Interferometer Design for bKAGRA Phase 1 and Beyond

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for the MIF subgroup

bKAGRA Phase 1 (-2018.3)

- Goal:
  - Start observation run using 3km cryogenic interferometer by the end of March 2018
  - TM temperature should be (close to) 20 K
  - No requirement for sensitivity
- Configuration:
  - 3 km cryogenic Michelson
  - minimum success: cryo Michelson with LSC
  - strict deadline (KAGRA will die if cannot make it)
  - concentrate on Michelson first
    (no power recycling before Michelson operation)
- Purpose:
  - Test cryopayload and cryogenic operation

bKAGRA 2018.4-6

- Interferometer team will have time after Phase 1 until ITM cryopayload installation, which starts on July 2, 2018
- Configuration:
  - 3 km cryogenic power-recycled Michelson
  - no strict deadline, but we have to finish it before ITM installation starts
    (try PRMI if it doesn't delay the final bKAGRA)
- Purpose:
  - Test cryopayload and cryogenic operation
  - Try 3-km cavity locking, multi-DOF locking
  - Spatial mode check

Steps for Cryogenic MI and PRMI

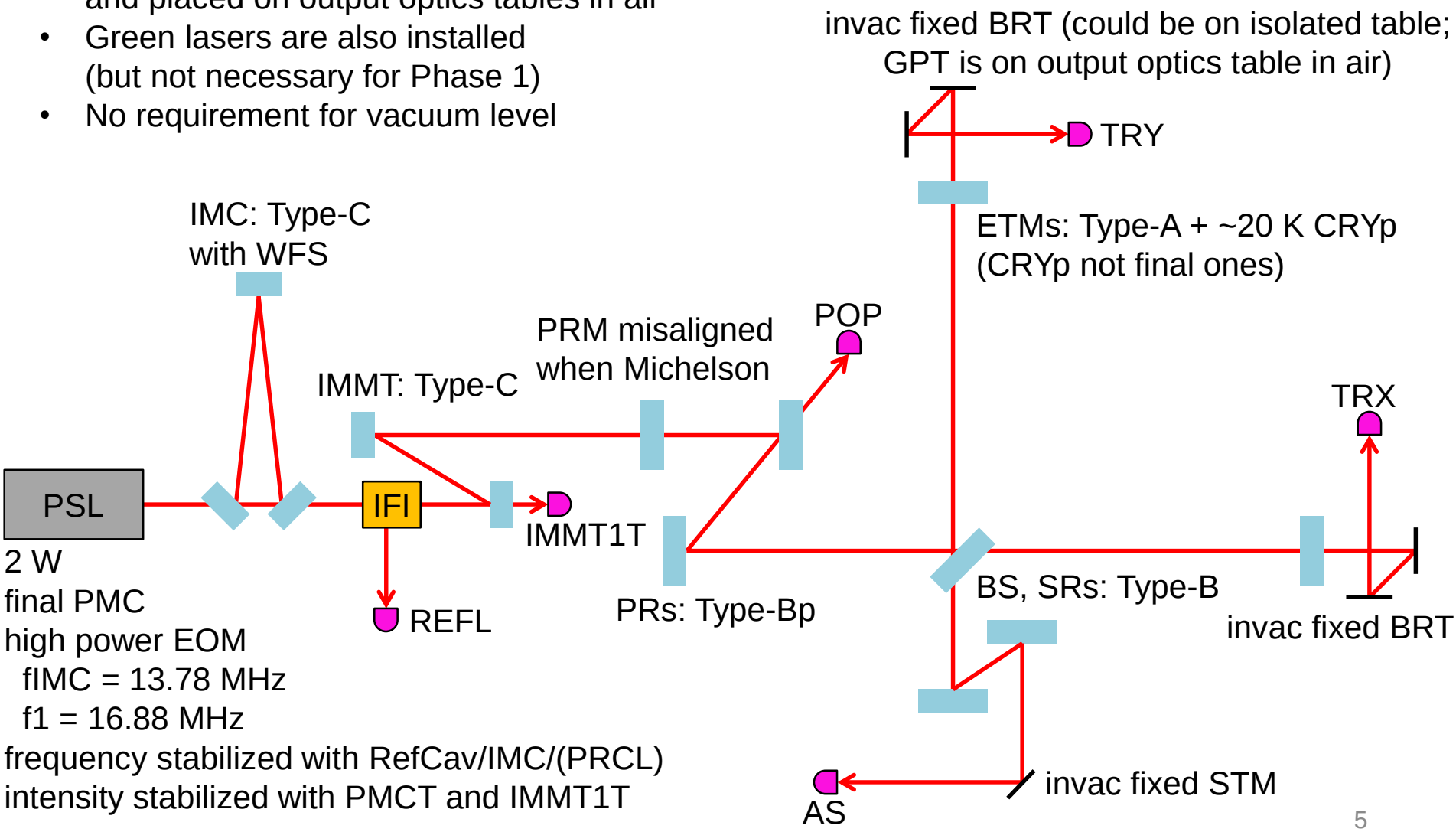
- 2017.7.6 PRs installed
- Initial alignment to both ends, beam collimation
  (no PR2-PR3 length tuning if beam is collimated well enough)
- 2017.11.1 ETMY CRYp installed
- Return the beam from ETMY to BS
  (we don't try PR-ETMY cavity)
- 2017.11.21 ETMY cool down starts
- 2018.2.2 ETMX CRYp installed
- Return the beam from ETMX to BS
- Lock room temperature Michelson
- 2018.2.19 ETMY cool down starts
- by 2018.3.31 Start observation run with 3-km cryogenic Michelson

