LCGT Detector Configuration

LCGT F2F meeting @ ICRR
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Waseda Inst for Advanced Study
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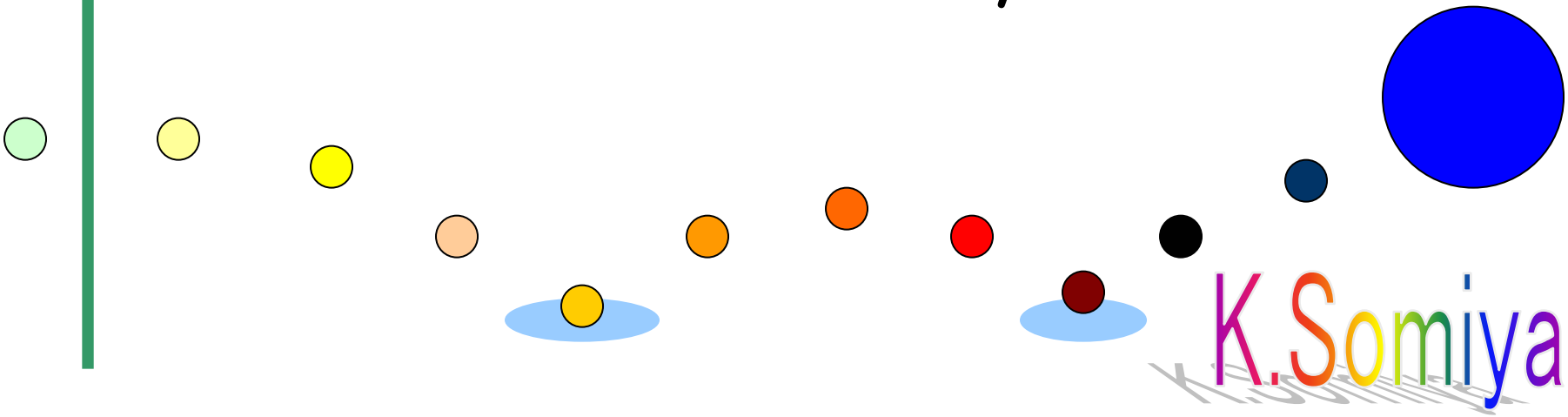


LCGT Goal

"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%)

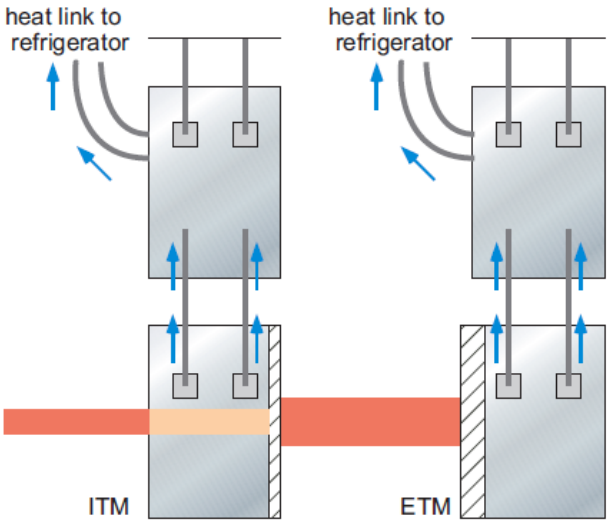
(2) Cooling mirrors to 20K and circulating 400kW light in 3km arms, we can realize the sensitivity.

