

Study on iKAGRA PMC

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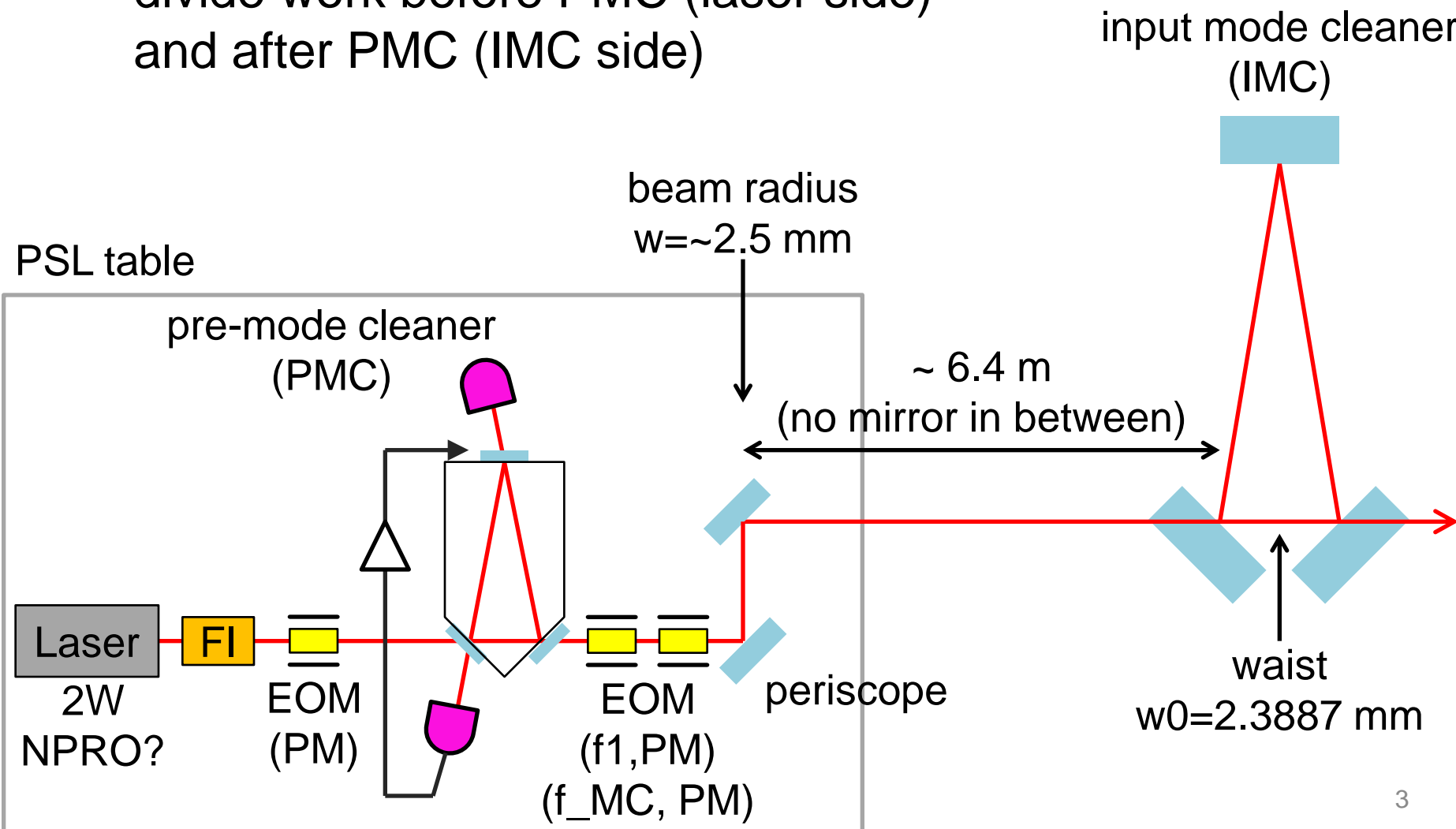
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Scope

- Derive some requirements for iKAGRA PMC
- Collect information about iKAGRA PMC candidates
- References:
 - [LIGO-T0900649](#) (aLIGO PSL design)
 - [LIGO-T0900577](#), [T0900578](#) (PMC servo circuits)
 - [LIGO-T990025](#) (iLIGO PSL design)
 - https://wiki-40m.ligo.caltech.edu/PSL/Pre_Mode_Cleaner
(eLIGO PMC specs)
 - [JGW-D1402348](#) (drawings of Miyoki-san's PMC)