[AFTER WE MEET THE DEADLINE]

- Shorten PR2-PR3 length by 2.4 cm (at max)
- Re-alignment
- Lock cryogenic PRMI
  if not possible, lock more cryogenic Michelson
  * PRMI could be unstable if PR2/3 RoC errors are the worst case

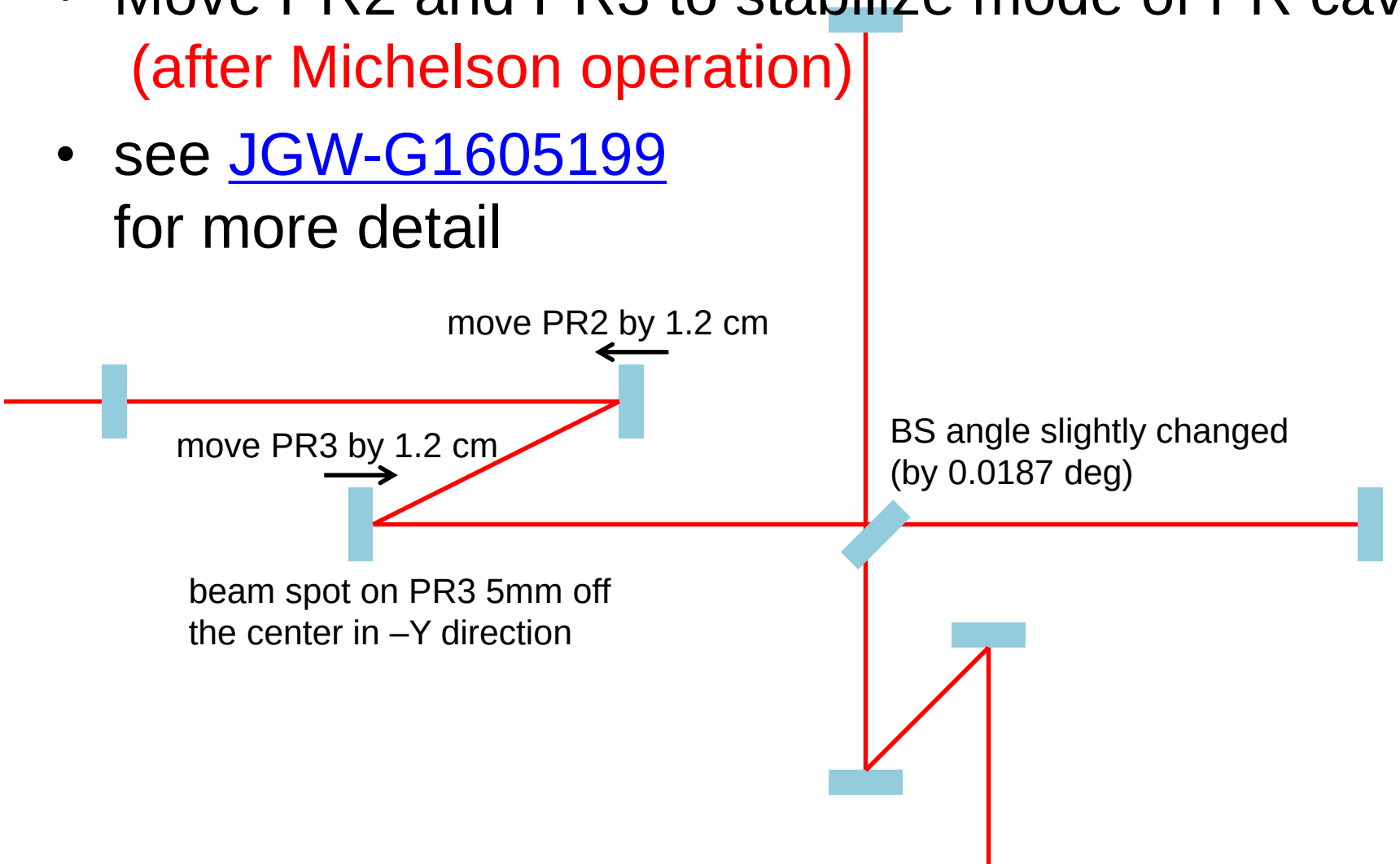
Configuration

- Every detection port listed here has both PD and QPDs (for ASC), and placed on output optics tables in air
- Green lasers are also installed (but not necessary for Phase 1)
- No requirement for vacuum level



Layout

- Adjust layout slightly to compensate ITM wedge
- Move PR2 and PR3 to stabilize mode of PR cavity
  (after Michelson operation)
- see JGW-G1605199
  for more detail



Length Sensing and Control

- Only use f1 sidebands
- Sensing matrix for PRMI:

[W/m]	MICH	PRCL
REFL_I	+9.92e-01	-7.48e+07
REFL_Q	+6.61e+04	-3.52e+07
AS_I	+8.97e+02	-2.23e-01