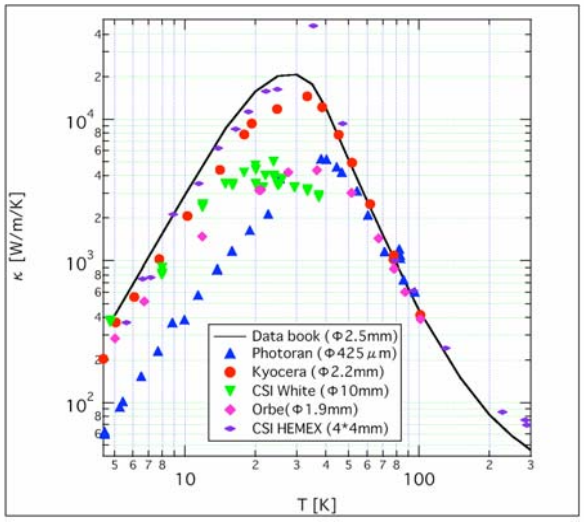
IFO Design

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

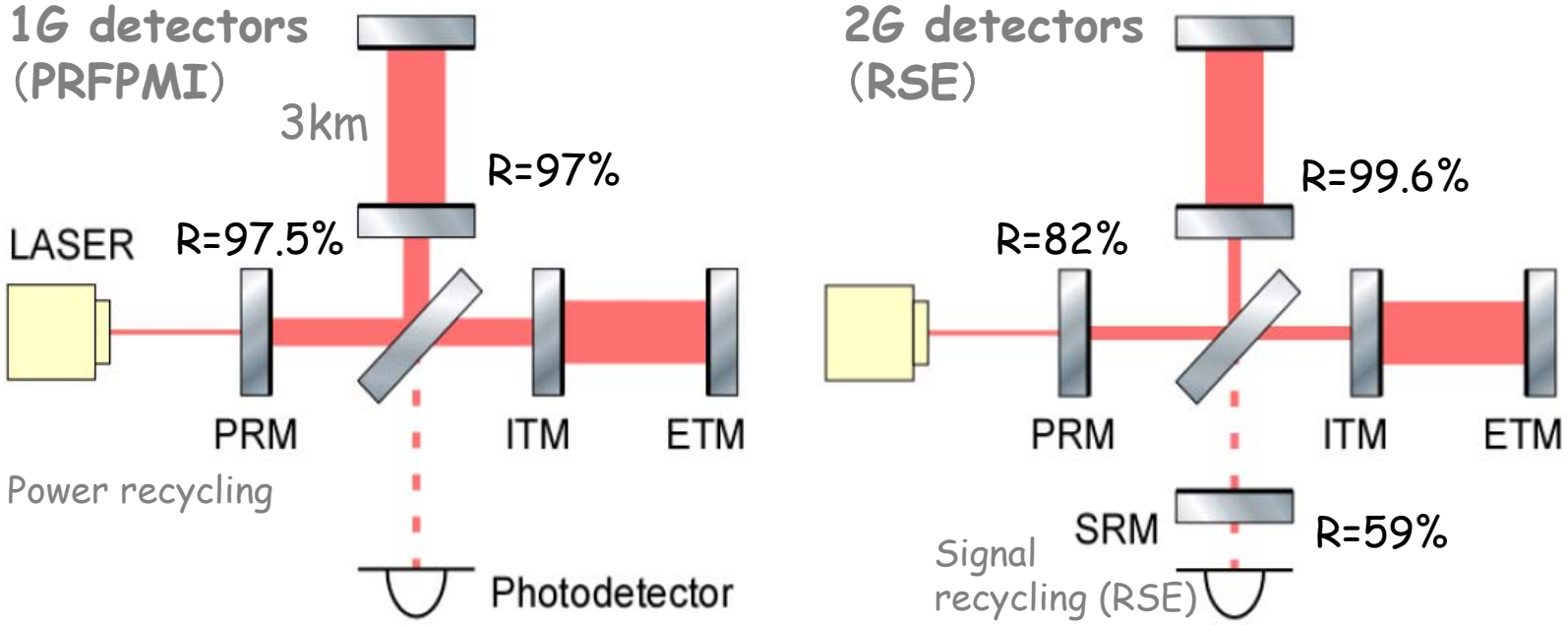
(3) Absorption of Sapphire substrate is not small