Why do we want PMC for iKAGRA

- beam pointing reference to IMC
- divide work before PMC (laser side) and after PMC (IMC side)



iKAGRA PMC Requirements

- PZT range
 - **larger than $\sim 4 \mu\text{m}$** (assuming thermal expansion of invar: $1\text{e-}6$, PMC spacer length: $\sim 20 \text{ cm}$, temperature drift: $\sim 10\text{K}$)
 - if IMC drift makes too much laser frequency drift, we may have to apply temperature servo for PMC (or laser)
- UGF
 - should be smaller than PZT resonant frequency
 - **higher than 100 Hz** (aLIGO is 10kHz)
 - requirement derivation is shown next 4 pages
- beam pointing drift
 - **smaller than $\sim 3 \text{ urad/day}$**
 - pointing drift should be smaller than IMC drift and TAMA stack tilt drift was $\sim 3 \text{ urad/day}$
[R. Takahashi+: [RSI 73, 2428 \(2002\)](#)]
- do not use so much money

UGF Requirement Derivation 1

- higher the better, but cannot be higher than PZT resonance
- frequency noise after PMC shouldn't be larger than that of free running NPRO
- assume PMC length fluctuation is same as seismic noise (too pessimistic)
- assume PMC half round trip length is 20 cm
- cavity length fluctuation will be suppressed by PMC servo
- residual length fluctuation will be converted into frequency noise of the transmitted beam with HPF

