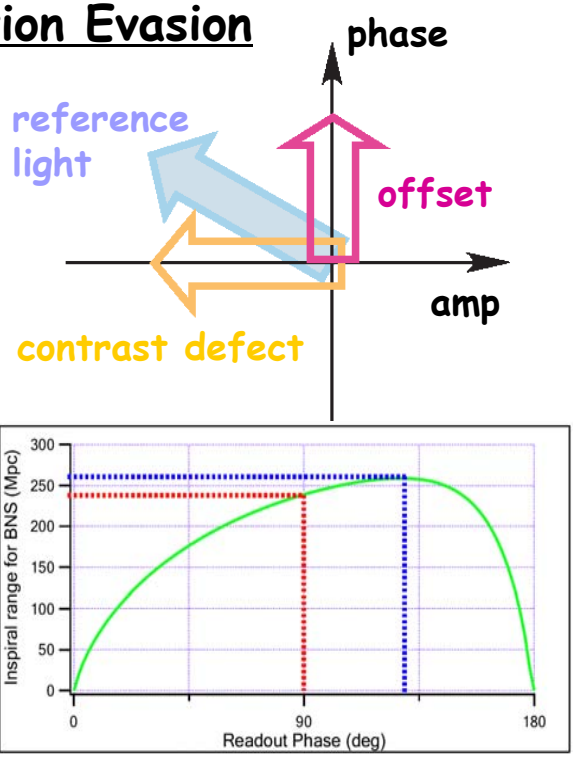
- 10% better shot noise
- lower laser noise
- almost no RF noise
- simpler OMC
- simpler PD