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

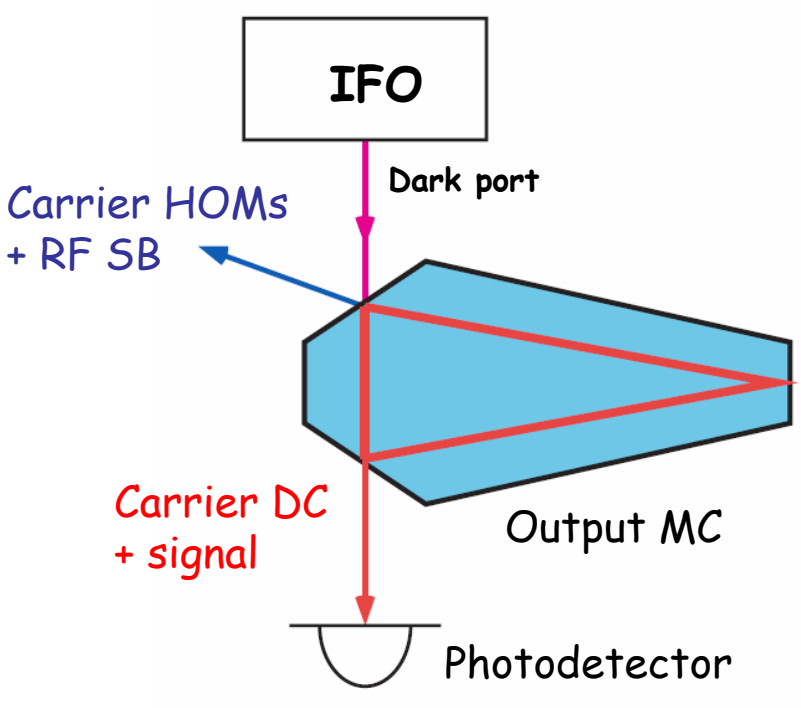
RSE=Resonant Sideband Extraction



Same shot-noise level but different power in ITMs

⇒ RSE is good for LCGT

DC readout



RF readout to DC readout

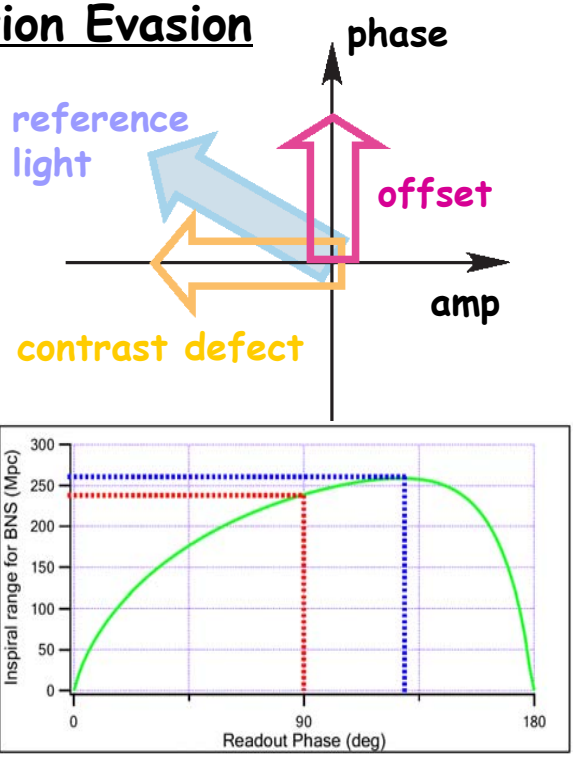
- 10% better shot noise
- lower laser noise
- almost no RF noise
- simpler OMC
- simpler PD