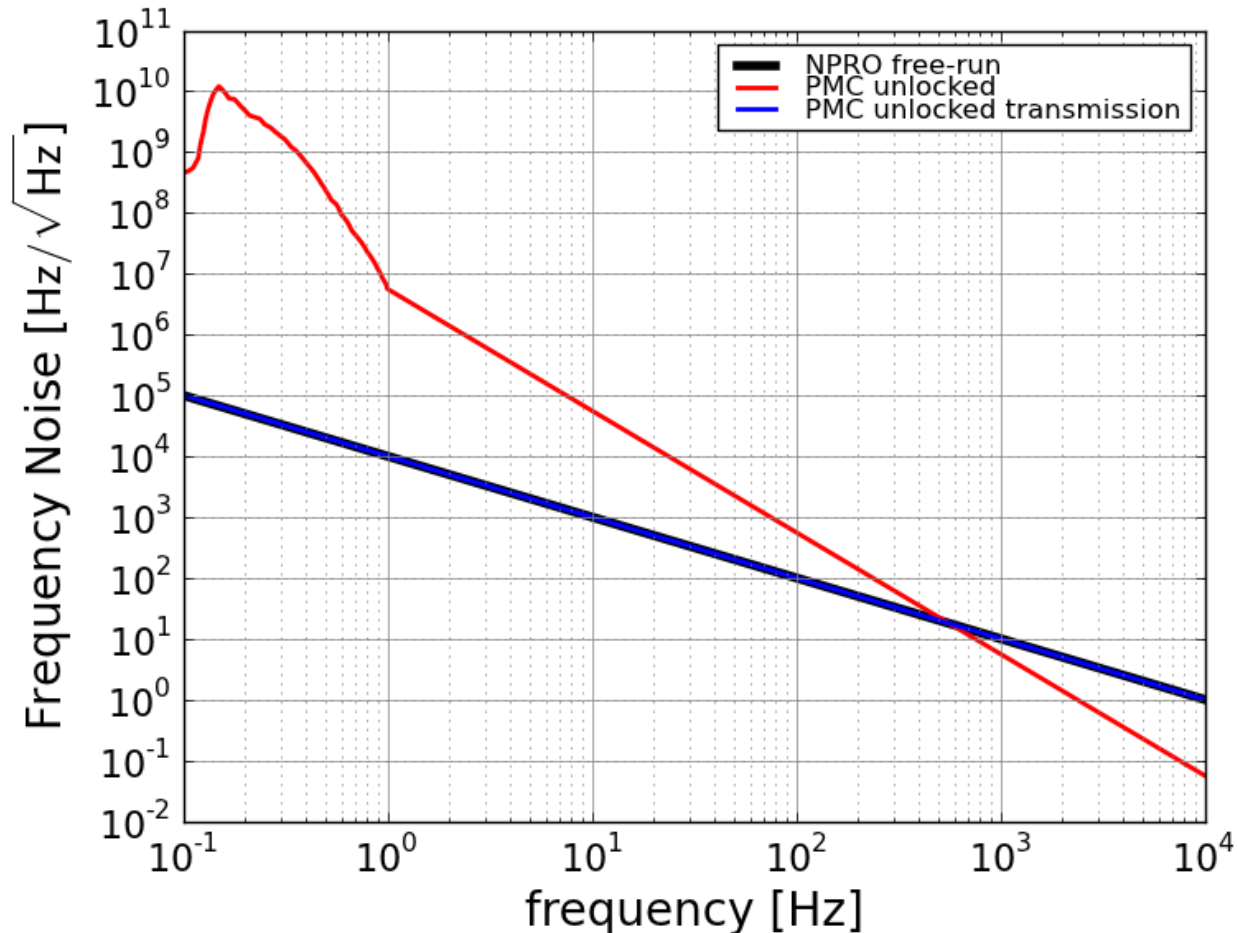
$$H(f) = \frac{1}{1 + i f_{cp}/f}$$

where f_{cp} is the cavity pole (~ 2 MHz)
(see [JGW-T1201121](#))

- frequency noise of the input beam will also be added

UGF Requirement 1

- UGF can be very low from frequency noise point of view (frequency noise from residual cavity length fluctuation is high-passed out and frequency noise of the transmitted beam is dominated by the original incident NPRO beam)



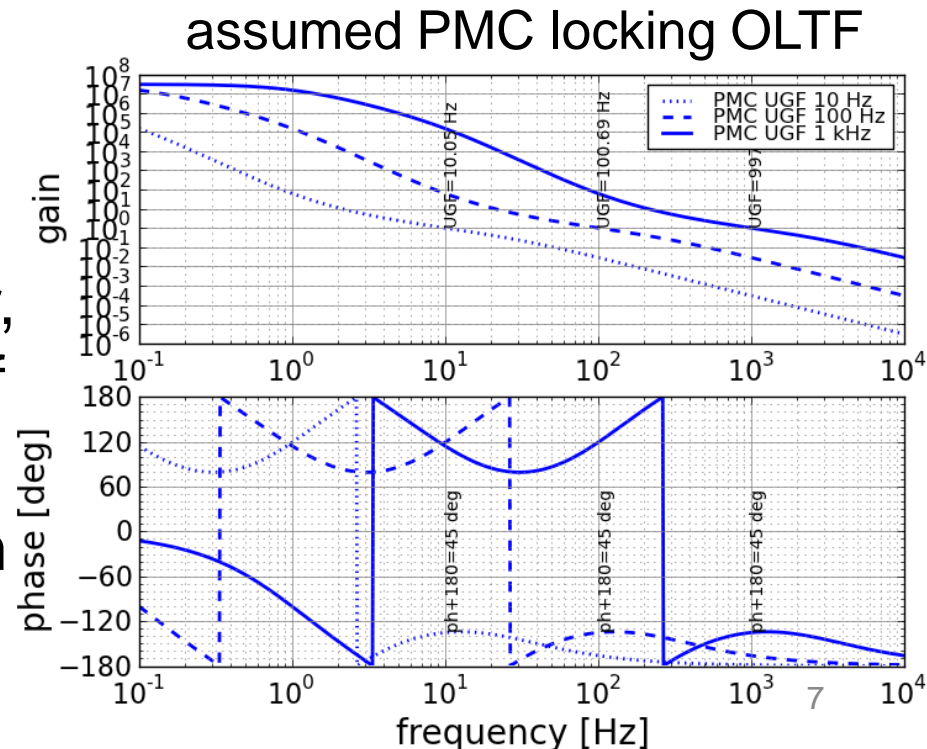
UGF Requirement Derivation 2

- intensity noise after PMC shouldn't be larger than that of free running NPRO
- residual cavity length fluctuation will be converted into intensity noise of the transmitted beam with

$$\frac{P_{\text{trans}}}{P_{\text{in}}} \simeq 1 - \left(\frac{4\mathcal{F}}{\lambda} \right)^2 \delta L$$