**Adding offset to the arms and use the leaking DC light as reference**

**DC readout lets us use QND technique to reduce quantum noise**

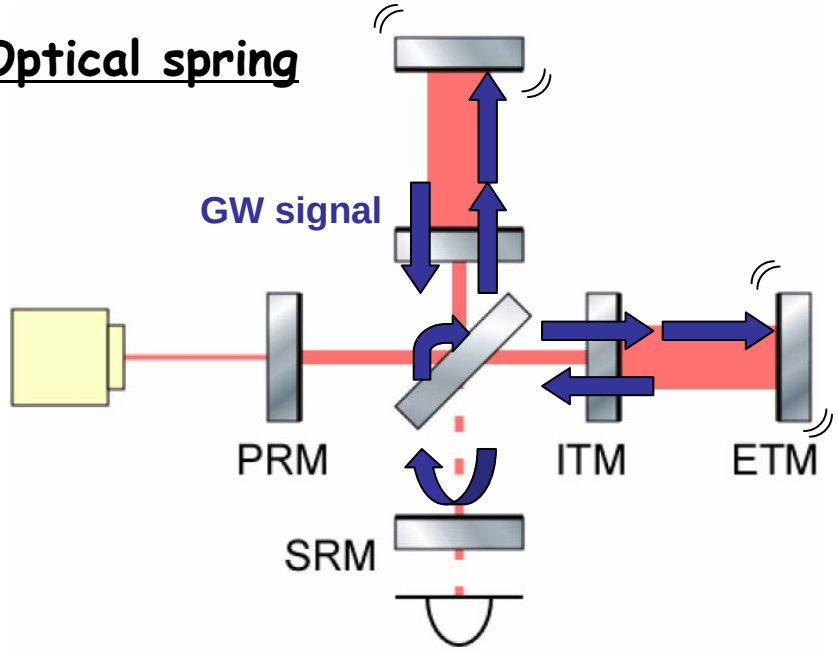
# BAE and Optical spring

## Back-action Evasion




RP noise can be compensated by optimizing the DC readout phase

## Optical spring



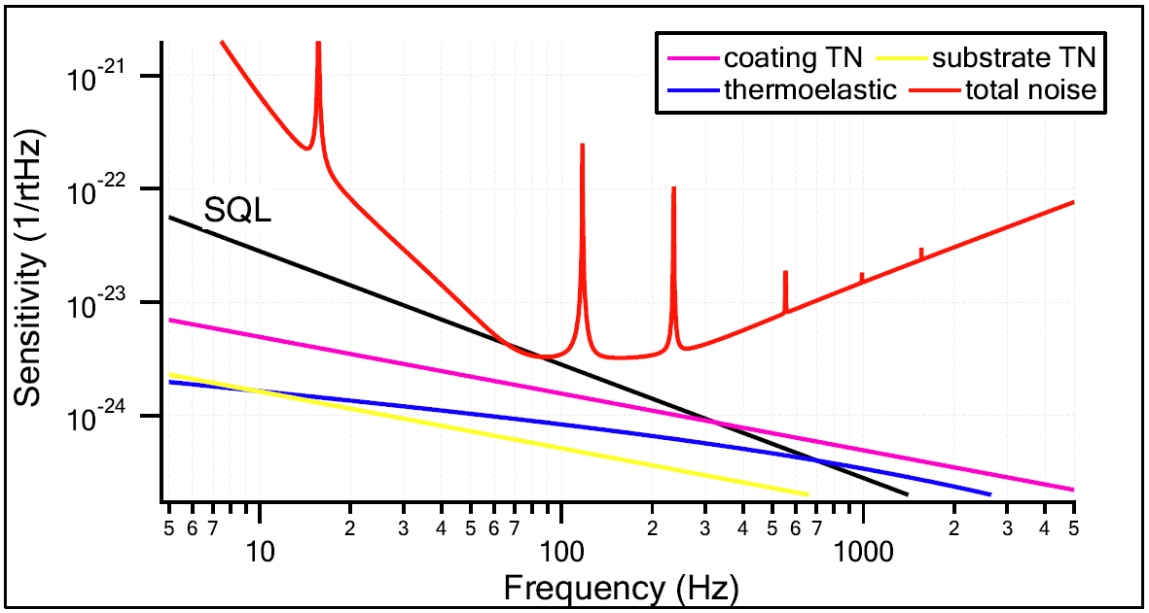