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

DC readout lets us use QND technique to reduce quantum noise

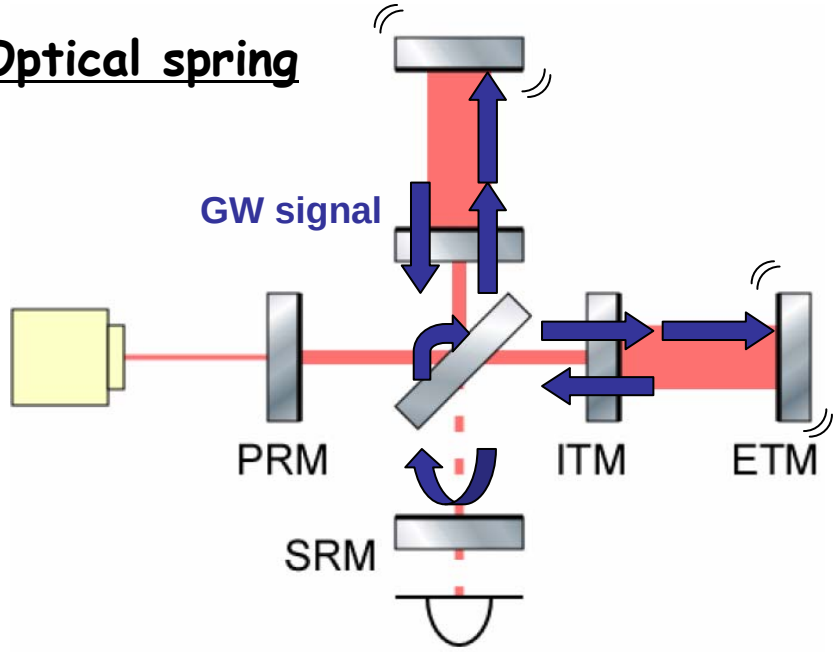
BAE and Optical spring

Back-action Evasion



RP noise can be compensated by optimizing the DC readout phase

Optical spring



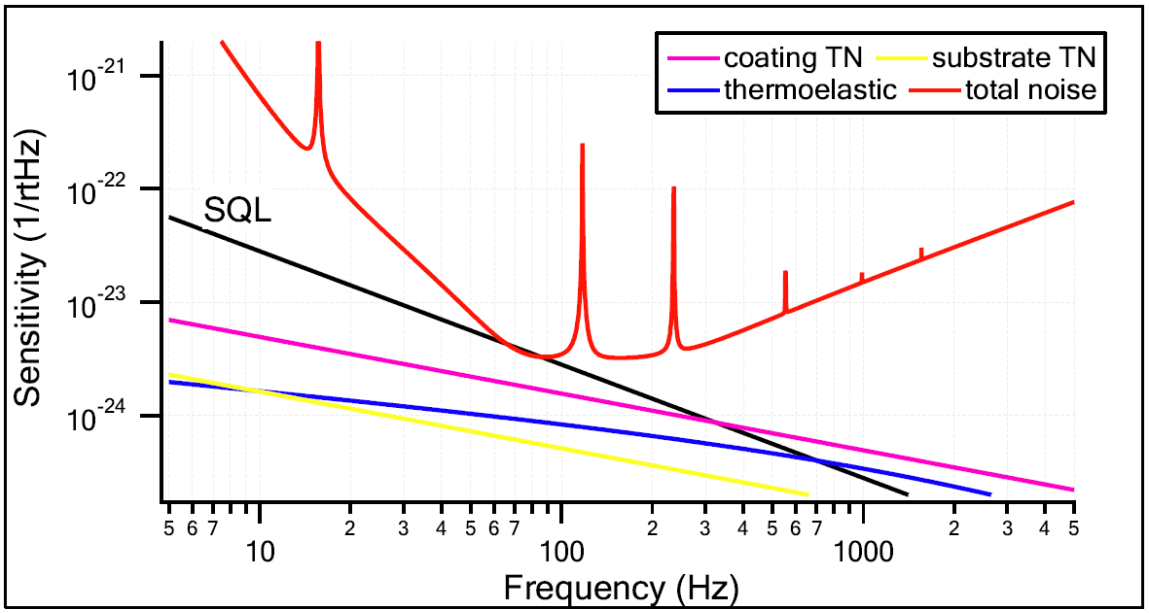
BRSE: ITM-SRM RT=(N+1/2)λ