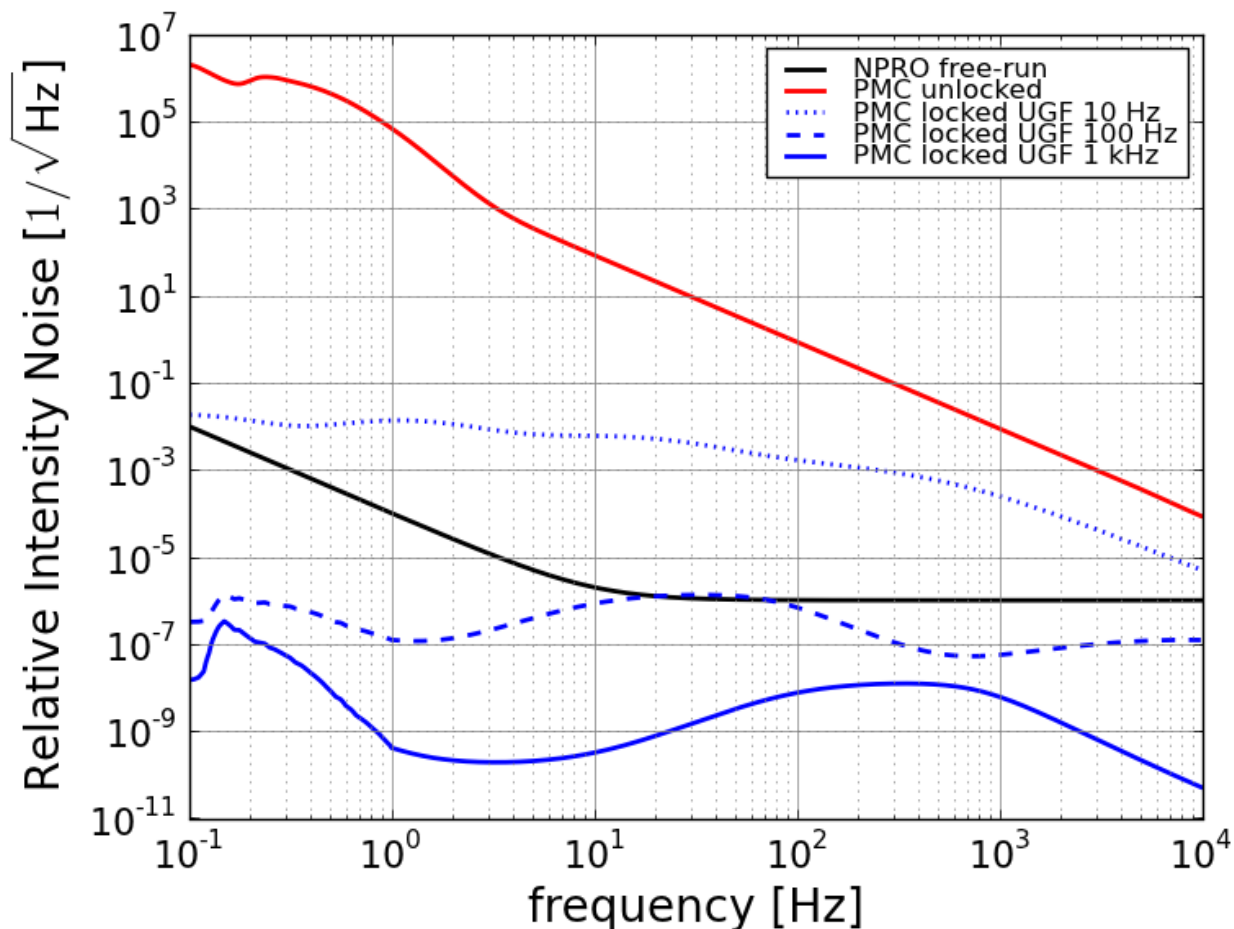
(assuming critically coupled cavity without any loss)

- since the effect is non-linear, we have to assume OLTF of PMC locking loop →
- calculation of spectrum from 2nd-order effect is shown in [my note](#) (in Japanese)