AS_Q	-1.67e+06	+4.16e+02

Alignment Sensing and Control

- Only use f1 sidebands (and TRX/Y DC)
- Sensing matrix for PRMI:

[W/rad]	COMM	DIFF	BS	PRM	PR2′	PR3′
REFLA_I	+4.98e+02	+2.36e-01	-4.16e+02	-8.13e+01	-2.08e-01	-1.21e+03
REFLB_I	-7.01e-01	-2.91e+00	-1.93e+00	-2.10e+01	-1.70e-03	+3.47e+00
ASA_Q	+9.80e-01	+1.87e+02	+1.56e+02	-1.39e-01	+1.31e-03	-2.27e+00
POPA_DC	+4.04e+01	+1.49e+01	-2.41e+01	+3.91e+02	+8.07e+02	-1.57e+01
TRXA_DC	+2.30e+01	+1.71e-01	+1.93e+01	-1.23e-01	-5.66e-03	-6.51e-01
TRYA_DC	-2.30e+01	+1.71e-01	-1.91e+01	-1.17e-01	-3.25e-03	-6.36e-01

- See JGW-G1605541 and JGW-T1605362 for more detail

Transverse Mode Spacing for PRMI

- g-factor
  0.8750 in pitch
  0.8958 in yaw
  (with designed RoCs & lengths, PR2-PR3 length shortened by 2.4 cm)
- See JGW-G1605541 JGW-T1605362 for more detail
- how to measure: LIGO-G080467