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

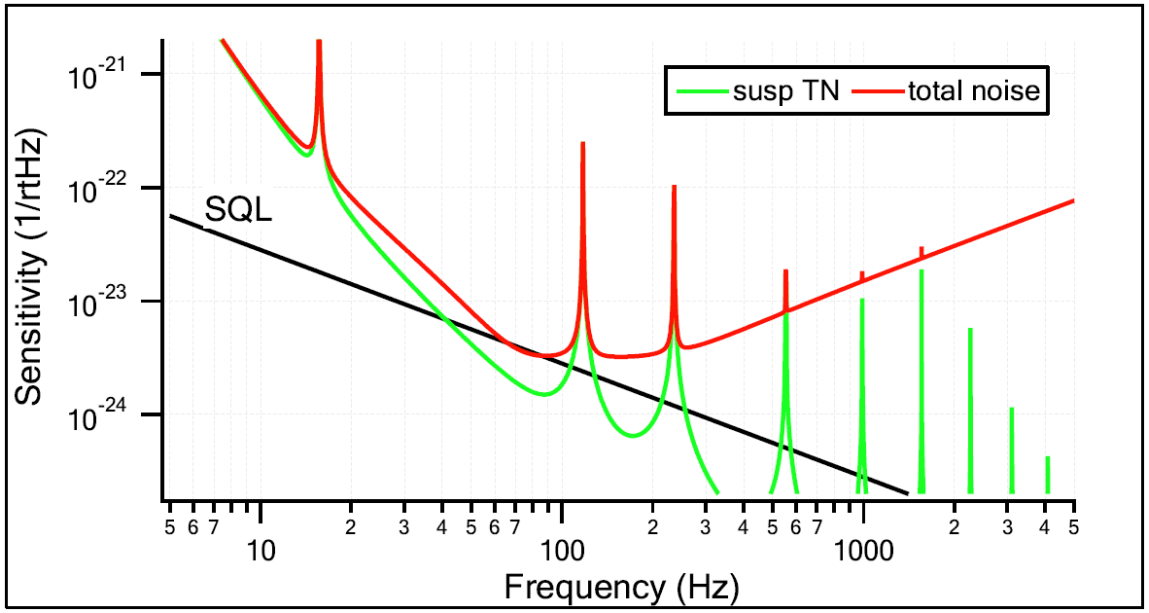
Mirror TE:
mirror expansion by temperature fluctuation via thermal expansion

Mirror BR:
mirror distortion by thermal energy in the substrate

Substrate Q=1e8
Ti-Tantala coating ϕ=5e-4
Silica coating ϕ=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