UGF Requirement 2

- UGF 100 Hz is enough from intensity noise point of view (cavity detuning is assumed to be $\sim 1e-12$ m, which corresponds to ~ 1 kHz; this is roughly 1 mV assuming PDH signal peak-to-peak is ± 1 V)



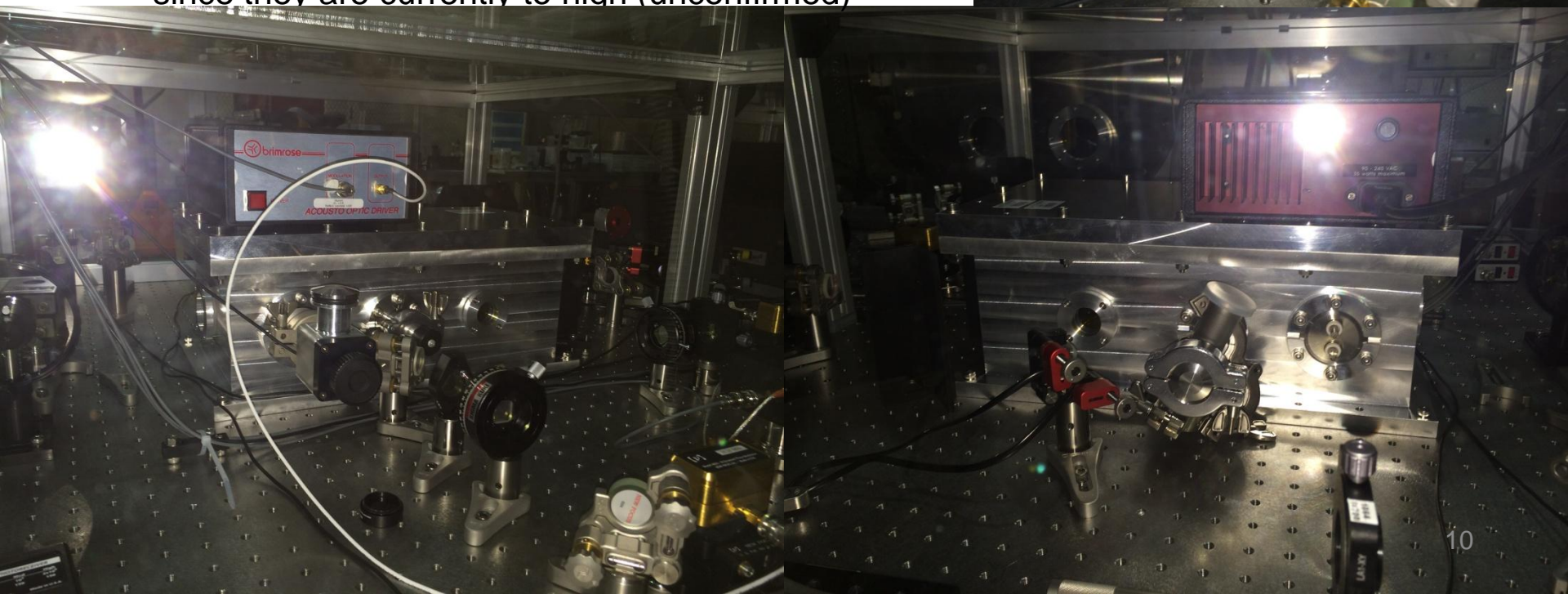
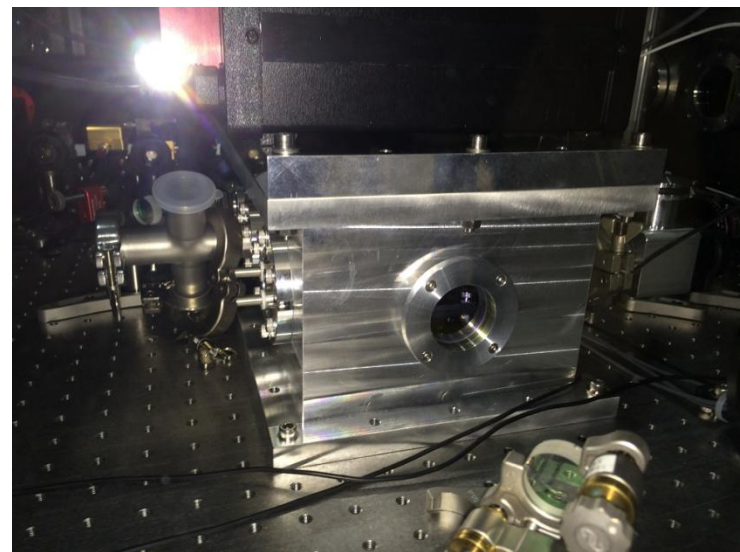
iKAGRA PMC Candidates