BRSE: ITM-SRM RT=(N+1/2)λ

DRSE: ITM-SRM RT≠(N+1/2)λ

We can beat the SQL by changing the SRM microscopic location

IR increases by 7% with BAE, and extra 12% with detuning.

# Mirror thermal noise




Coating BR:
mirror distortion by thermal energy in the coatings

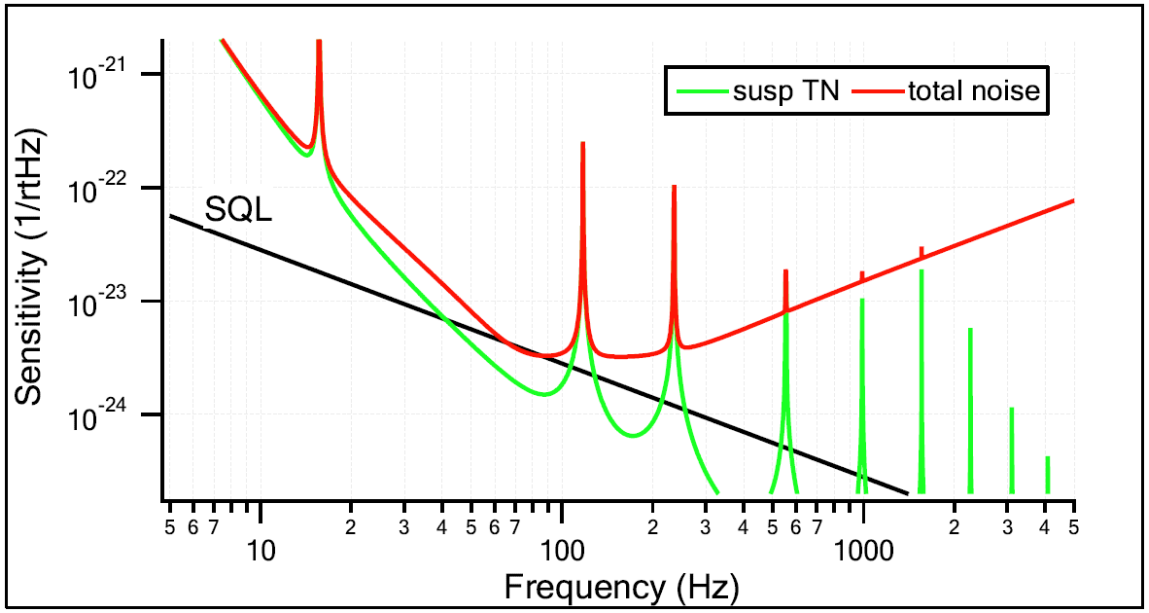
Mirror TE:
mirror expansion by temperature fluctuation via thermal expansion