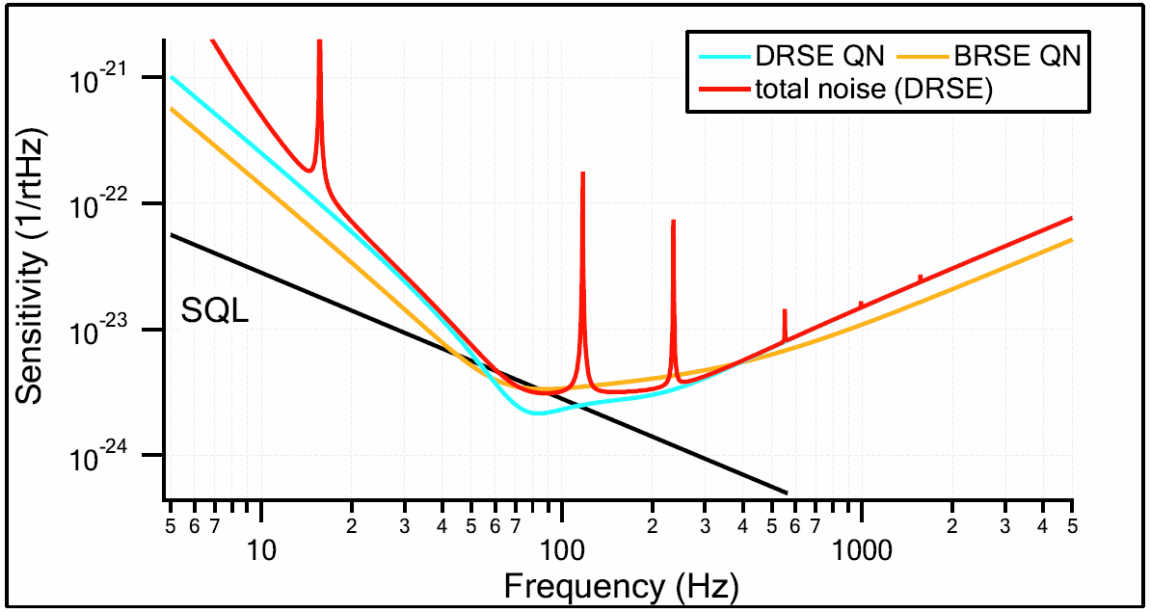
Suspension thermal noise

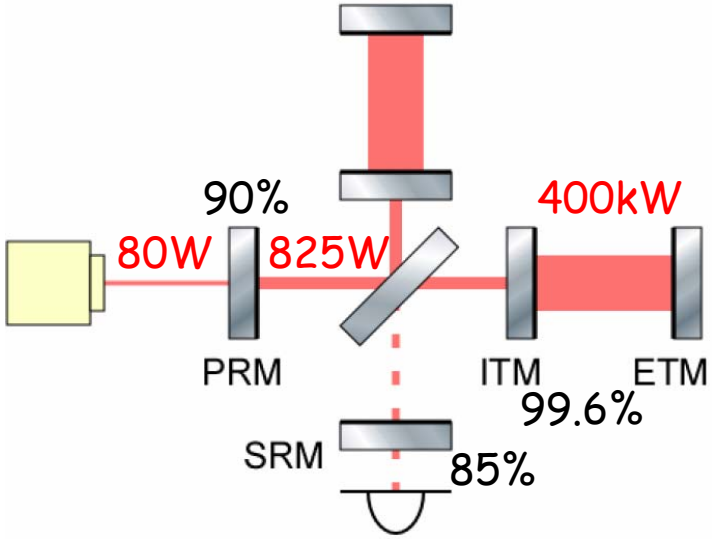


Values are for TM/IM/RM fiber
(test mass/intermediate mass/recoil mass)
Material=Sapphire/Tungsten/BeCu
Structure loss=5e-8/1e-4/5e-6
Fiber length=30cm/50cm/30cm
Fiber d=1.6mm/0.6mm/0.4mm
Clamp loss=0/1e-3/0
Temperature=16K/10K/16K
Mini GAS freq=0.4Hz
HV coupling=1/200
IM/RM mass=60kg/30kg