- Miyoki-san's seems like the strongest candidate

	Mio lab	Miyoki-san	eLIGO
Shape	triangular	triangular	triangular
Mirror RoCs	30 cm	30 cm	100 cm
Round-trip length	42 cm	40 cm	41 cm
FSR	714 MHz	750 MHz (calc)	713 MHz
Finesse	2900 (s), 220 (p)	measured mirror reflectivity was 99.97 %?	800
Transmissivity	77 % (s), 86 % (p)	~20 %? (s), ~13 %? (p)	?
Spacer	Invar	Invar	Fused Silica
Comment	Originally planned to be used for characterization of bKAGRA laser.	No PZT attached yet . Aluminum vacuum enclosure also available. (drawings: JGW-D1402348)	Rana offered spare one. Needs shipping fee.

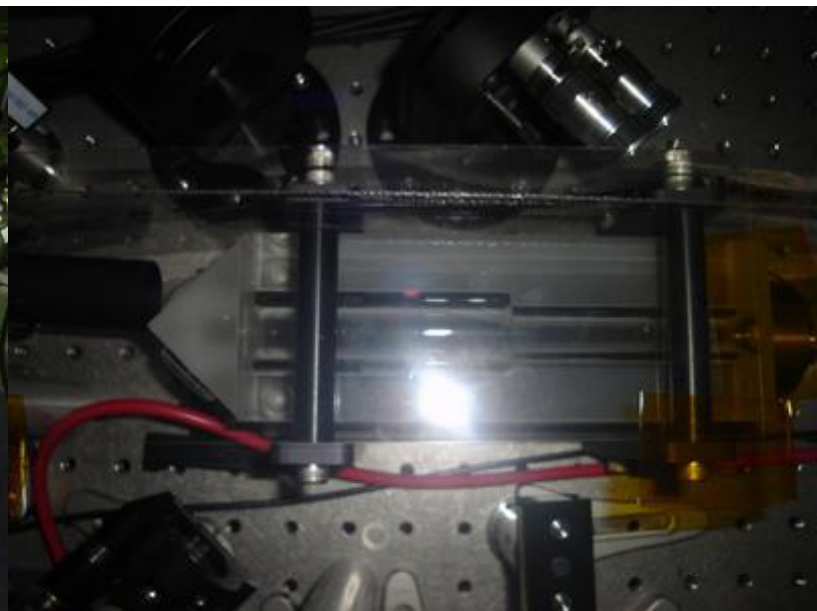
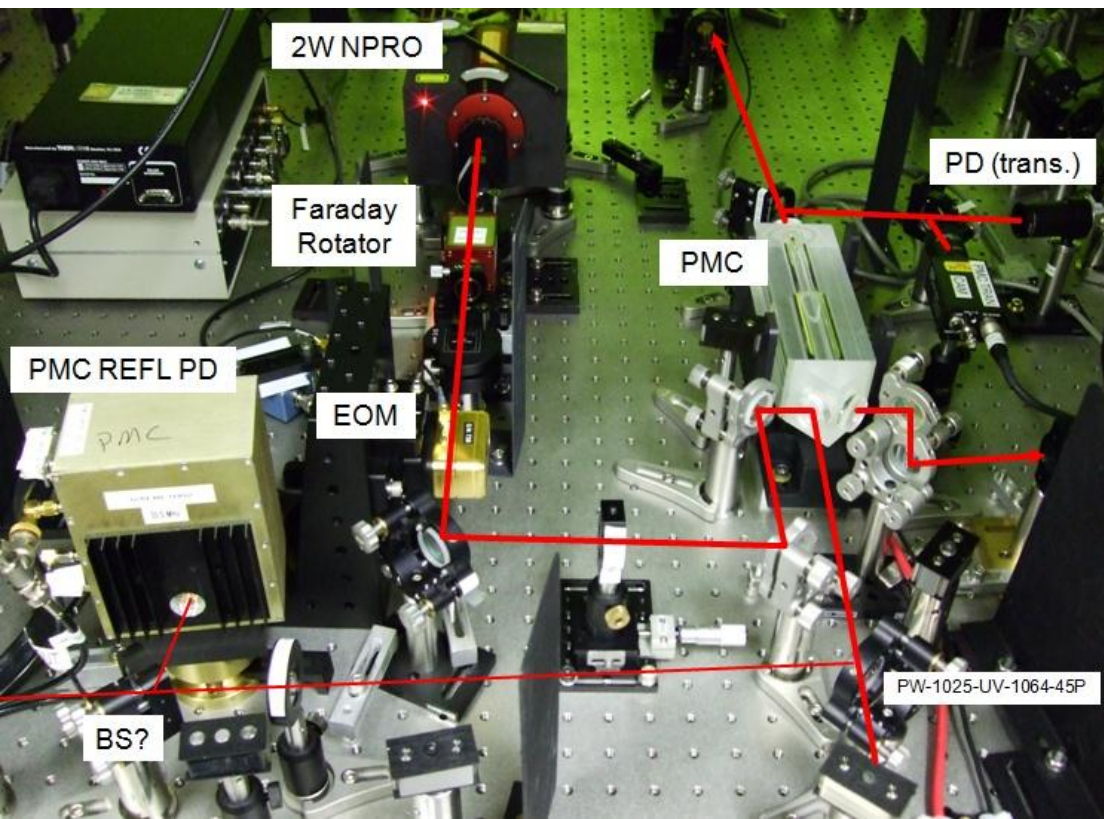
Miyoki-san's PMC