Mirror BR:
mirror distortion by thermal energy in the substrate

Substrate Q=1e8
Ti-Tantala coating $\phi$=5e-4
Silica coating $\phi$=3e-4
ITM:9 layer, ETM:18 layer

- Mechanical loss of coatings increases at 20K; aLIGO:2e-4/5e-5
  *UK Measurement tells 8e-4/5e-4, but it'll be better by 60% with 600C annealing
- Sapphire Substrate Q of 1e8 is a measured value
- Beam radii are 3.5cm on ITM, and 4.2cm on ETM
  ~ should be tuned to avoid HOM resonance (g1=-0.87, g2=-0.60)
  ~ ITM beam size is limited by BS size and property of Kamaboko mirror

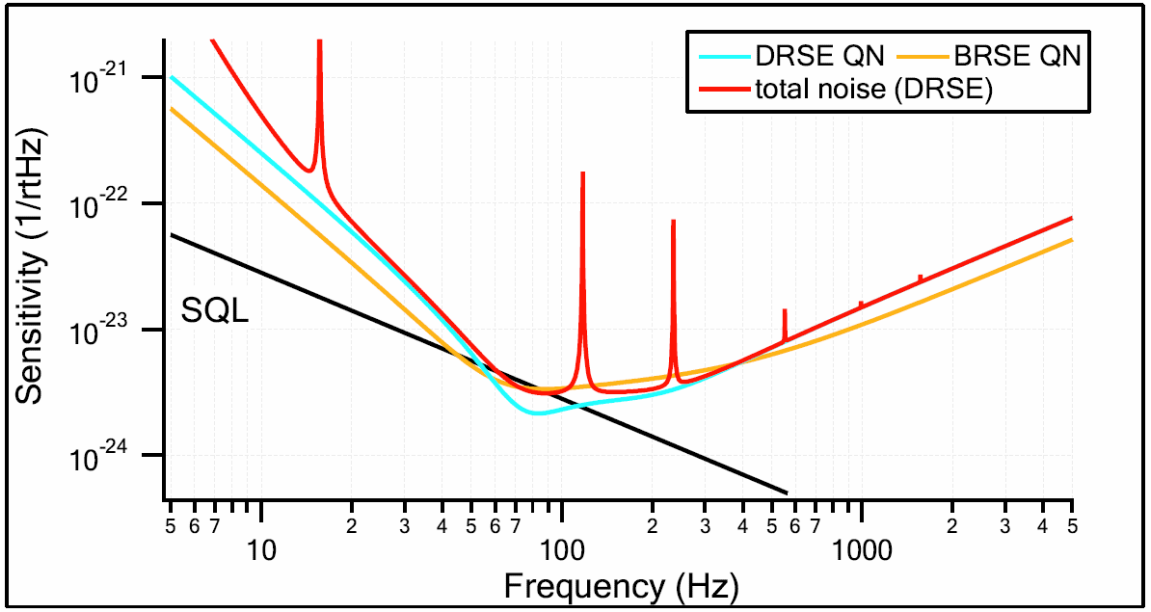
# Suspension thermal noise

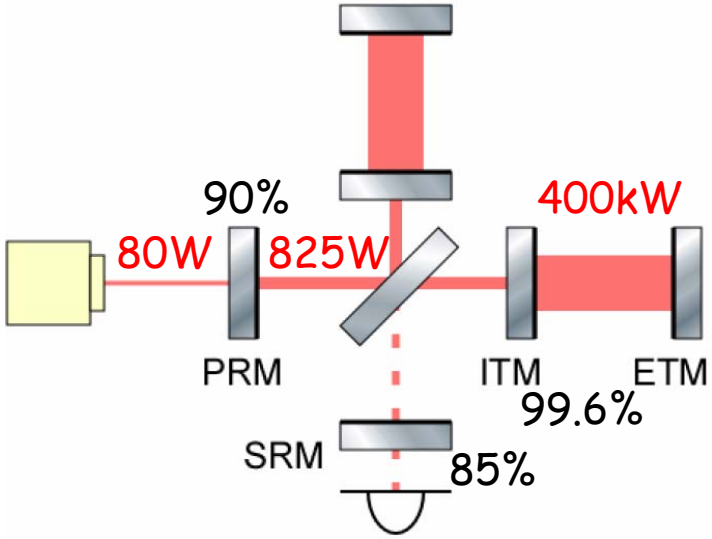



Values are for TM/IM/RM fiber
(test mass/intermediate mass/recoil mass)
Material=Sapphire/Tungsten/BeCu
Structure loss=5e-8/1e-4/5e-6
Fiber length=30cm/50cm/30cm
Fiber d=1.6mm/0.6mm/0.4mm
Clamp loss=0/1e-3/0
Temperature=16K/10K/16K
Mini GAS freq=0.4Hz
HV coupling=1/200
IM/RM mass=60kg/30kg

- Sapphire fiber Q is a measured value
- Fiber length has been reduced to move a violin-mode peak
  *40cm -> 150Hz, 30cm -> 235Hz
- Vertical resonance at 117Hz is hard to move away;
  thus HV coupling and IM/RM loss requirements are strict