- 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

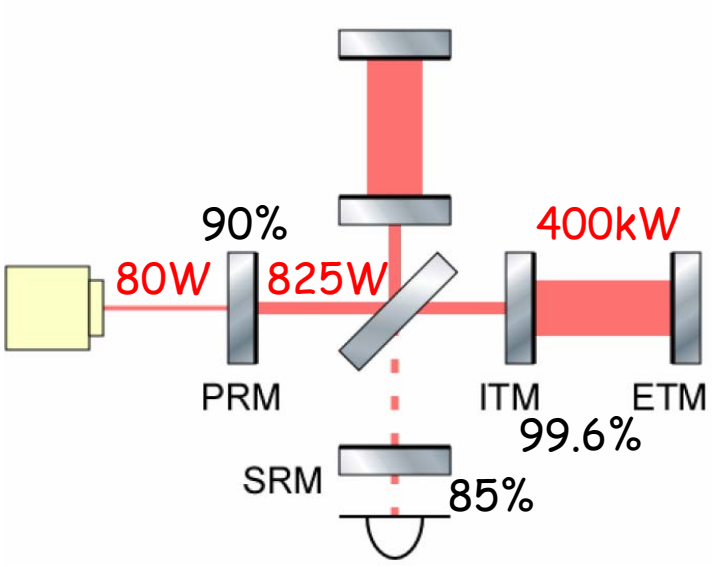
Quantum noise

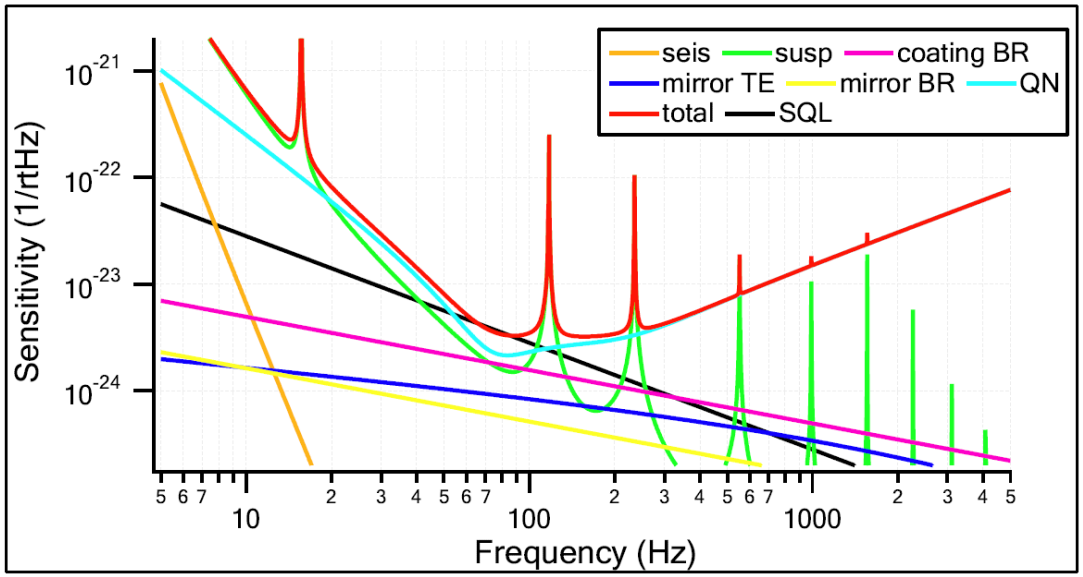




- For DRSE, ϕ=86.5 deg, ζ=134.2 deg
- For BRSE, ζ=119.3 deg
- The best sensitivity is better with DRSE
- Bandwidth is broader with BRSE
- QN exceeds the SQL at around a certain frequency

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)

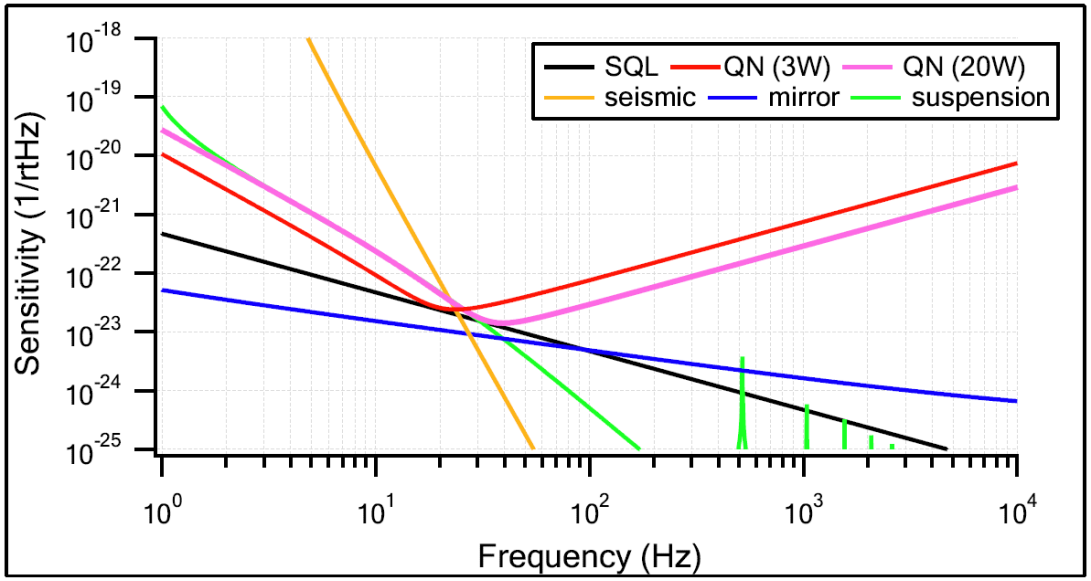
ISC + Electronics: LSC/ASC Loop noise

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
- IR=74Mpc with 20W
- 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