- photos taken by Nakano-kun
- end mirror diameter is 30 mm, but smaller one is also available (according to Miyoki-san)
- PZT resonance will be ~few kHz with 30 mm mirror
- have to modify jigs to put smaller mirror if we need higher PZT resonance
- PZT is already bought, but viton O-ring is not
- we might also have to replace in/output mirrors since they are currently too high (unconfirmed)



eLIGO PMC

- photos taken at Caltech 40m
- no modification is needed, but we have to ship it
- shipping fee is currently under estimation (23.5 kg mirror was 18万円 according to Kikuchi-san; PMC is ~3 kg)



Electronics, Electro-Optics

- high voltage amplifier for PZT
 - **we need this also for periscope mirror**
 - at least 4 channels in total for iKAGRA IOO (NPRO, PMC, periscope x 2)
 - Thorlabs [MDT693B](#): 3ch, 25万円, ~1 week
 - MESS-TEK [M-2629](#): 6ch, 63万円, ~1 week
 - if there's no money, we have to borrow from someone
- analog servo filters
 - to achieve high UGF (above ~400 Hz), we need analog circuits (with switches using BO of CDS for DC boosts)
- EOM
 - if there's no money, we have to borrow from someone
 - **modulation frequency must be set from MIF group**
- RF PD (for PMC_REFL), DC PD (for PMC_TRANS)
 - broadband?

binary output digital system

Test at ICRR, Kashiwa

- PMC test will be done at Kashiwa by Nakano and Michimura
- test includes;
 - PZT resonances
 - finesse, FSR, TMS
 - beam pointing stability
 - servo filters (possibly with digital system)
- detailed schedule, plans will be fixed soon
(~ 1 month between May to Sept 2014)
- iKAGRA PSL table will be shipped to ICRR soon
- students from Niigata U or Toyama U could help
(maybe only during summer vacation)

Conclusions so far

- we will put PMC also for iKAGRA
- requirements are not so severe at all, but we should check pointing stability by measurement
- PZT range should be larger than ~ 4 μm
- UGF should be higher than ~ 100 Hz from intensity noise point of view; this means PZT resonant frequency should be higher than ~ 1 kHz; but this could be achieved with 30 mm mirror; also, 100 Hz UGF servo is easily done with CDS
- we need PZT drivers (~ 50 万円 or borrow), mirrors? (~ 10 万円), EOM (borrow?), servo filters(AEL), RF PD(AEL), and DC PD (AEL)
- sideband frequency for PMC should be set soon (MIF)
- assembly and test will be done by Nakano and Michimura at ICRR, Kashiwa