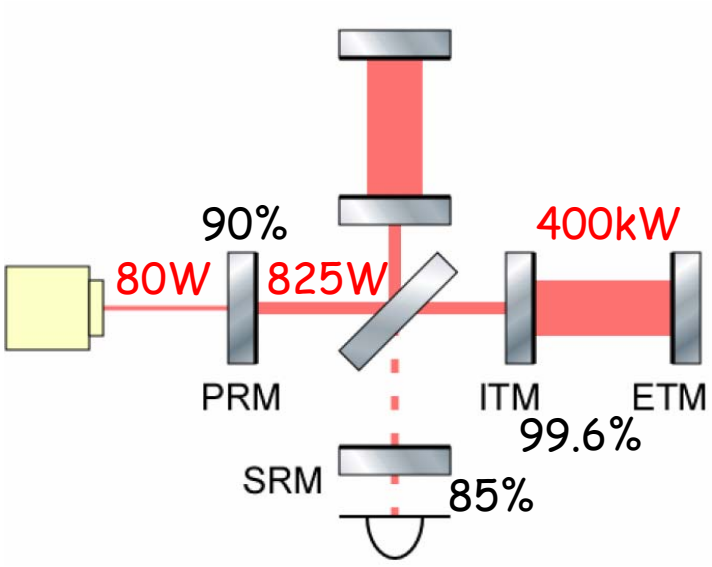
# Quantum noise

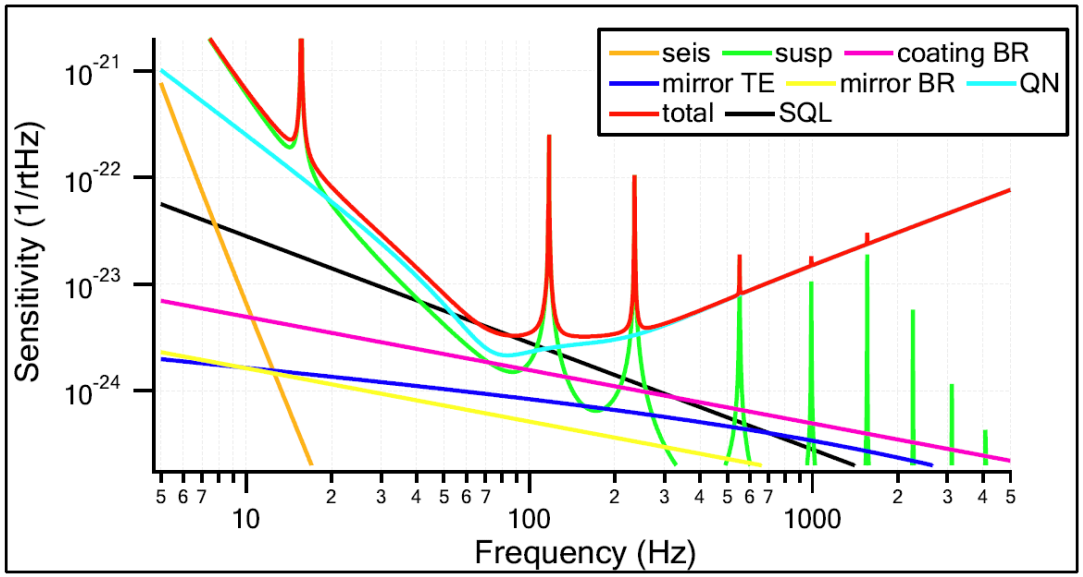



- For DRSE, $\phi$=86.5 deg, $\zeta$=134.2 deg
- For BRSE, $\zeta$=119.3 deg
- The best sensitivity is better with DRSE
- Bandwidth is broader with BRSE
- QN exceeds the SQL at around a certain frequency

# Sensitivity summary




- Inspiral range for NSNS binaries is 273Mpc
- Default configuration is DRSE but compatible with BRSE
  (IR=245Mpc w/BAE, 232Mpc w/o BAE)
- LCGT goal (220Mpc; 2 events per year) can be achieved even with 10% sensitivity reduction by technical noise

# Requirements to Subsystems

Laser: 150W, FN, IN

IOO: 60% transmission of TEM00 carrier, MZ noise

Mirror: opt loss<45±15ppm, substrate abs<600ppm,
coating abs<0.5ppm, the rest has been introduced

Suspension: thermal conductivity>$0.128/T^{2.75}$, the rest has been introduced

Isolation: seismic noise<(2e-17/f^6.5)[1/rtHz]

Vacuum: (TBD)

Cleanliness: (TBD)

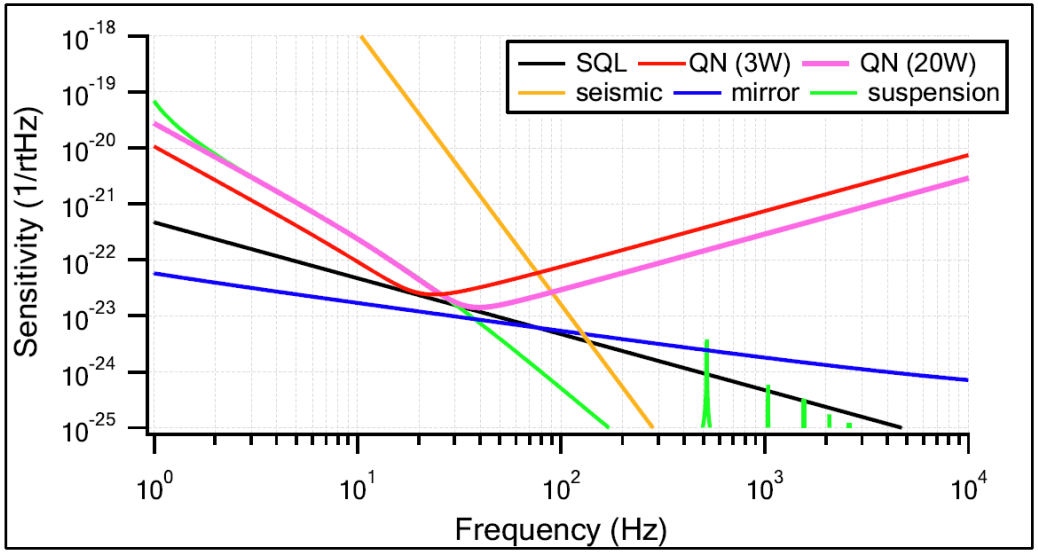
ISC + Electronics: LSC/ASC Loop noise

Digital: digital noise

⋮ etc. etc. …

I'll talk about this on Saturday

# Toward the construction (iLCGT)




- FPMI at room temperature
- 3-stage suspension
- 10kg silica mirrors
- Finesse 1550
- 1-month observation in 2014

## Parameters to be determined on iLCGT construction

- Tunnel tilt
- Vacuum level
- Cleanliness
- Vacuum-chamber location (detune/folding)
- MC design
- BS